Teaching Practices in Preservice Science Teacher Education

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PART 13: STRAND 13

Pre-Service Science Teacher Education

Co-editors: Maria Evagorou & Marisa Michelini
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STRAND 13: INTRODUCTION

PRE-SERVICE SCIENCE TEACHER EDUCATION

Strand 13 focuses on pre-service science teacher education and invites submissions from researchers working either in preschool, primary and secondary school teacher formation. Specifically, as part of the ESERA 2017 conference, we invited researchers to submit under Strand 13 studies related to professional knowledge of teachers, pre-service teacher preparation, instructional methods in pre-service teacher education, programs and policy, field experience, relation of theory with practice, and issues related to pre-service teacher education reform.

A large number of submissions (146) were reviewed for the 12th biennial conference held in Dublin, and we would like to thank all reviewers for their time and effort. One hundred and three contributions were accepted for presentation under Strand 13: Pre-service science teacher education. Specifically, two symposia, 66 oral presentations, 26 poster presentations, and three workshops were accepted for presentation. This chapter of the e-proceedings brings together 29 submissions from seventeen different countries representing four of the continents: Europe, Africa, Asia and America, proving the international nature of the conference. The papers included in this volume illustrate the trends in pre-service science teacher (PSTs) education across the world currently, and focus on a variety of issues and science disciplines. Specifically, the volume includes studies focusing on chemistry pre-service teacher education; physics pre-service teachers; and primary and pre-primary pre-service teachers. The topics range from studies on PSTs’ content and pedagogical knowledge in specific subjects, interdisciplinary and transversal; on PSTs’ readiness to teach and assess multicultural and inclusive classrooms; on PSTs emotions when engaging in scientific practices; on orientation, interdisciplinary teaching, the use of technology in PST training and the use of video vignettes in teacher training.

We anticipate that this collective volume will become the basis of conversations discussing the changes and challenges in pre-service science teacher education across continents, and that the interest in Strand 13: Pre-service science teacher education will continue to grow.

Maria Evagorou and Marisa Michelini
KNOWLEDGE BASE FOR CHEMISTRY TEACHERS EVALUATED IN BRAZILIAN SELECTION EXAMS

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The literature points out controversies about the knowledge base for teaching that a teacher should dominate. As a result of this lack of definition, there is also a lack of definition about the body of knowledge that needs to be worked on in teacher training courses as well as evaluated in public teacher selection exams. The purpose of this study was to outline the knowledge base for teaching that Brazilian legislation and the public exams for selecting teachers are prioritizing. Our focus was the High School chemistry teachers. The present study brings a qualitative and quantitative survey of the knowledge evaluated in these exams, as well as the analysis of the current public legislation at the time of these chemistry teachers' selection exams. Our analysis was based on the knowledge base for teaching. The mapping of the knowledge base that a chemistry teacher must possess according to the legislation and public selection exams analyzed reveals that a Brazilian chemistry teacher must know the specific content of chemistry, have knowledge of pedagogical theories, be able to interpret texts, know the Brazilian Law of Education Guidelines and Bases of 1996, to know how to use a computer and to have knowledge of basic mathematics. This profile is very far from what the literature of teacher knowledge presents. Judging from the edicts and the public exams, as well as from public policy documents, the Brazilian future teachers basically need to know chemistry but do not need to know how to teach chemistry. From the documents analyzed, there is no specificity of knowledge that distinguishes between the teacher profession and other professions. Thus, the contribution that these analyzed documents offer is a devaluation of the teacher profession, when in fact they should act in the opposite way.

Keywords: PCK, teachers' knowledge, selection of chemistry teachers

INTRODUCTION

There is in literature a range of knowledge, skills, aptitudes and personal characteristics that are taken into account when it comes to the profile of a good teacher. Shulman (1986, 1987) contributed enormously to research on the knowledge base for teaching by developing a research program known as teacher knowledge. In an attempt to represent the knowledge base of teachers, Grossman (1990) proposed a model (Figure 1) that presents the domains of this knowledge, namely: subject matter knowledge, general pedagogical knowledge, pedagogical content knowledge (PCK) and context knowledge. In this model, the PCK occupies a central position, influencing and being influenced by the other domains of knowledge (Fernandez, 2014). The PCK is the knowledge of teachers, which combines content and pedagogy during and for teaching. A teacher with a high PCK, among other characteristics, knows the content well; knows the purposes for teaching it; knows how to conduct the learning process well; is flexible with the content, adjusting it to the level of knowledge of the students; knows how to select the more adequate ways for teaching; is aware of the context in which he teaches and the difficulties of his students and still can evaluate the learning of his students.
Figure 1. Model of the relationship between the domains of teacher knowledge proposed by Grossman (1990)

In Grossman’s model a teacher's PCK is directed by the design of the purposes for teaching specific content. According to Shulman (1986), the knowledge that the teacher develops to teach specific content in a way that favors student learning is the "amalgamation" between content knowledge and pedagogical knowledge. It is built through practice, with the use of your teaching strategies and is a kind of specific knowledge of the professional teacher. It encompasses the appropriate forms of presentations and explanations of a particular topic of the subject and also the understanding of what is difficult or easy for students to learn. With this, we can highlight the difference between a chemist and a chemistry teacher, because the PCK is a knowledge attributed to the teacher, that is, not every specialist in a given area is able to teach with the same specialty because, to teach, knowledge of specific content is only part of the story. The pedagogical knowledge of content is, in general, knowledge about how to teach content to students in a given context (Fernandez, 2014).

There is a wide range of knowledge, skills, attitudes and personal characteristics that are discussed when it comes to being a good teacher and the discussion on this issue contributes to the educational systems that can profile the teacher they want to have. (Gatti, 2013)

The public tender for teachers is the form used by the Brazilian states to make effective teachers who will teach in public schools in Brazil, unlike most private schools that prefer to select their teachers through several stages, which may include the appointment, interviews and regency of presented by the candidate to a team of evaluators of the institution.

In this sense, the selective processes of teachers can give indications of what knowledge is being prioritized to define a good teacher. In this work, we map the body of knowledge adopted by Brazilian legislation that directs the training of chemistry teachers and to map what kind of knowledge has been considered in the public tenders that select chemistry teachers for public school.

**THEORETICAL BACKGROUND**

It is a consensus in the academic literature that a teacher should master the contents he teaches. The existing doubt and discussion is in relation to the level and breadth of that domain. Shulman (1986) defended the idea that a teacher should "understand not only that something is in a certain way, but also the reason for it to be so, on the basis of what evidence this is
justified, and under what circumstances confidence in such evidence can be weakened and even denied.”

For Cooper and Alvarado (2006), the solid subject matter knowledge to be taught is fundamental, since it is necessary that the teacher has sufficient knowledge of contents to teach well. This is a consensus among teachers as well. The lack of this knowledge means that some teachers with poor training who cannot reach other ways of approaching certain content, give their classes supported in textbooks, mechanically, without autonomy to promote innovative activities or develop new strategies for teaching. In addition to subject matter knowledge, other specific knowledge required by the teacher is listed. Several researchers have studied the knowledge base for teaching using various methodologies and theoretical perspectives. Authors such as Tardif (2012), Shulman (1987), Schön (1992) and Perrenoud (2000) generated a series of classifications and typologies about teacher knowledge, some with common elements, and others with subtle differences.

According to Perrenoud (2000), "competence is the ability to mobilize resources to activate cognitive potentials to cope with a type of situation." The author establishes competency domains for the ongoing training of teachers, which includes: organizing and directing learning situations, managing the progression of learning, knowing and evolving differentiation devices, engaging students in their learning and their work, working as a team, participating in school administration, informing and involving parents, using new technologies, face ethical duties and dilemmas in the profession and manage their own continuing professional developing.

Faced with the need for innovation and change, it is already a consensus that it is no longer enough for the teacher to know the subject and teaching techniques, it is necessary also to have access to the knowledge and skills inherent in the profession and to be able to question and reflect on your job. Gatti (2013) says that there is now a great expectation regarding the intellectual education of the teacher, who must have a solid scientific and cultural background, a domain of the mother tongue as well as of the new languages related to the technology of the area in which he is a specialist. When dealing with the profile of the teacher, one should not only discuss what knowledge he has, what he knows, but also discuss his abilities and attitudes, that is, what he must know how to do.

Carvalho and Gil-Pérez (2011) report that until recently, research highlighted the characteristics of the good teacher, or the dichotomy between good and bad teacher. Nowadays, however, they inform us that the focus has now been on what knowledge teachers should have. Managers of educational systems want a teacher as close to the ideal as to spend less time and resources on in-service training. However, even if it comes from a great training course, there are certain components of the profile that will only be fulfilled with the professional experience. It is hoped that the candidate for teaching has had the opportunity to teach, plan activities, select objectives, understand contexts, and other aspects related to pedagogical work (Gatti, 2013).

For Lopes and Freitas-Reis (2015), for example, teaching sciences goes beyond the fixing of terms and concepts; is to create learning situations by enabling the student to have a scientific knowledge base in order to use them as part of their life. It is necessary to reflect on the contents to be taught, how to organize them and to approach them, taking into account the social function of these contents, which should not have a disciplinary character only.
The content knowledge needed by the teacher, according to Carvalho and Gil-Pérez (2011), encompasses the following aspects: knowledge of the history of science; knowledge of the methodological guidelines used in the construction of knowledge; knowledge of Science / Technology / Society interactions associated with the construction of knowledge; knowledge of recent scientific developments and their perspectives; know how to select appropriate content; and be prepared to acquire new knowledge.

According to Shulman (1987), the teacher has a specialized knowledge of the subject, of which he is the protagonist, which he called the Pedagogical Content Knowledge (PCK). Teachers should understand ways to represent content to learners by knowing how to turn content into teaching purposes. Although important, only the full knowledge and mastery of the specific content does not guarantee that the teacher will know how to teach successfully, an extra skill is necessary to make its students understand the content, promoting learning. The PCK represents the ways of formulating and presentation of a certain content, making it comprehensible to students. Shulman (1987) says that the PCK can include analogies, illustrations, examples, explanations and demonstrations, that is, a link between knowledge of content and pedagogical knowledge.

Grossman’s model (already presented in Figure 1) is very well known in literature, hence, can be used as an object of study and bring contributions during teacher training.

The link between content and pedagogical knowledge shapes teachers’ decisions about materials, approaches, and assessment. In addition to the pedagogical knowledge of content, teachers should possess general pedagogical knowledge, including skills in the areas of classroom management and discipline. (Cooper & Alvarado, 2006). Among the various knowledge required by the teacher, such as in particular the specific knowledge, pedagogical knowledge, curricular and pedagogical content, there must be an interaction, delineating and giving rise to what we call knowledge of the teaching profession.

According to the Organisation for Economic Cooperation and Development (OECD, 2006) the selection process of teachers must take place "based on clear, transparent and widely accepted standards", highlighting what the candidate must "know" and "know how to do" in order to be effective in their profession. Also according to this organization, the selection of teachers by a central agency, often done in an impersonal way, becomes insufficient to not meet the needs of schools. There is a lack of communication and information for both the selectors and the candidates in this type of selection process. In some European countries there is a very large involvement of the school in the recruitment and selection of its teachers, that is, they have already opted for open recruitment, where each school or place combines candidates with specific vacancies. The open recruitment process, according to the organization, offers the advantage to the candidates to choose the school where they intend to teach and to make contact before the accomplishment of some contract of employment. The OECD questions, however, the effectiveness of impersonal selective processes that many countries adopt. Some of these processes fail to evaluate the teacher characteristics required in their specificities and do not allow the creation of a commitment link of the teacher to the needs of the school where they will act. More direct interaction through personal interviews and school visits by the candidates tends to improve the balance between the needs of the candidates and those of the schools.
Based on this context, the analysis of the questions of the Brazilian public tenders can reveal the types of knowledge required and thus analyze the desired profile of chemistry teacher for state public schools. In addition, from the selection policies, one can strategically define the professional profile for the teacher (Gatti, 2013).

Within this context, this work sought to what type of knowledge of Brazilian chemistry teachers have been considered in the assessments that select chemistry teachers from the public school of the state network. This research, therefore, focused on the analysis of the knowledge requirements present in the examinations of selective processes and its public tender notices, for the positions of professor of chemistry of the High School of the state public schools, that are governed by the Secretary of Education of each Brazilian state.

**METHODOLOGY**

We analyzed the official training documents of chemistry teachers in Brazil and the tests of teacher selection from 2005 to 2013. To base the analysis we used the categories of Grossman's model (Figure 1). Sixty examination tests were analyzed, in a total of 3576 of objective questions, 39 of discursive questions with their items and sub items and 16 tests in which a writing was required. There were 12 tests from the Northern region (Acre, Amazonas, Amapá, Pará, Rondônia and Tocantins states), 17 from the Northeast (states of Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte Sergipe) 6 from the South (Paraná and Santa Catarina), 16 from Southeast (states of Espírito Santo, Minas Gerais, Rio de Janeiro and São Paulo), 9 from Central-West (Federal District, Goiás and Mato Grosso). The distribution of the tests by the Brazilian states is presented in Table 1 and in the Figure 2.

**RESULTS AND DISCUSSION**

**Analysis of the Brazilian public legislation for the training of chemistry teachers**

In the National Curriculum Guidelines for the Training of Basic Education Teachers (Brazil, 2001a), it appears that contents must be treated in three different dimensions: conceptual (theories, concepts, information); Procedural (know-how); and attitudinal (values and attitudes). The profile idealized by the document for the chemistry teacher is suggested with some skills and abilities, observed from the point of view of the components of the Grossman model as follows:

**Subject Matter Knowledge:** to have a solid knowledge of the specific content; understand concepts, laws and principles of chemistry, know the physical-chemical properties of materials and their behaviors; be prepared to engage in research and projects related to the chemical education; understand the steps and processes of a research in chemical education; follow the educational and scientific advances of the chemistry area; to recognize chemistry as a human product and to understand its relations and its historical aspects; know how to search and identify important sources of information in the area and understand the scientific-technological texts, how to interpret and use various forms of graphic representation and expressions; to know the characteristics of the chemical education research; to experience projects and curricular proposals for the teaching of chemistry; incorporate research results favorably into their practices; know how to work in a team.
Table 1. Distribution of the exams by the Brazilian states and regions of Brazil.

<table>
<thead>
<tr>
<th>Brazilian State</th>
<th>Amount of exams per state</th>
<th>Years of the publications of calls for tenders</th>
<th>Region</th>
<th>Amount of exams per region</th>
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<tbody>
<tr>
<td>Acre</td>
<td>2</td>
<td>2010, 2013</td>
<td></td>
<td></td>
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<tr>
<td>Amazonas</td>
<td>1</td>
<td>2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amapá</td>
<td>2</td>
<td>2005, 2012</td>
<td>North</td>
<td>12</td>
</tr>
<tr>
<td>Tocantins</td>
<td>1</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bahia</td>
<td>1</td>
<td>2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maranhão</td>
<td>2</td>
<td>2005, 2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paraíba</td>
<td>2</td>
<td>2005, 2011</td>
<td></td>
<td></td>
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<tr>
<td>Pernambuco</td>
<td>3</td>
<td>2006, 2008, 2010</td>
<td></td>
<td></td>
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<tr>
<td>Rio Grande do Norte</td>
<td>1</td>
<td>2011</td>
<td></td>
<td></td>
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<tr>
<td>Sergipe</td>
<td>2</td>
<td>2003, 2012</td>
<td></td>
<td></td>
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<tr>
<td>Paraná</td>
<td>2</td>
<td>2007, 2013</td>
<td>South</td>
<td>6</td>
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<tr>
<td>Minas Gerais</td>
<td>1</td>
<td>2011</td>
<td>Southeast</td>
<td>16</td>
</tr>
<tr>
<td>Goiás</td>
<td>3</td>
<td>2003, 2009, 2010</td>
<td></td>
<td></td>
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<tr>
<td>Mato Grosso</td>
<td>2</td>
<td>2006, 2009</td>
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Figure 2. Distribution of exams by States and Regions of Brazil

**General Pedagogical Knowledge:** to know psychopedagogical theories about teaching-learning process and principles of educational planning (students and learning); act in accordance with current legislation; have the ability to critically evaluate existing didactic resources in the market (curriculum and instruction).
**Pedagogical Content Knowledge**: prepare the students for the conscious exercise of citizenship (conception of the purposes to teach a specific content); to arouse the scientific interest in its students and to act for their intellectual development; reflect their practice in the classroom and know how to identify teaching / learning problems (knowledge of students' understanding); know how to work in the laboratory, use this space in class, use creativity in solving problems and educational challenges during chemistry teaching; be able to provide didactic and instructional resources; know how to use computers; knowing how to interpret and use various forms of graphic representations; knowing how to communicate and present research results and projects (knowledge of instructional strategies).

**Context Knowledge**: knows how to evaluate the role of science in society and to recognize the involvement of ethics in some decisions; know how to critique social, technological, environmental, political and ethical aspects related to chemistry in society; to be socially aware of their profession, to be able to disseminate and disseminate relevant knowledge to the community; to know the educational reality, to consider the context in which it is inserted as a professional, to know the Brazilian educational problems, to consider the social, economic and political context of the school reality; to carry out activities that collaborate with society through their professional training.

The Opinion of the Education National Council (CNE / CES 1.303 / 2001 - Brazil, 2001b) is the one that points out the National Curricular Guidelines for Chemistry Courses. This document informs that the essential curricular contents are those that involve the theory and the laboratory, and the basic curricular contents are those of Mathematics, Physics and Chemistry. The specific contents are those that differentiate each course, that is, the "professional contents", which higher education institutions are freer to format according to the professional profile they wish to form. Extra-class academic activities are those that occur through professional practice, through internships, monitoring, participation in congresses and other events, and where credit is given. The complementary contents are those offered by the institution that are more comprehensive in the theme and even common to courses in other areas. Table 2 presents the skills and abilities cited in this document and categorized according to the Grossman model.

Opinion 01303/2001 often uses terms related to specific content. The topic content knowledge appears in this text in a more specific way: in the section "to understand the steps of a research" and in the item "to know the fundamentals and nature of the researches in Chemistry", related to the idea of the substantive and syntactic structures of the Grossman model. General pedagogical knowledge appears less strongly but is still present. It is distributed in the items that compose the skills and competences as in: "knowing psycho-pedagogical theories about teaching-learning and principles of educational planning". The context knowledge category is present in "understanding and evaluating technological, environmental, political and ethical social aspects" and in several other sections. The pedagogical knowledge of the content appears timidly in some sections that we can relate to this category, such as the "searching for relevant information, knowing how to interpret and using different forms of representation".

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<th>Subject Matter Knowledge</th>
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<tr>
<td>- Content</td>
<td>To have a solid knowledge of the content. To understand concepts, laws and principles of Chemistry, knows the physical-chemical properties of materials and their behaviors. Be prepared to engage in research and projects related to the teaching of Chemistry, to comprise the steps and processes of a research in teaching Chemistry. Accompany the educational and scientific advances of the Chemistry area. To recognize Chemistry as a human product and to understand its relationships and its historical aspects. Know how to search for and identify important sources of information in the area and understand scientific-technological texts, know how to interpret and use various forms of graphic representation and expressions. Know chemistry teaching research characteristics. Experience projects and curricular proposals for the teaching of Chemistry. To incorporate research results favorably into its practices.</td>
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<tr>
<td>- Syntactic structure</td>
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<td>- Substantive structure</td>
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<tr>
<th>General Pedagogical Knowledge</th>
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<tbody>
<tr>
<td>- Learners and learning</td>
<td>Know psychopedagogical theories about teaching-learning and principles of educational planning.</td>
</tr>
<tr>
<td>- Classroom management</td>
<td>Practice the teacher profession with dynamic and creative spirit</td>
</tr>
<tr>
<td>- Curriculum and instruction</td>
<td>Act in accordance with current legislation.</td>
</tr>
<tr>
<td>- Others</td>
<td>To have the ability to critically evaluate the didactic resources that already exist in the market. Be able to work as a team. Be critical in relation to own knowledge, seek to be in continuous professional development.</td>
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<th>Pedagogical Content Knowledge</th>
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<tbody>
<tr>
<td>- Conceptions of purposes for teaching subject matter</td>
<td>Be a citizen and prepare students for the conscious exercise of citizenship.</td>
</tr>
<tr>
<td>- Knowledge of students’understandings</td>
<td>To awake the scientific interest in the students and act for their intellectual development. Reflect on own practice in the classroom and know how to identify teaching / learning problems.</td>
</tr>
<tr>
<td>- Knowledge of instructional strategies</td>
<td>Know how to work in the laboratory, to use this space in class, know to act promptly applying first aid when any incident occurs. Use creativity in solving educational problems and challenges during Chemistry teaching. To have ability to provide didactic and instructional resources. Knows how to use computers, including teaching Chemistry. Can interpret and use various forms of graphic representation and expressions. Be prepared to engage in research and projects related to the teaching of Chemistry. Be able to communicate and present research results and projects.</td>
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<th>Context Knowledge</th>
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<tr>
<td>- Students</td>
<td>Know how to evaluate the role of science in society, and recognize the involvement of ethics in some decisions. Know how to critique social, technological, environmental, political and ethical aspects related to chemistry in society. To have social awareness of its profession, have the capacity to disseminate knowledge relevant to the community. Know the educational reality, consider the context in which he is inserted as a professional. Know the Brazilian educational problems, consider the social, economic and political context of the school reality. To carry out activities that collaborate with society through the professional training.</td>
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<td>- Community</td>
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<td>- District</td>
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<td>- School</td>
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With respect to the 60 tests of selection of professors of chemistry evaluated we had 3,758 occurrences of subjects in the 3,576 objective questions and in the twenty tests of essay questions. The final result is presented in Figure 3, where the predominance of questions that require the specific knowledge of chemistry is evident.

**Figure 3. Occurrences of all categories (%) in the 60 tests of selection of chemistry teachers**

The themes that predominate in the category of chemical knowledge are Aqueous solutions and concentrations (5.9% of all occurrences in this category); Stoichiometry (5.2%) and Thermochemistry (5.0%). In the Portuguese language knowledge category: text interpretation (23.1%). In the category pedagogical knowledge, the predominant theme was Guidelines and Basic Law (9.2%), evaluation (8.7%) and pedagogical theories (8.1%). In the category Others, the predominant theme is computer science and new technologies (22.9%), mathematics (14.4%) and public administration, regional geography and economy (10.2% each).

Very few tests work with essay questions. Out of 60 tests, only 20 contained essay questions. The predominance in these questions is pedagogical knowledge (41.5%), specific content knowledge (31.7%), pedagogical content knowledge (22.0%) and context knowledge (4.9%). There was not a single issue where the candidate had been exposed to a real classroom situation.

**CONCLUSION**

The chemistry teacher profile that has been selected in public exams for Brazilian chemistry teacher is the one who must master the specific content of chemistry, have knowledge of pedagogical theories, be able to interpret texts, know the Law of Guidelines and Bases, and know to use a computer. The official documents are broader, but they also do not approximate their guidelines to what the chemistry teacher will face in the classroom.

On the other hand, through the teacher knowledge literature presented, what a teacher needs to know is much broader and deeper than what appears as a result of this research. Judging by public examinations, as well as Brazilian public policy documents, Brazilian future chemistry teachers basically need to know chemistry but do not need to know how to teach chemistry.

**ACKNOWLEDGEMENT**

The authors are grateful to the financial support, Grant #2013/07937-8, São Paulo Research Foundation (FAPESP).
REFERENCES


PRE-SERVICE CHEMISTRY TEACHERS’ CONCEPTIONS OF HOW TO TEACH ‘ACIDS AND BASES’

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The topic ‘acids and bases’ is an important part of the Austrian syllabus for chemistry in secondary schools. On the one hand, it allows the establishment of cross-connections to everyday experiences and phenomena, and on the other hand, it is a rewarding example for chemical reactions following the ‘donator-acceptor-principle’ as a basic concept. In order to teach ‘acids and bases’, teachers have to draw on (amongst other things) a proper understanding and using of the particle concept, thinking in models, dealing with different historical explanatory approaches, and planning and interpreting appropriate experiments. Furthermore, teachers have to know about the significance of learners’ conceptions for teaching and learning this topic and how to deal with them. For this reason, pre-service chemistry teacher education has to provide opportunities to learn, apply, and reflect on such knowledge and competencies so as to build up professional knowledge and skills. This paper provides an insight into a pre-service teacher education course in chemistry didactics and students’ progress on their way to developing an appropriate professional knowledge and skills concerning the topic ‘acids and bases’. Having taught this university course for several semesters, we realised that – for all our efforts – at the end of the term many students still struggle with their own misconceptions concerning ‘acids and bases’ and still confound different models. To investigate how these specific difficulties manifest themselves, we used a questionnaire and started to analyse videotapes of the students’ microteachings. Selected findings from the questionnaires compiling students’ conceptions as well as a first insight into the analysis of the microteachings will be presented and discussed. Furthermore, possible reasons for students’ persistent confusions concerning the topic ‘acids and bases’ are extracted from the literature and summarised.

Keywords: pre-service teacher education, conceptual change, microteaching

‘ACIDS AND BASES’ AS FRAMEWORK FOR AN INTRODUCTION IN CHEMISTRY DIDACTICS

The chapter ‘acids and bases’ is an important part of the Austrian syllabus for secondary schools where it is embedded within the basic concept ‘donator-acceptor-principle’. The syllabus follows the definition of acid-base-reactions as proton-transfer-reactions and also refers to it in connection with the topic ‘chemical changes’ focusing on ‘protolysis equilibrium’. Corresponding to this, all textbooks for chemistry in upper schools use the acid-base definition following Brønsted.

In order to be able to teach this and other topics successfully, chemistry teachers need a sound knowledge of chemistry as well as profound pedagogical and didactical knowledge and skills. To develop an appropriate professional knowledge and skills, student teachers have to build up a reliable bridge between chemistry-related content knowledge and knowledge of instructional strategies for teaching chemistry.
For this, they need …

- a strong and reliable content knowledge base
- knowledge and appreciation of learners’ conceptions and their specific difficulties with ‘acids and bases’
- knowledge about different representations, models and approaches to deal with ‘acids and bases’
- knowledge about student-oriented teaching and learning strategies for ‘acids and bases’ and
- skills to plan, conduct and reflect effective learning environments.

The course ‘Introduction to Chemistry Didactics’ at the University of Vienna offers an opportunity to do so. Accordingly, our teaching goal is to support student teachers to develop their ability to teach ‘acids and bases’ successfully. To introduce pre-service chemistry teachers to the challenges of teaching chemistry at school, and to start discussions about the relevance of learners’ (pre-)conceptions, the students are asked to complete a questionnaire referring to selected basic aspects of the topic ‘acids and bases’. This is aimed at stimulating students’ reflection about their own (mis-)conceptions, triggering conceptual change, and introducing the importance of knowing about learners’ pre- and alternative conceptions for fruitful teaching and learning. Building on this discussion, students are introduced to selected papers from international journals dealing with the relevance of knowing about and dealing with learners’ alternative and mis-conceptions in general as well as those concerning ‘acids and bases’. The problem of mixing up different models (Arrhenius and Brønsted) and the subsequent confusions are specially stressed (cf. Van Driel & Verloop 1999, 2002; Barke 2015). The next relevant step is to link content knowledge with suitable instructional strategies. To stimulate this, students are assigned to construct a Content Representation-table (CoRe) following Loughran et al. (2012). Based on this and to merge theory with practice, students are now asked to design and conduct a 15 minute learning opportunity (microteaching) in the context of ‘acids and bases’ in which they have to address one selected ‘big idea’ (out of the CoRe), as well as one competence appropriate for this ‘big idea’. The resulting microteachings are videotaped to give students a basis to reflect on the pros and cons of their lessons. In their final papers, students have to select two sequences of their microteachings (a good and an improvable one) and reflect on them while bringing together their theoretical knowledge and practical experience using arguments based on relevant literature. These reflections can be seen as a mirror of students’ actual pedagogical content knowledge and skills.

Based on the experience of several courses, we realised that at the end of the term many of the student teachers still struggle with their own mis-conceptions concerning ‘acids and bases’, they still mix up the macroscopic level and the sub-microscopic level and confound different models. For this reason, we decided to immerge deeper into the matter to get answers to the following questions:

- What are student teachers’ main problems while teaching ‘acids and bases’?
- What are the prevalent characteristics and manifestations of these problems?
To do so, we decided to apply the questionnaire not only at the beginning but also at the end of the courses. In addition, we started to develop an analytical framework so as to systematically analyse the microteaching videos which could then be used to identify and better understand student teachers’ main problems when teaching ‘acids and bases’. Using these insights, we aim to design and test learning opportunities to help student teachers overcome these problems.

In the following, we present a short insight into selected students’ perceptions to give an impression of the challenge student teachers as well as teacher educators face in pre-service chemistry teacher education. Firstly, we will outline the difficulties pre-service chemistry teachers seem to have with the topic ‘acids and bases’ by giving insight into selected findings from 218 questionnaires (ten closed-ended questions; most of them with the request to give reasons for the decision). Only since winter semester 2016-17, students are asked to complete the questionnaire at the end of the term as well. Secondly, we will sketch the analysis of the videotaped microteachings, which has only recently started, to identify and characterise students’ struggle with teaching ‘acids and bases’, and thirdly, we will discuss the causes that possibly lie behind these matters of facts.

**PRE-SERVICE CHEMISTRY TEACHERS’ STRUGGLE WITH THE TOPIC ‘ACIDS AND BASES’**

One of the main problems seems to be that many student teachers use the terms ‘acid’ and ‘acidic solution’, as well as ‘base’ and ‘basic solution’ synonymously. This becomes apparent in students’ answers to the questions whether ‘HCl is muriatic acid’ and if ‘NaOH is soda lye’ (Figure 1).

![Figure 1. Students’ perceptions concerning the difference between acid and acidic solution respectively base and basic solution (N = 218)](image)

For example, students’ give the following reasons for the chosen answer:

- Because muriatic acid is the trivial name of hydrogen chloride.
- Because we learned it that way.
- Because OH⁻ ions can be separated.
- Because NaOH likes to accept H⁺.
It becomes obvious that students do not distinguish between hydrogen chloride, which is a gas, and muriatic acid, which is the aqueous solution of hydrogen chloride. Furthermore, strictly speaking HCl stands for one hydrogen chloride molecule and not for the substance, the gas, consisting of a vast number of hydrogen chloride molecules. The same applies analogically to NaOH and soda lye; with the exception that sodium hydroxide consists of ions. Another point is the argument of some of the students that ‘NaOH is soda lye because OH ions can be separated’. Firstly, sodium hydroxide (Na’OH) is a solid substance consisting of sodium ions and hydroxide ions. Secondly, the students’ reasoning goes back to the Arrhenius model and disregards the fact that it is not the release of hydroxide ions that is responsible for the basic character but the ability of the hydroxide ion to accept a hydrogen ion (proton).

In the laboratory jargon, the aqueous solution of hydrogen chloride, the muriatic acid, is repeatedly labelled as ‘HCl’ and the respective bottles are commonly marked with this label. Chemists know what they mean when they use the term ‘HCl’ while talking about muriatic acid, but learners are irritated when teachers do not distinguish clearly between acid (hydrogen chloride molecule; HCl) and acidic solution (muriatic acid; chloride ions and oxonium ions and water molecules; Cl(aq) + H3O+(aq)). In this case, learners will probably have no chance to understand acids in terms of Brønsted as particles from which hydrogen ions (protons) can be removed (Barke, 2015). The same applies for bases and basic solutions. As a result, learners at school, as well as student teachers, are not able to recognise the formation of water molecules (H2O) out of oxonium ions (H3O+) and hydroxide ions (OH-) as the driving force of the neutralisation reaction. In the laboratory jargon, scientists seldom differentiate between the macroscopic (phenomenon level) and the sub-microscopic (particle level) level (Johnstone, 2000), which also causes confusion amongst the learners because it is not clear whether the substance or the particle is referred to.

These problems are also mirrored in students’ responses to the following item: Students were asked to quote whether the statement ‘During the neutralisation acid and base react under formation of salt and water.’ is appropriate or not. Phrases like this can be found commonly as take home message in textbooks and learners’ exercise books. Only 24 out of 218 student teachers realised that this statement causes trouble in several aspects. For instance, students give the following reasons for their answers:

- NaOH + HCl → NaCl + H2O.
- acid splits off H⁺ → turns to salt; base splits off OH⁻; → OH⁻ + H⁺ → H₂O
- Because salts have a neutral pH-value.

Student teachers seem not to be aware of the following three points: Firstly, the term ‘neutralisation’ describes one special case of neutralisation reactions, in which equimolar quantities of hydrogen ions and hydroxide ions react under the formation of water molecules and the pH-value ends up at pH 7, therefore neutral. The unambiguous term in this statement should be ‘neutralisation reaction’ instead of ‘neutralisation’. Secondly, in chemistry the term ‘salt’ is used to refer to an ionic compound in which the ions are arranged in a solid ionic crystal. The word ‘Salt’ in the mentioned take home message, on the other hand, is used for ions in an aqueous solution (e.g. Na+(aq) und Cl⁻(aq)) which is misleading. Thirdly, these ions do
not play any role in the abovementioned reaction. In the context of neutralisation reactions, the only relevant reaction is the one between oxonium ions (H$_3$O$^+$) and hydroxide ions (OH$^-$) forming water molecules (H$_2$O).

Subsequently, the focus is laid on students’ answers and reasoning to two related questions with four answers at choice in each case. Only one answer is considered to be correct (here in bold type):

1. What is the difference between a strong and a weak acid?
   a. Strong acids have a higher pH-value than weak acids.
   b. Strong acids contain more hydrogen atoms than weak acids.
   c. Strong acids are more concentrated than weak acids.
   d. **Strong acids ionise more than weak acids.**

2. What has to be known so as to make a clear statement about the strength of an acid?
   a. The concentration.
   b. The number of hydrogen atoms in the compound.
   c. **The potential degree of ionisation in water.**
   d. The pH-value.

The strength of an acid or a base is often falsely described with a pH-value that is notably low or notably high for strong acids or strong bases, respectively. Almost twenty percent of the student teachers are not aware of the fact that it is only the degree of ionisation that can be used to characterise the strength of an acid or a base.

This outcome does not seem to be alarming at first. In the following work with the student teachers, when they have to plan and conduct a learning opportunity, however, it becomes apparent that most of them have considerable uncertainties with regard to their subject matter knowledge. For example, they frequently try to show the strength of an acid using an indicator or they argue that strong acids are more concentrated than weak acids (Lembens & Becker, 2017). This problem is not only due to different meanings of the word ‘strong’ in everyday and technical language. In addition to this discrepancy in meaning in everyday and technical language, there were partially or even wholly incorrect statements in textbooks mainly for lower secondary schools (e.g. ‘strong acids have a low pH-value’) which student teachers, as well as in-service teachers pass on without further reflection.

Figure 2 shows only the participants of the last two semesters who filled out the questionnaire at the beginning and at the end of term. We can see an improvement from 54 (76%) correct answers to 58 (89%). In fact, all the participants of summer term 2017 ticked the correct answer at the end of the semester.
Figure 2. Students’ perceptions concerning the difference between a strong and a weak acid (Question 1). Semester 2016/17+17; pre and post (N = 75; pre 5 absent, post 14 absent)

Strongly interrelated with this question is question 2 (‘What has to be known so as to make a clear statement about the strength of an acid?’). The answers to question 2 emphasise the subject-specific uncertainties of the student teachers. Only half of the participants recognise the fact that ‘The potential degree of ionisation in water.’ is what has to be known to make a clear statement about the strength of an acid. Even though 176 (81%) of the same students seemed to know that the difference between a weak and a strong acid is defined as the potential degree of ionisation in water, they struggle with this closely related question. Figure 3 again only shows the participants of the last two semesters who filled out the questionnaire at the beginning and at the end of the course. We can see an improvement from 45% correct answers to 60%. However, what seems to be rather problematic for us is to know that there are still 40% of the participants with inappropriate conceptions at the end of the course.

Figure 3. Students’ perceptions concerning what has to be known so as to make a clear statement about the strength of an acid (Question 2). Semesters 2016/17+17; pre and post (N = 75; pre 5 absent, post 14 absent)
The inconsistency in the replies to these two questions show rather clearly participants’ deep uncertainty concerning the topic ‘acids and bases’. As mentioned above, these troubles also become obvious when the teacher students plan and conduct their microteachings at the end of term.

**Microteachings reveal student teachers’ inappropriate conceptions**

Microteaching refers to a teacher education technique that consists of a well prepared and videotaped mini-lesson. This is followed by a review in order to obtain constructive feedback from peers and supervisors, and to improve the teaching and learning experience. Preparing the lesson, watching the video and reflecting about what has worked out well and which improvements could be made, provides students an authentic and intense view of their own teaching. Hattie considers microteaching as an effective method for improving student outcomes and ranks it among the top five effects on student learning and achievement (Hattie, 2012). By now, we have collected experiences with microteachings from nine semesters (with a minimum of four per semester) and have developed the impression that students often do not seem to be able to design and conduct a 15-minute learning opportunity that is free from subject-specific shortcomings. The microteachings at the end of term reveal several obstacles, such as mixing up the Arrhenius with the Brønsted model, confusing the phenomenon and the particle level, using unclear language, as well as raising subject-specific shortcomings.

A very frequent problem appears to be the fact that many students use the terms ‘acid’ and ‘acidic solution’, as well as ‘base’ and ‘basic solution’ synonymously, not being aware that they address the particle level when saying ‘acid’ and the phenomenon level when saying ‘acidic solution’. Furthermore, they are confusing themselves while referring to hydrogen ions, when talking about the properties of acids and hydroxide ions when referring to the properties of bases, not perceiving that they are mixing up two different and incompatible models.

To systematically investigate how these specific difficulties are manifesting themselves, we started to develop an analytical framework to analyse the microteaching videos with the aim to identify and understand student teachers’ main problems when teaching ‘acids and bases’. The first step was to get a general idea of which problems and mis-conceptions occur during the microteachings. Based on the big ideas from the collaboratively developed Content Representation-table (CoRe) (Loughran et al., 2012) and findings from literature, several categories for the analytical framework were defined as a starting point. This category-system is now enhanced and extended inductively while analysing relevant parts of the videos in detail. Afterwards, the revised category-system will be used for a detailed analysis of all video-taped microteachings.

Using the findings from the systematical analysis of the microteachings and the questionnaires, we do not only want to identify the student teachers’ main problems with the subject matter and their prevalent characteristics, but also strive to design and test more effective learning opportunities for pre-service teacher education to overcome outlasting mis-conceptions regarding the topic ‘acids and bases’. In order to do so, we also draw on preceding findings from the literature.
SEARCH FOR POSSIBLE CAUSES: INSIGHTS GAINED FROM EDUCATIONAL RESEARCH

Why are student teachers so uncertain while dealing with the topic ‘acids and bases’? This question suggests itself while working with the student teachers. All of them have learned about ‘acids and bases’ in school, they passed the exam of a basic lecture on chemistry called ‘General Chemistry’ and the corresponding practical course at university. Obviously these learning opportunities are not suitable to help the students to build up a scientifically appropriate conception about the topic ‘acids and bases’. At this point, the question why this happens asserts itself.

In lower secondary education, ‘acids and bases’ are mostly taught in accordance with the model by Arrhenius, which defines acids as substances that release hydrogen ions in water and bases as substances which release hydroxide ions in water. This definition remains very stable in the minds of learners which may be the reason for their difficulties in replacing this concept later on with the scientifically more appropriate model by Brønsted. Brønsted defines acids as particles from which hydrogen ions can be removed and bases as particles which can accept hydrogen ions. Using the Brønsted model, we are able to describe acid-base-reactions beyond aqueous solutions. Despite learning and knowing the new Brønsted or Lewis model in upper secondary school, learners see no significance for a conceptual change and retain the Arrhenius model they initially apprehended, and additionally, they mix up the different models without being aware of this (Lembens, 2017).

Several studies reveal that experienced teachers’ knowledge and conceptions about models of acids and bases may also be limited and confused (Van Driel & Verloop 1999, 2002). Teachers often lack knowledge of learners’ conceptions about models and their function in science, or this knowledge is not expressed in planning and conducting lessons. Justi & Gilbert (2000) show that teachers often do not refer to particular models while teaching chemistry, but rather transfer properties from one model to another, which finally leads to teaching hybrid models. This in turn inevitably causes confusion amongst the learners. Drechsler & Schmidt (2005) found that not all chemistry teachers are aware of the existence and the applicability of the different historic and recent acid and base models. To prepare their lessons, they consult textbooks which mostly neither discuss explicitly the application of models nor the distinction between the different models – thus, they also apply hybrid models.

As a consequence of such textbooks and such teaching at school, we find pre-service chemistry teachers in our university courses whose thinking is dominated by the limited Arrhenius model. They are not aware of mixing up different models, and do not distinguish between the macroscopic and the sub-microscopic level. Therefore, they are hardly able to define acids and bases beyond ‘acids have a pH-value lower than seven and bases have a pH-value higher than seven’ and furthermore, they do not distinguish between acids and acidic solutions and bases and basic solutions, respectively, while confusing the particle level with the phenomenon level. The technical chemistry courses at the beginning of their education at the university do not seem to offer sufficient learning opportunities to develop scientifically appropriate conceptions or to see the need to reflect about one’s own understanding of subject matter knowledge. The prevailing concepts seem to be extremely resistant to change, which reveals itself during the
microteachings at the end of the course ‘Introduction to Chemistry Didactics’. Obviously, even our course does not enable all student teachers to carry out a conceptual change.

**NEXT STEPS**

The next steps on our way to develop and test effective learning opportunities in the context of ‘acids and bases’ are: to review the most common textbooks for primary and secondary chemistry teaching in Austria; to conduct interviews with experienced chemistry teachers; to further develop and validate the analytical framework for the analysis of the microteachings; to analyse the microteachings; to identify and characterise student teachers’ main obstacles; to develop, test and refine effective learning sequences and, at the end, to write an evidence-based didactical program for fruitful and effective teaching in the context of ‘acids and bases’.

**ACKNOWLEDGEMENT**

We thank all student teachers and our colleagues at the Austrian Educational Competence Centre Chemistry for irritating and fruitful discussions stimulating our reflection about our own understanding in the context of ‘acids and bases’.

**REFERENCES**


TEACHING TO TEACH: INDICATIONS OF FORMATIVE CHEMISTRY TEACHER TRAINING IN TEACHING PRACTICE OF ITS UNDERGRADUATES

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Research on teacher education recognizes that there is a basic knowledge to the profession. In this paper we adopt the view that the Pedagogical Content Knowledge (PCK) is the articulating element of the Knowledge Base for Education, the core knowledge of a teacher. In the process of chemistry teacher education several actions are conducted to develop the knowledge necessary for teaching across different disciplines and activities, but still little study on the influence of the formative action of teacher educators in the chemistry teaching practice of its undergraduates. The ultimate goal is to point out the relationship between the formative action of teacher educators and the knowledge mobilized during teaching practice for chemistry student teachers. The research is qualitative in that a multiple case study was conducted with three chemistry student teachers and twelve of their trainers by having as teaching focus the content redox reactions. Therefore, the data collected with the undergraduates were based on Content Representation (CoRe), interviews, materials used in classes, field diary records and internship reports. Data from teacher's formers were based on interviews, CoRe, educational materials for teachers and written records of the classes. The analyses of the data were based on the Bourdieu’ understanding to describe the relationships of power and the reproduction of practices within a field. The methodology of content analysis was used with support of the ATLAS.ti software in the analysis of the data set. It was possible to identify evidence of the influence of trainers on student's teachers from the triangulation of data. The results point out to differences in the incorporations done by undergraduates of theoretical elements and aspects of teaching practice from trainers with distinct characteristics and knowledge derived from the practice of teachers of subjects in the fields of chemistry and pedagogy.

Keywords: formative action, PCK, teacher trainers.

INTRODUCTION

The profession of teacher educator requires the development of specific knowledge, skills and abilities that are not always built in the context of undergraduate or graduate training. Teaching someone knowledge is not the same as teaching someone to teach that knowledge to others. Vaillant (2003) in mapping the situation in Latin America, points out that the Latin American trainer has little information and knowledge to support his training activities and that he continues to develop his teaching based on the education received as a student, whether in basic education or higher.

In Brazil, in order for someone to become a professor of higher education, he is asked to have a graduate education, with no request for mastery of specific skills and abilities to teach; the same is true for those who will be trainers of new teachers: they do not need to have any experience and specific knowledge for teaching.
In the context of this research, we assume that teacher trainers "are all professionals involved in the learning processes of the teaching of future teachers or those who are already developing teaching activities: teachers responsible for university courses as Teaching Methodologies and Supervised Internship, those of the pedagogical disciplines in general, those of the specific disciplines of different areas of knowledge and the professionals of the schools that welcome the future teachers" (Mizukami, 2005).

In this work we understand the knowledge necessary for teaching in the perspective of the knowledge base for teaching of Grossman (1990), namely: subject matter knowledge, general pedagogical knowledge, knowledge of the context and pedagogical content knowledge (PCK). Among the knowledge of this base, the PCK is considered the central professional knowledge of teachers (Kind, 2009; Fernandez, 2014).

We also use the idea that the trajectories of personal and professional formation influence the way of being and teaching. The linking pictures (Josso, 2006) and how we connect and learn from others tell us a lot about what we do or do not do, about our confidence in our abilities, our commitment to doing things the best way.

Every life story is a real plot. It is the social plots, the relationships with the other, that people invoke when telling their life stories and that are far from being autonomous. It is because the human being does not live alone but in a world relations. Generally, individual stories are dependent on wider social frames, sometimes embedded in them, and sometimes resulting from them. It is at this point that we come to consider a metaphor proposed by Josso (2006), of the connection figures as sailor knots. Josso justifies the use of the metaphor by saying:

[...] The attempt to use this metaphor is to give the impression that the connection is at the same time what gives a support, that holds and that maintains a relative stability, that allows the movement in a defined perimeter, but also what prevents to leave this perimeter, which goes in, which can be hurt when trying to achieve freedom without achieving it, which undoes more or less easily to find freedom of movement. The node also refers to the complexity of the connection, joining two wires or strings to many other wires. There is, therefore, in this metaphor, also, the two and the greatest number. There is no human being who is not, re-connected, connected, or symbolically like Robinson Crusoe. Hence the importance of the theme of the connection in the understanding of our process of formation and knowledge. (Josso, 2006).

In addition, we rely on Bourdieu (1983), especially on the notions of Field, Capital and Habitus to understand how the formative action of teacher trainers influences the teaching practice of their graduates. Bourdieu assists us in understanding how the social space of university teaching is organized, how the social, cultural, symbolic and scientific capitals of the trainers influence their teaching and the power relations present between the agents of the different training areas that make up a course of chemistry teacher education.

In Bourdieu the discussions about the Field are intertwined with other notions such as those of Capital and Habitus and pass through their works at different times, addressing the most diverse areas: fashion, literature, science, religion, marriage, education, politics, among others. The Field is a social space that has a particular structure, with specific objectives, that works relatively autonomously in relation to other social spaces, refers to a "[...] universe in which agents and institutions are inserted which produce, reproduce or diffuse art, literature or science. This universe is a social world like the others, but obeying more or less specific social laws "(Bourdieu, 2004).
It is common the analogy of the field with a game, with its rules, created by its players, but that are not always clear to all who participate in the game. Some agents or institutions are able to create or change the rules and do so because of the Capital they hold and the position they hold in the field. Thus, there is a constant struggle between the agents of the field who hold the greatest amount of capital and dictate the rules of the game, the norms of the Field, and define which is, at a given moment, the set of important objects for the field. On the other side are those who threaten the position of the dominant ones by conquering enough capital to become important. The different forms of capital that allow for different structural configurations of the Field are: economic capital, cultural capital, social capital and symbolic capital.

Habitus is defined by Bourdieu as "a system of durable and transposable dispositions which, integrating all past experiences, functions at every moment as a matrix of perceptions, appreciations and actions - and makes possible the accomplishment of infinitely differentiated tasks, thanks to the analog transfer of schemes" (Bourdieu, 1983). The experiences lived by each person in function of their position in the field effect their subjectivity, composing a "matrix of perceptions and appreciations", which guides their actions in later situations. The habitus would then be the result of the incorporation of the social structures and the place of origin of the person in the field, which would "structure the actions and representations of the subjects" (Nogueira & Nogueira, 2004).

It is through habitus that the past survives at the present moment and tends to remain in the future actions of the social agents. This, according to Bourdieu (1983), is a process of interiorization of exteriority and exteriorization of interiority. Everything that characterizes a social position that the individual occupies (tastes, preferences, symbols, beliefs, gestures) is incorporated by him, not always consciously, and becomes part of the composition of the individual himself, that means becomes a habitus. And it is from this generating matrix of actions that individuals act, guided by a practical sense that was constituted in the historical moment that they lived.

Studies in the perspective of life histories show that in the first years as a teacher, we refer to images, personal and professional postures, to the performances of teachers who have remained in our memories. So, we can infer that "our formative processes do not begin in an intentionally chosen course, but in the different spaces and times where we already live the student experience" (Cunha & Isaias, 2006). That is, our history of education is marked by the course of student and teacher life that we have characterized as an ongoing process whether it is reflected or not.

**METHODOLOGY**

This research is characterized as a multiple case study (Yin, 2010) to be carried out with three undergraduate students of the Chemistry Teacher Education course from a Brazilian public university (identified anonymously as Adriano, Juliana and Rafaela ) and eleven of their training teachers (encoded as P1, P2, till P11). We used the method of life stories during the conduct of interviews. The data collection was carried out in a specific situation - the practice of teaching redox process in basic education, during 2011 and 2012. For the evaluation of the basic knowledge of the teaching we preceded a multireferential analysis (Baxter & Lederman,
1999). Data were collected from multiple sources, including semi-structured interviews, lesson plans, teaching practice reports, teacher journals, guided reflections written by student teachers', teacher work samples and class notes written by undergraduates in various disciplines. The steps can be summarized in: i.) identification of Knowledge Base for teaching and PCK of chemistry student teachers'; ii.) indications of didactic practice on student teachers classes related to their trainers; iii.) Crossing ideas and stories. Data analyzes include categories from the Model of Teacher Knowledge (Grossman, 1990) and Hexagonal model of PCK for science teaching (Park & Oliver, 2008). We also use the Atlas.ti software to help with the analyzes.

RESULTS AND DISCUSSION

In a first analysis we outline the state of development of the knowledge for the teaching of the undergraduates. In a descriptive-interpretive work, we seek to clarify what each student thinks and what each one does by teaching the theme oxirreduction, pointing out how different knowledge can influence the development of the other components of the base and the PCK. We analyze the knowledge for the teaching of the trainers and show how they understand their responsibility in the training of the pre-service chemistry teachers.

In analyzing the relationships between life histories, we sought the bonds that were established between the subjects, the networks of relationships in the histories of their lives in the academic period, to understand what relationships were established and what kind of link they generated among the participants in the search. With this analysis we intend to identify elements of influence of the formative action of the trainers in the habitus and the basic knowledge of the teaching of the pre-service teachers from the bonds between the individual and collective life histories of each pre-service teacher and teacher.

At the same time, we delineate the capital and habitus of the trainers and of the undergraduates, identifying how the variation of the capital volume of each component of the university teaching field in the undergraduate course in Chemistry Education analyzed puts it in different positions in the field itself, as it generates new relations among agents and is reflected in the construction of the individual and collective habitus of the pre-service teachers, and as elements of this habitus appear in the teaching practice of the student teachers.

In the analysis of the capital and the habitus of the trainers we identify individual characteristics of each agent and aspects common to each group of teachers (of specific content and pedagogical / methods disciplines).

We present in Table 1 a summary of the constituent elements of the contents of the disciplines of the Chemical Education course and / or aspects present in the formative action of the different teacher trainers that were incorporated into the knowledge for the teaching and for the PCK of the student teachers. Formative action is composed by what is taught and how it is taught; in other words, the contents of the subjects and the teacher's conduct of the classes he teaches, the activities he develops, and the way he organizes class actions.

For the construction of Table 1 were listed the most characteristic elements of the teaching practice of each student teacher, recognized from the analysis of their knowledge for teaching
and their teaching habitus. From the description of these elements we look for in the syllabus of the disciplines taught by the trainers which of those elements were constituents of the disciplines. We analyzed the logbooks and materials provided by the teachers to identify if that aspect was commonly evidenced in the teaching practice of the teacher.

Table 1. Aspects and elements of the formative action of the trainers incorporated into the teaching practice of the student teachers

<table>
<thead>
<tr>
<th>Student Teacher</th>
<th>Aspect/Element incorporated into your PCK</th>
<th>Present in the formative action of the trainer</th>
<th>Theoretical element of the discipline</th>
<th>Practical aspect of the discipline/trainer action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adriano</td>
<td>Study of the knowledge of the subject related to daily life</td>
<td>P7 Science Teaching</td>
<td>Science Teaching</td>
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<td></td>
<td></td>
<td></td>
<td>Chemistry Teaching</td>
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<td></td>
<td></td>
<td></td>
<td>Chemistry Teaching I</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P11</td>
<td>--</td>
<td>Chemistry in the high school</td>
</tr>
<tr>
<td></td>
<td>Emphasis on experimentation in its various modes: demonstrative, investigative, for verification of concepts</td>
<td>P7 Chemistry Teaching I</td>
<td>Chemistry Teaching I</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P9 Chemistry Teaching II</td>
<td>Chemistry Teaching II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preparation of experiments with alternative materials</td>
<td>P7 Chemistry Teaching I</td>
<td>Chemistry Teaching I</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P9 Chemistry Teaching II</td>
<td>Chemistry Teaching II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Active participation of students in experimentation</td>
<td>P6 --</td>
<td></td>
<td>Experimental Inorganic Chemistry</td>
</tr>
<tr>
<td></td>
<td>Relation of contents of different series and disciplines, understanding of the relation between the disciplines of the sciences area</td>
<td>P1 --</td>
<td></td>
<td>Physics</td>
</tr>
<tr>
<td></td>
<td>Resolution of exercises in classroom and correction of exercises</td>
<td>P2 --</td>
<td></td>
<td>Theoretical Inorganic Chemistry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P3 --</td>
<td></td>
<td>Eletrochemistry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P6 --</td>
<td></td>
<td>Theoretical Inorganic Chemistry</td>
</tr>
<tr>
<td></td>
<td>Valuing the good relationship between teacher and students</td>
<td>P8 Didactic</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P11</td>
<td>--</td>
<td>Chemistry in the high school</td>
</tr>
<tr>
<td></td>
<td>To value the previous knowledge / level of understanding of the students with respect to certain content to be able to teach it</td>
<td>P1 --</td>
<td></td>
<td>Physics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P8 Didactic</td>
<td></td>
<td>Didactic</td>
</tr>
<tr>
<td></td>
<td>Emphasis on student participation in class</td>
<td>P2 --</td>
<td></td>
<td>Theoretical Inorganic Chemistry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P8 Didactic</td>
<td></td>
<td>Didactic</td>
</tr>
<tr>
<td></td>
<td>Special attention to the training needs of the students to adapt concepts to their cognitive level</td>
<td>P6 --</td>
<td></td>
<td>Theoretical Inorganic Chemistry</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>Slow the pace of learning and resume concepts</td>
<td>P2 --</td>
<td></td>
<td>Theoretical Inorganic Chemistry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P6 --</td>
<td></td>
<td>Theoretical Inorganic Chemistry</td>
</tr>
<tr>
<td>Strand 13</td>
<td>Attention to the basic concepts of oxidation</td>
<td>P2</td>
<td>Experimental Inorganic Chemistry</td>
<td>Experimental Inorganic Chemistry</td>
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<td>--------------------------------------------</td>
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<tr>
<td></td>
<td>P6</td>
<td></td>
<td>Experimental Inorganic Chemistry</td>
<td>Experimental Inorganic Chemistry</td>
</tr>
<tr>
<td></td>
<td>Use of Information and Communication Technologies</td>
<td>P7</td>
<td>Chemistry Teaching I</td>
<td>Chemistry Teaching I</td>
</tr>
<tr>
<td></td>
<td>Activities involving modeling work in chemistry teaching</td>
<td>P7</td>
<td>--</td>
<td>Chemistry Teaching I</td>
</tr>
<tr>
<td></td>
<td>Resolution of exercises in classroom and correction of exercises</td>
<td>P2</td>
<td>--</td>
<td>Theoretical Inorganic Chemistry</td>
</tr>
<tr>
<td></td>
<td>P3</td>
<td></td>
<td>--</td>
<td>Electrochemistry</td>
</tr>
<tr>
<td></td>
<td>P6</td>
<td></td>
<td>--</td>
<td>Theoretical Inorganic Chemistry</td>
</tr>
<tr>
<td></td>
<td>Valorization of the activity of planning and preparation of classes</td>
<td>P8</td>
<td>Didactic</td>
<td>Didactic</td>
</tr>
<tr>
<td></td>
<td>Continuous assessment as a means to reorient classroom actions in the classroom</td>
<td>P8</td>
<td>Didactic</td>
<td>Didactic</td>
</tr>
<tr>
<td></td>
<td>P10</td>
<td></td>
<td>Chemistry Teaching III</td>
<td>Chemistry Teaching III</td>
</tr>
<tr>
<td></td>
<td>Science, Technology and Society Approach - CTS</td>
<td>P7</td>
<td>Science Teaching</td>
<td>Science Teaching</td>
</tr>
<tr>
<td></td>
<td>P9</td>
<td></td>
<td>Chemistry Teaching I</td>
<td>Chemistry Teaching I</td>
</tr>
<tr>
<td></td>
<td>Environmental education</td>
<td>P7</td>
<td>Chemistry Teaching I</td>
<td>Chemistry Teaching I</td>
</tr>
<tr>
<td></td>
<td>P9</td>
<td></td>
<td>--</td>
<td>Chemistry Teaching II</td>
</tr>
<tr>
<td></td>
<td>Constructivist aspects: student to be active in his own learning</td>
<td>P1</td>
<td>--</td>
<td>Physics</td>
</tr>
<tr>
<td></td>
<td>P8</td>
<td></td>
<td>--</td>
<td>Didactic</td>
</tr>
<tr>
<td></td>
<td>P10</td>
<td></td>
<td>Chemistry Teaching III</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Emphasis on teaching for understanding</td>
<td>P8</td>
<td>Didactic</td>
<td>Didactic</td>
</tr>
<tr>
<td></td>
<td>Special attention to the teacher-student relationship, more human aspects, need for attention to the person, letting talk, listening</td>
<td>P8</td>
<td>Didactic</td>
<td>Didactic</td>
</tr>
<tr>
<td></td>
<td>P10</td>
<td></td>
<td>--</td>
<td>Chemistry Teaching III</td>
</tr>
<tr>
<td></td>
<td>Learn chemistry to make decisions as a citizen</td>
<td>P7</td>
<td>Chemistry Teaching I</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>P9</td>
<td></td>
<td>Chemistry Teaching II</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Work by project, focus on understanding aspects of reality</td>
<td>P1</td>
<td>--</td>
<td>Physics</td>
</tr>
<tr>
<td></td>
<td>P7</td>
<td></td>
<td>Chemistry Teaching I</td>
<td>Chemistry Teaching I</td>
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<td></td>
<td>P9</td>
<td></td>
<td>Chemistry Teaching II</td>
<td>Chemistry Teaching II</td>
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<tr>
<td></td>
<td>Rafaela</td>
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</tbody>
</table>
Adriano incorporates quite a lot of the idea that P6 has about conducting experimental classes: students need to do! At various times in their classes this is evidenced by situations in which the students must conduct the activities, they must organize themselves to understand the process of the experiment and act on the theoretical proposal of accomplishment of the experimental activity. Regardless of the direction of the experimental activity - investigation or verification of knowledge - Adriano requests that the students prepare the solutions, calculating the amount of reagent required for each concentration. He speaks in one of the analysis documents of his practices that:

    [...] in conducting activities in this way students have the opportunity to discuss, question their hypotheses and initial ideas, and also, when they work in an investigative way, collect and analyze data to find possible solutions to the problem.

Juliana incorporates the understanding of the importance of the work with the modeling in the chemistry teaching of P7 and P10 and makes use strongly in its classes of activities with models for the oxirreduction subject, especially for the submicroscopic process of the transfer of electrons that occurs in a reaction of oxidation. Besides being present in his classes this was reported in the interview and in the CoRe. Juliana works from the knowledge of the students' alternative conceptions, for example, before beginning the development of the subject in class she seeks to know: Can an Oxidation process be separated from a Reduction process? Why?.

To develop the idea that the two processes are complementary, she produces for her classes a didactic video that shows the reaction of a piece of metal with an acid (Zinc and Hydrochloric Acid). The video is part of a simple experiment carried out in the classroom by the student teacher to illustrate an oxidation reaction and to relate the three representational levels: macroscopic, submicroscopic and symbolic. In the video, from the visualization of the same experiment done in the room, the student teacher applies a zoom tool to illustrate what happens at the submicroscopic level with the chemical species and the particles, especially the electrons, from the ionization process to the formation of new substances. Subsequently, it inserts the symbolic representation of the reaction, the writing of the formulas and chemical equations of the reaction in the video. The use of images to represent the chemical species is very strong in Juliana's classes, which articulate them in various activities (exercises, evaluations, questionnaires).

This use of images is quite common in the practice of teacher P7. On the influence of trainers in her teaching, Juliana said in the interview:

    [...] that in Higher Education certainly [there is] more [influence] because you are already in contact, you are already thinking directly in your teacher education, then you are already looking for more, try to get the teacher everything good that he brings. I certainly did not mirror in one, more in several.

Juliana assumes, in the interview, the direct influence of P2 on her teaching practice, on her way of conducting pedagogical actions, in the serious way of facing her profession and requesting the participation of the students in the class. Regarding the study of the oxirreduction theme developed in the subject of Theoretical Inorganic Chemistry by P2, Juliana assumes that the teaching I had was good and that the way of P2 conducting classes, based on the difficulties students had about the subject was complemented what she explained in class when she realized the deficiencies in the students' learning. Juliana goes on to say that I do not think I would have learned if classes were not conducted that way.
Referring to the Didactics teacher (P8) Juliana says she showed me what was important [... to do in the classroom [...] everything that is done in the classroom has to think about the student. Just as she speaks of the influence of P8 on her practice, on the issue of valuing student-centered teaching, she assumes that other trainers also exert influence, whether in the process of taught content or developed teaching practice.

For Rafaela, we were struck by the incorporation she made of projects work, with special attention to the understanding of aspects of the students' reality, including activities in the field. One of the projects that two of the student teachers subjects of this research proposed for students of basic education was related to the oxiirreduction theme. They articulated the CTS approach, environmental education, experimentation with alternative materials (battery building), battery and battery collection activity, textual production and discussion from a video on pollution and battery disposal. This project was proposed by Adriano and Juliana (in a group that had three other classmates) in the discipline Chemistry Teaching II, but it was in the teaching practice of Rafaela's Oxiirreduction that it was improved and implemented in the classroom. She added new teaching strategies and impregnated the project with her personal characteristics of understanding chemistry teaching. Rafaela says in the interview that P1 was a remarkable teacher in his profession, because:

 [...] he related many facts, many reactions to everyday life. [...] it was a very valid apprenticeship that we carried and could be using and the very clear way of explaining it, a lot of content and, very nice thing, he liked what he was teaching and he liked to teach

We stress here the importance of all the activities developed in the classes for the training of undergraduates, even those in which it is not the teacher who teaches the class that makes them. When a teacher proposes an activity in the classroom, he does not imagine the repercussion of that activity for all students. Rafaela incorporates one of these activities in her practice, based on the observation of the theoretical proposal made by classmates. Even those activities and strategies of teaching that are not intentional in the practice of the trainer reach the graduates. Every way of acting and the importance that the trainer attributes to each teaching activity in his own discipline are perceived and sometimes incorporated into the teaching practice of the student teachers.

Analyzing the details of Table 1 it is possible to notice the absence of incorporations of any of the undergraduates of theoretical and practical elements of the formers P4 and P5. It can also be observed that the number of teachers that influence Adriano's teaching practice is balanced, four of each area, for Juliana is higher among content teachers in the area of chemistry and related (four teachers) in comparison to the number (three teachers), and for Rafaela, there are four teachers of the pedagogical area that influence their teaching practice, compared to a professor in the area of chemistry and related who exerts influence in their way of teaching oxidation.

Adriano incorporates three elements / aspects of the formative action of four teachers in the area of chemistry related, in relation to the four elements / aspects of the formative action of four trainers of the pedagogical area. We consider teacher P11 as a teacher of the pedagogical area, since it acts in the supervision of curricular internship, a discipline related to the learning of teaching practice (teaching method) and not to teaching-learning by the student teacher of
the specific content of the chemistry. In Adriano we find a situation that is interesting, at the same time that a greater number of professors of the area of chemistry has exerted influence in its teaching practice, the number of incorporations among the teachers of the pedagogical area is greater. A possible explanation for the fact that Adriano has influences from a larger number of professors in the field of chemistry is that they have a greater power of influence in the university teaching field of the analyzed course, we refer to three of these trainers (P2, P3 and P6) who participate in the same research group (which generate distinct links) and which have a larger volume of capital than the other trainers. In this sense, when we perceive the incorporations to the teaching practice of the student teacher and to his own habitus, we reaffirm that Adriano understood the rules of the field and traces strategies to belong to him, in short, understood the sense of the game developed by the teachers of the field.

Juliana incorporates six elements / different aspects of the formative action of the chemistry trainers, with the teachers P2 and P6 influencing a significant number of actions of the student teacher practice. On the other hand, there are also six elements / aspects of the formative action of the trainers of the pedagogical area that influence the student teacher. There are two incorporations that are common to teachers in both areas. In the incorporations to Juliana's teaching practice there is a balance between the groups of teachers of both areas, but it is necessary to emphasize the predominance of three teachers: P2, P6 and P8. These are the same teachers mentioned by the student teacher in her interview as influential in her teaching, which may indicate a self-knowledge of Juliana about her own education and her practice. She is a teacher in training who assumes her identity as a teacher from the beginning of the training process (even before the beginning of the course), when she says that she observes her teachers in the way she teaches, knowing that she is also learning to be a teacher there.

Regarding the number of elements / aspects incorporated into the teaching practice of Rafaela, we have two incorporations of one professor in the area of chemistry, against seven of all teachers in the pedagogic area, two of which are common to teachers in both areas. It is noticed that the strongest influence in the knowledge for the teaching of Rafaela is of the professors of the area of didactic and teaching of chemistry (pedagogical), being that the teachers that worked with disciplines of chemistry did not have elements and aspects of its practices incorporated to the PCK of this student teacher and the physics teacher influenced her in her way of conducting classes and understanding the learning process of the students and not in the specific contents of the subjects of the area.

By comparing Figures 1 and 2, we can see that more aspects of the teaching practice of the disciplines taught by the trainers have been incorporated than the theoretical elements of the disciplines themselves, included in their specific syllabus, programs and contents. This raw data clearly indicates that in their teachers’ classes, students learn not only the contents they teach, but the way of teaching, to the point of incorporating into their teaching practice and teaching habitus characteristics of the teaching of the subjects they attended graduation student. We refer to the incorporation of aspects of the teaching practice of undergraduate trainers only, since the data we collect reinforce this more strongly, although it is explicit in the interviews of all the graduates the influence on the teacher’s habitus of teachers prior to joining the course
of Chemistry teacher education, reinforcing the idea of the construction of the teaching habitus throughout life and in different socializing instances.

![Figure 1. Theoretical aspects from the disciplines incorporated by student teachers](image1)

![Figure 2. Practical aspects from the disciplines incorporated by student teachers](image2)

**CONCLUSION**

The three chemistry student teachers' have very different teaching backgrounds and have had diverse influences from different trainers even though they have taken the same course. In the interviews the distinct aspects of teaching are evident, consistent with the ties established in their life histories with the formers teachers. Trainers influence the teaching practice of their undergraduates not only through the content of their disciplines, but also through their worldview, teaching, and the mode of action and teaching and assessment strategies they use.
in the classroom. However, such influences on the teaching practice of the student teachers are very diverse. While Adriano has a greater balance between influences of teachers of the chemistry area and of education and teaching, Juliana has a predominance of the influence of the chemistry trainers and in Rafaela, the influences of the formers teachers from the didactic and teaching disciplines prevail. In addition to the trainers, the graduates are also influenced by their colleagues during the initial training. Thus, it is pointed out the need for all teacher trainers, regardless of training area, to pay greater attention to their teaching and to the activities they carry out in the disciplines they teach, since, consciously or unconsciously, the training actions developed by teachers clearly influences the teaching practice of the student teachers.

In general, the incorporations derived from teachers teaching practice are based on the conduction of activities, classroom management, students' knowledge and their understanding of the subjects taught, class planning and management, and instructional strategies. Data reveal a certain balance between the General Pedagogical Knowledge and the PCK, with some characteristics that point to the Knowledge of the Context. On the other hand, of the theoretical elements that have been most incorporated there is a predominance of General Pedagogical Knowledge. There was little incorporation of elements / aspects of the Subject Matter Knowledge, specifically redox process. The knowledge most learned by the student teachers from the practice and teaching conceptions of their formers teachers are practically balanced between curricular aspects of the disciplines and aspects of the practice. Therefore, it is not enough for the teacher trainer to pay attention only to what he teaches, but we must pay attention to the way he conceives his teaching and the activities he does. According to one of the trainers: "For teachers students, your class is a practical demonstration for them. They are looking at you, evaluating you, taking you as some good or not examples."

Even if they attended a same course, the graduates got involved with different formers teachers and extra-curricular activities throughout the course which resulted in different habitus. There are not clearly aspects common to all undergraduates, that is, the incorporation of repertoires that the student teachers do of the activities and learning in the classroom are distinct, partly dependent on its network of relations with the other members of the field, the trainers and its objectives for the teaching of chemistry contents. The capital of these trainers is also reflected in the intensity of these relationships, so that the teacher in the chemical area who is more involved with projects and research ends up having a greater influence on the teaching practices of the student teachers, while in the pedagogical area it influences more that trainer who is more coherent in its practice with the theoretical elements of its discipline.

ACKNOWLEDGEMENT

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REFERENCES

AUTONOMY-SUPPORTIVE TEACHING BEHAVIOR IN SCIENCE LESSONS – AN INTERVENTION FOR PRE-SERVICE TEACHERS

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Fostering students’ motivation is an essential characteristic of every teaching process. However, teachers often lack practical methods to support it in class. There are several approaches to foster students’ motivation, such as autonomy-supportive teaching behavior (ASTB) based on Self-Determination Theory (Ryan & Deci, 2017). Although these approaches are at disposal, they do not seem to find their way into practice. Consequently, efforts are needed to transfer theoretical and empirical findings into the classroom. An intervention for pre-service teachers providing theoretical and practical approaches to foster students’ motivation might be appropriate to deal with this situation. To address this issue, we conducted a pilot study with 58 science teacher trainees (M_age=25.18±3.79 years; M_semester=7.78±1.23; 65% female). The experimental group consisted of 35 teacher trainees that took part in an intervention about ASTB. Teacher trainees in the control group (n=23) did not participate in this intervention. We assessed the teacher trainees’ beliefs about the easy implementation and effectiveness of ASTB as well as their future intentions to apply ASTB. Furthermore, the teacher trainees’ theoretical and practical knowledge were examined. The results revealed significant differences concerning the teacher trainees’ beliefs about ASTB, their future intentions to apply ASTB as well as their theoretical and practical knowledge thereof in the comparison of the experimental and control group. We found that the teacher trainees in the experimental group assumed ASTB to be more effective and easier to implement than the teacher trainees in the control group after the intervention. Moreover, the teacher trainees in the experimental group showed higher scores in the test of their theoretical and practical knowledge and stated higher intentions to apply ASTB than the teacher trainees in the control group after the intervention.

Keywords: motivation, teaching practices, initial teacher education (pre-service)

INTRODUCTION

Despite numerous approaches in the field of teacher professionalization, there is still a degree of uncertainty regarding which implementations are most effective in this area (Pressley, Graham, & Harris, 2006). Self-Determination Theory (Ryan & Deci, 2017) has proved to be a useful framework for designing school-based interventions in various studies (Reeve & Cheon, 2016). These studies show that interventions can effectively change teaching behavior in class (Reeve & Cheon, 2016; Su & Reeve, 2011). For these behavioral changes to take place, participants must recognize the relevance, the easy implementation, and the effectiveness of the communicated behavior (Reeve & Cheon, 2016; Su & Reeve, 2011). One opportunity to design a meaningful intervention is the subject-specific adaption and training of teaching behavior.

There is increasing evidence that interventions with teacher trainees are especially effective (e.g., Su & Reeve, 2011). With regard to autonomy-supportive teaching behavior (ASTB) in the sense of Self-Determination Theory (Ryan & Deci, 2017), teacher trainees are an important
target group because they tend to use controlling teaching behavior in class (Martinek, 2010). Several studies have shown that controlling teaching behavior can have a negative effect on students’ motivation (Assor, Kaplan, Kanat-Maymon, & Roth, 2005; De Meyer et al., 2016), whereas ASTB can influence their motivation positively (Basten, Meyer-Ahrens, Fries, & Wilde, 2014; Hofferber, Basten, Großmann, & Wilde, 2017; Taylor, Schepers, & Crous, 2006; Tessier, Sarrazin, & Ntoumanis, 2010). Since students’ motivation decreases throughout their school career (e.g., Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002) and teachers often lack methods to foster it (Reeve, Jang, Carrell, Jeon, & Barch, 2004; Winther, 2006), the communication of ASTB seems to be especially important.

Based on this research, we developed an intervention to communicate ASTB to pre-service teachers. To successfully implement ASTB in class, teachers need theoretical and practical knowledge about autonomy support that is in accordance with Self-Determination Theory (Ryan & Deci, 2017). Therefore, we were interested in whether our intervention would foster the participants’ acquisition of practical and theoretical knowledge with regard to ASTB. In addition, since teachers are more likely to implement ASTB when they are convinced that it is easy to implement and effective (Reeve & Cheon, 2016), we examined whether our intervention would have an impact on these beliefs and on the participants’ future intentions to apply ASTB in their lessons.

THEORETICAL BACKGROUND AND CURRENT STATE OF RESEARCH

Basic Needs Theory, a sub theory of Self-Determination Theory (Ryan & Deci, 2017), proposes that there are three innate basic psychological needs, namely the need for relatedness, competence, and autonomy. The degree to which these needs are satisfied has an impact on an individual’s well-being and his or her quality of motivation (Deci & Ryan, 2000). The need for relatedness describes an individual’s wish for meaningful interactions with significant others and striving to belong to a social community (Ryan, 1995; Ryan & Deci, 2017). The need for competence involves the ambition to perceive and extend one’s own capability and effectiveness in an action (Deci, 1975; Deci & Ryan, 2000; Ryan & Deci, 2002, 2017). The need for autonomy describes an individual’s desire to perceive him-/herself as origin of his or her action (Reeve, 2002; Reeve, Nix, & Hamm, 2003). Feeling autonomous means experiencing choice and volition in one’s action (Reeve et al., 2003).

Organismic Integration Theory, a second sub theory of Self-Determination Theory (Ryan & Deci, 2017), depicts a continuum of motivation ranging from extrinsic to intrinsic motivation. The goal of an intrinsically motivated action is the action itself (Deci & Ryan, 2000; Vallerand & Ratelle, 2002). These actions are characterized by enjoyment, curiosity, and spontaneity (Deci & Ryan, 2000; Vallerand & Ratelle, 2002). Extrinsic actions take place because the individual wants to obtain the result of an action that is separable from the action itself (Ryan & Deci, 2002; Vallerand & Ratelle, 2002). An extrinsically motivated action can be regulated in four different ways: external, introjected, identified, and integrated (Ryan & Deci, 2002, 2017; Vallerand & Ratelle, 2002). These types of regulation can be arranged on a continuum of self-determination (Ryan & Deci, 2002; Vallerand & Ratelle, 2002). An external
regulation is the most heteronomous form of regulation whereas an integrated regulation is the most autonomous regulation (Vallerand & Ratelle, 2002).

Since these subtheories describe the needs and motivation of every individual, they are important for both students and teachers. The satisfaction of the three basic needs is essential for students’ well-being and the quality of their motivation to learn as well as for well-being in the teaching profession and the motivation to teach (Martinek, 2012; Niemiec & Ryan, 2009; Reeve, 2002; Reeve & Cheon, 2016). In addition, the teacher’s motivation to teach can have a direct and indirect impact on the students’ motivation in class (Müller, Andreitz, & Hanfstringl, 2008; Pelletier, Séguin-Lévesque, & Legault, 2002). Studies have shown that students’ motivation decreases throughout their school career (e.g., Jacobs et al., 2002). One opportunity to foster students’ motivation in class is autonomy-supportive teaching behavior (ASTB) in the sense of Self-Determination Theory (Ryan & Deci, 2017). The positive effects of ASTB on students’ motivation have been found in several studies (Basten et al., 2014; Hofferber et al., 2017; Taylor et al., 2006; Tessier et al., 2010). ASTB can also have a positive impact on students’ knowledge acquisition (Boggiano, Flink, Shields, Seelbach, & Barrett, 1993; Hofferber, Eckes, & Wilde, 2014). Therefore, an intervention that communicates ASTB might be useful for the professionalization of teachers when it comes to fostering motivation. Since teachers often lack didactic-methodological skills to support their students’ motivation in class (Reeve et al., 2004; Winther, 2006), the communication of this behavior is particularly important. Furthermore, interventions dealing with the Basic Needs Theory and Organismic Integration Theory might help teachers to reflect on the satisfaction of their own basic needs and their motivation to teach.

In addition to supporting students’ motivation in class, Self-Determination Theory (Ryan & Deci, 2017) has turned out to be a suitable framework for designing school-based interventions (Chatzisarantis & Hagger, 2009; Reeve et al., 2004). Previous studies have found that these interventions can have a significant impact on not only the participants’ knowledge and behavior, but also their beliefs and intentions (Aelterman, Vansteenkiste, Van den Berghe, De Meyer, & Haerens, 2014; Reeve & Cheon, 2016). In order for changes in beliefs and behavior to occur, the participants must first recognize the relevance, the easy implementation, and the effectiveness of the communicated concepts and behavior (De Naeghel, Van Kerr, Vansteenkiste, Haerens, & Aelterman, 2016; Reeve & Cheon, 2016; Su & Reeve, 2011). Furthermore, meta-analyses show that interventions with teacher trainees are especially effective (e.g., Su & Reeve, 2011). Teacher trainees do not yet have a stable teacher personality and their teaching behavior in class is still flexible (Martinek, 2010; Tessier et al., 2010). Interventions that provide approaches to foster students’ motivation should therefore already be implemented during the teacher training phases at the university level. On the basis of this research, we developed an intervention for pre-service teachers dealing with ASTB. To check the effectiveness of our intervention, we investigated the following research questions.
RESEARCH QUESTIONS

1) Does the intervention foster the participants’ acquisition of theoretical and practical knowledge about autonomy-supportive teaching behavior?

2) Does the intervention affect the participants’ beliefs about the easy implementation and effectiveness of autonomy-supportive teaching behavior?

3) Does the intervention affect the participants’ future intentions to apply autonomy-supportive teaching behavior?

METHOD

Sample

Fifty-eight science teacher trainees in advanced semesters (M_{age}=25.18±3.79 years; M_{semester}=7.78±1.23; 65% female) participated in the current study. These trainees came from courses that had prepared them for a one-semester practical phase. Thirty-five of them were assigned to the experimental group and took part in an intervention focusing on autonomy-supportive teaching behavior (ASTB) in science lessons. The control group (n=23) did not participate in this intervention.

Test instruments

We developed an open-ended knowledge test that contained seven items that assessed the teacher trainees’ theoretical knowledge and eight items that assessed their practical knowledge of ASTB. We rated each item with zero, one, or two points. Zero points were awarded for an incorrect answer or when no answer was given at all. The teacher trainees received one point for an answer that was partly correct. Two points were given for a complete and correct answer. Interrater agreement for these items was found to be excellent (theoretical knowledge: Cohen’s κ=.91; practical knowledge: Cohen’s κ=.93).

The Teaching Scenarios Measure (TSM; Reeve et al., 2014) was used to examine the teacher trainees’ beliefs about the easy implementation (four items) and the effectiveness (four items) of ASTB as well as their future intentions to apply ASTB (four items). Specifically, the teacher trainees received a written scenario that depicted ASTB. The term “autonomy-supportive” was not used in or to label the scenario. After reading the scenario, the teacher trainees were asked to rate different statements with regard to this scenario on a five-point rating scale (“0=strongly disagree” to “4=strongly agree”). Both the knowledge test as well as the TSM were applied in the pre- and posttest.

In the posttest, we also investigated the teacher trainees’ perception of autonomy with nine items of the Learning Climate Questionnaire (LCQ; Black & Deci, 2000). In this test instrument, the experimental group stated their perception of autonomy during the intervention whereas the control group rated their perception of autonomy during their regular course. These items were rated on the same five-point rating scale. Internal consistencies as well as example items for all test instruments can be seen in Table 1. The Cronbach’s-alpha values for all test instruments ranged from satisfying to excellent.
Table 1. Internal consistencies and example items for the applied test instruments.

<table>
<thead>
<tr>
<th>Test Instruments</th>
<th>Example Item</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical knowledge test (seven items)</td>
<td>Define an external regulation and give an example.</td>
<td>( \alpha_{\text{post}} = .67 )</td>
</tr>
<tr>
<td>Practical knowledge test (eight items)</td>
<td>Give two examples of instructions that use neutral language from your science lessons.</td>
<td>( \alpha_{\text{post}} = .81 )</td>
</tr>
<tr>
<td>Teaching Scenarios Measure (Reeve et al., 2014)</td>
<td><strong>beliefs about the easy implementation</strong> (four items)</td>
<td>This approach to teaching is easy to do.</td>
</tr>
<tr>
<td></td>
<td><strong>beliefs about the effectiveness</strong> (four items)</td>
<td>This approach to teaching is effective in terms of motivating and engaging students.</td>
</tr>
<tr>
<td></td>
<td><strong>future intentions</strong> (four items)</td>
<td>In the future, I intend to motivate my students this way.</td>
</tr>
<tr>
<td>Learning Climate Questionnaire (nine items; Black &amp; Deci, 2000)</td>
<td>The instructor provided me choices and options.</td>
<td>( \alpha = .88 )</td>
</tr>
</tbody>
</table>

Study design

One week before the intervention, the teacher trainees’ theoretical and practical knowledge regarding ASTB, their beliefs about this type of behavior, and their intentions to apply it in future lessons were assessed. The teacher trainees’ beliefs and intentions were measured using the Teaching Scenarios Measure (TSM; Reeve et al., 2014). After that, the teacher trainees in the experimental group participated in an intervention that was divided into two parts. In the first part, they were provided with a theory session on Self-Determination Theory (Ryan & Deci, 2017), which had a special focus on the three basic needs and the continuum of motivation (Basic Needs Theory, Organismic Integration Theory). Afterwards, two training sessions took place in which five autonomy-supportive methods were practiced and discussed. After the intervention, the teacher trainees’ knowledge, their beliefs that were related to ASTB and their future intentions to apply it were assessed again. Furthermore, the perceived degree of their own autonomy was examined using the Learning Climate Questionnaire (LCQ; Black & Deci, 2000).

The control group only attended the pre- and posttest and received no intervention. During the intervention, the teacher trainees in the control group participated in their regular course and prepared for the practical phase using different educational theories. The study design is summarized in Figure 1.
Figure 1. Study design. The Teaching Scenarios Measure (TSM; Reeve et al., 2014) assessed the teacher trainees’ beliefs about and future intentions to apply ASTB. The Learning Climate Questionnaire (LCQ; Black & Deci, 2000) measured the teacher trainees’ perceived degree of autonomy.

Design of the sessions

While designing our intervention, we considered the findings of recent studies and meta-analyses of interventions based on Self-Determination Theory (Ryan & Deci, 2017). Among other things, these stressed that participants should perceive their own basic needs as being satisfied during the intervention (Assor, Kaplan, Feinberg, & Tal, 2009; De Naeghel et al., 2016). For this purpose, the instructor of the intervention implemented the communicated five autonomy-supportive methods during the intervention.

Studies have shown that interventions are particularly effective if they a.) are both knowledge- and skill-based, b.) do not exceed three hours per session, and c.) utilize different types of media (De Naeghel et al., 2016; Su & Reeve, 2011). To foster knowledge as well as skill acquisition, two types of sessions were designed: One session was designed to give the teacher trainees theoretical input that teaches basic knowledge about the basic psychological needs and the different qualities of motivation according to Self-Determination Theory (Ryan & Deci, 2017); the second type consisted of two sessions designed to have the teacher trainees practice their skills in fostering their students’ autonomy in science lessons. In the training sessions, five autonomy-supportive methods were focused on: providing rationales, acknowledging negative feelings, offering choices, using neutral language, and giving informative feedback (Table 2). In terms of methodology, these sessions were based on work in small groups. In their groups, the teacher trainees analyzed videos of different teaching behavior in class, designed rationales for topics in science lessons, and performed role plays dealing with negative feelings by way of example. At the end of each session, the introduced methods were reflected on and discussed. Audio and video sequences, tablets, laptops, smartphones as well as paper-and-pencil-based tasks were used in the sessions. Each one lasted 1.5 to 2 hours.

As continuous instrumental support and follow-up activities are important for an intervention to be effective (Assor et al., 2009; Su & Reeve, 2011), the teacher trainees were provided with a.) a glossary that included important definitions and assumptions related to Self-Determination Theory (Ryan & Deci, 2017), b.) a booklet for supporting students’ motivation in class, and c.) a reader with theoretical discussions and empirical studies on the basic needs and the qualities...
of motivation anchored in Self-Determination Theory (Ryan & Deci, 2017). One follow-up activity entailed the observation of autonomy-supportive and controlling teaching behavior in class with a self-developed observation grid based on the Learning Climate Questionnaire (Black & Deci, 2000).

Table 2. Five autonomy-supportive methods that were communicated in the intervention (cf. Su & Reeve, 2011).

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
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<tbody>
<tr>
<td>providing rationales</td>
<td>emphasizing the relevance of a topic or an action</td>
</tr>
<tr>
<td>acknowledging negative feelings</td>
<td>accepting, legitimating, and addressing negative feelings</td>
</tr>
<tr>
<td>offering choices</td>
<td>offering meaningful content-related and methodological choices</td>
</tr>
<tr>
<td>using neutral language</td>
<td>using language that imparts flexibility and minimizes pressure</td>
</tr>
<tr>
<td>giving informative feedback</td>
<td>presenting a students’ performance with appreciation; giving advice for the further learning process</td>
</tr>
</tbody>
</table>

Statistics

First, we calculated a univariate analysis of variance to investigate the teacher trainees’ perceived degree of autonomy. To analyze the effects of the intervention on the teacher trainees’ knowledge, beliefs, and future intentions to apply ASTB, we used analyses of variance with repeated measures.

RESULTS

First, we surveyed the teacher trainees’ perceived degree of autonomy. The analysis of variance revealed a significant difference in the teacher trainees’ perceived degree of autonomy between the experimental and the control group with a large effect size ($F(1,57)=21.87$, $p<.001$, $\eta^2=.28$). The results of the Learning Climate Questionnaire (Black & Deci, 2000) showed that the teacher trainees in the experimental group stated a significantly higher perceived degree of autonomy during the intervention than the trainees in the control group in their regular course ($M_{EG}=3.68\pm0.27$; $M_{CG}=3.18\pm0.55$). We therefore assume that the implementation of the autonomy-supportive behavior of the instructor during the intervention was successful.

Second, when it came to the extent of the teacher trainees’ theoretical and practical knowledge regarding autonomy-supportive teaching behavior (ASTB), the analyses of variance with repeated measures revealed significant interaction effects of the factors time and treatment with large effect sizes (Table 3). The teacher trainees in the experimental group had higher scores on the theoretical and practical knowledge test than the teacher trainees in the control group after the intervention (Table 3).

Third, we found significant interaction effects with a large and a medium effect size of the factors time and treatment with respect to the teacher trainees’ beliefs about the easy implementation of ASTB as well as their intentions to apply it in future lessons (Teaching
Strand 13

Scenario Measure; Reeve et al., 2014; Table 3). The interaction effect for the teacher trainees’ beliefs about the effectiveness of this behavior showed a tendency with a small to medium effect size (Teaching Scenario Measure; Reeve et al., 2014; Table 3). After the intervention, the experimental group thought ASTB was easier to implement and attributed higher ratings of effectiveness to this approach than the control group (Table 3). In addition, the teacher trainees in the experimental group stated higher intentions to apply ASTB after the intervention than the teacher trainees in the control group (Table 3).

Table 3. Means (M), standard deviations (SD) and the results of the analyses of variance (ANOVA) with repeated measures for all applied test instruments.

<table>
<thead>
<tr>
<th></th>
<th>Main effect time</th>
<th>Main effect treatment</th>
<th>Interaction effect time x treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M ±SD pretest</td>
<td>M ±SD posttest</td>
<td></td>
</tr>
<tr>
<td>Theoretical knowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EG</td>
<td>2.33±1.99</td>
<td>5.94±2.14</td>
<td>F(1,56)=94.48, p&lt;.001, η²=.63</td>
</tr>
<tr>
<td>CG</td>
<td>1.35±1.05</td>
<td>2.11±0.92</td>
<td>F(1,56)=35.43, p&lt;.001, η²=.39</td>
</tr>
<tr>
<td>Practical knowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EG</td>
<td>4.56±2.34</td>
<td>11.57±1.96</td>
<td>F(1,56)=173.35, p&lt;.001, η²=.76</td>
</tr>
<tr>
<td>CG</td>
<td>4.20±1.81</td>
<td>5.48±1.70</td>
<td>F(1,56)=54.29, p&lt;.001, η²=.49</td>
</tr>
<tr>
<td>Beliefs about the easy implementation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EG</td>
<td>1.50±0.62</td>
<td>2.45±0.75</td>
<td>F(1,56)=25.50, p&lt;.001, η²=.31</td>
</tr>
<tr>
<td>CG</td>
<td>1.54±0.82</td>
<td>1.64±0.70</td>
<td>F(1,56)=5.61, p&lt;.05, η²=.09</td>
</tr>
<tr>
<td>Beliefs about the effectiveness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EG</td>
<td>2.92±0.42</td>
<td>3.34±0.47</td>
<td>F(1,56)=17.98, p&lt;.001, η²=.24</td>
</tr>
<tr>
<td>CG</td>
<td>2.86±0.42</td>
<td>3.03±0.51</td>
<td>F(1,56)=3.17, p&lt;.1, η²=.05</td>
</tr>
<tr>
<td>Future intentions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EG</td>
<td>2.90±0.64</td>
<td>3.40±0.61</td>
<td>F(1,56)=10.53, p&lt;.01, η²=.16</td>
</tr>
<tr>
<td>CG</td>
<td>2.89±0.48</td>
<td>2.95±0.53</td>
<td>F(1,56)=3.07, p&lt;.1, η²=.05</td>
</tr>
</tbody>
</table>

Note. Means and standard deviations are shown for the experimental group (EG) and the control group (CG) in the pre- and post-test separately. With regard to the ANOVA, the main effects of the factors time and treatment as well as the interaction effect of both factors for the comparison of the experimental and control group are shown.

DISCUSSION AND CONCLUSION

The intervention seemed to be effective regarding the teacher trainees’ theoretical and practical knowledge. Furthermore, it can be assumed that the intervention had a positive impact on the teacher trainees’ beliefs about the effectiveness and the easy implementation of autonomy-supportive teaching behavior (ASTB) as well as their intentions to apply it in future lessons. The results of all scales are in line with theory and previous empirical findings. The minor tendency we found with regard to the beliefs about the effectiveness of ASTB may be reasonably attributed to the small sample size and/or ceiling effects. One should also consider that the teacher trainees had already indicated that they thought that ASTB is quite effective in the pretest. This is probably because the teacher trainees were in more advanced semesters of their studies and may have already been exposed to classroom autonomy support and its
positive effects. Ceiling effects can further be assumed in the teacher trainees’ perception of autonomy.

Learning environments that satisfy the learners’ basic needs can have a positive effect on their motivation and knowledge acquisition (cf. Niemiec & Ryan, 2009; Reeve, 2002). Satisfying the need for autonomy is especially important for self-determined types of motivation and successful learning (e.g., Basten et al., 2014; Boggiano et al., 1993; Hofferber et al., 2017; Hofferber et al., 2014; Reeve, 2002; Taylor et al., 2006). We assume that the design of our intervention and the instructor’s implementation of ASTB fostered the teacher trainees’ perception of autonomy, the quality of their motivation, and consequently their knowledge acquisition.

Research has shown that interventions based on Self-Determination Theory (Ryan & Deci, 2017) can have an impact on participants’ beliefs (Aelterman et al., 2014; Reeve & Cheon, 2016). Our data support the results of these studies. We assume that acquiring knowledge about and practicing ASTB in an autonomy-supportive setting with a range of choice and without assessment had a positive influence on the teacher trainees’ beliefs about ASTB. It may further be assumed that the changes in the teacher trainees’ beliefs are indicators for a process of accommodating new concepts (cf. Reeve & Cheon, 2016; Tillema & Knol, 1997). Teacher trainees often harbor controlling teaching concepts and tend to exhibit controlling teaching behavior in class (cf. Martinek, 2010). The acquisition of knowledge about and the practice of ASTB might have led to a change of these existing concepts. Despite evidence of this change, we cannot confirm that the teacher trainees will actually use ASTB in their future lessons. Findings from previous studies show that the adoption and the use of new concepts are contingent upon existing beliefs about these concepts (e.g., Tillema & Knol, 1997). Tillema and Knol (1997) proved that a change in behavior can only be expected if the beliefs of an individual change. Hence, the positive impact of the intervention on the teacher trainees’ beliefs about ASTB might result in a change of their behavior.

The reported intentions to apply ASTB may also indicate whether the teacher trainees will actually use the communicated methods in their future lessons. Intention is assumed to be a significant predictor of behavior in several social psychological models (cf. Sheeran, 2002). Since the teacher trainees’ intentions to apply ASTB were positively affected by the intervention, it can be assumed that they will be more likely to apply it in their future lessons. Nevertheless, future studies should investigate whether and how the intervention affects the teacher trainees’ teaching behavior in class. Furthermore, the effects of the trainees’ teaching behavior after the intervention on their students’ perception of autonomy and their students’ motivation could be examined.

In order to further evaluate the effectiveness of our intervention, we plan to conduct follow-up surveys during the next semester. After a replication of the current pilot study, the intervention might be adapted to other subject-specific didactics and in-service teachers.

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PREREQUISITES AND OBSTACLES IN TECHNOLOGY INSTRUCTION: PRE-SERVICE TEACHERS' PERSPECTIVES

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In this presentation we address the problem of technology education in the realm of restricted curricula. We asked pre-service teachers how and when they would implement technology in their lessons. Exploratory component analyses showed that anticipated obstacles and operational beliefs form reliable and overarching classes of instruction-determining factors. Besides data exploration using principal component analyses and group comparisons, correlation analysis shows significant relations between perceived obstacles and operational beliefs of student teachers. Although digitally native, it seems that student teachers rather avoid technology in their classrooms. They are insecure and demand support from colleagues at school. It seems the more knowledge the students have, the more they would avoid teaching technology, because it is too difficult. We assume that the problem here is situated in the pedagogical content competence of pre-service teachers. Discussion and future research: The results suggest that in-school collaboration could be a fruitful start to implement technology in instructional practice. As a deeper knowledge of technology correlates with more avoidance in class, one could guess that teachers do not have a systematically developed pedagogical content competence to implement technology education in classrooms. In a wider context we suggest a motivating university education for student teachers, so they can be the future collaborators at school, they demand today. We suggest (Quasi-) Experimental study designs to evaluate the efficacy of adapted teacher education and in-school collaboration in terms of technology-oriented instruction. This study only focused on obstacles and reliabilities of scales could be higher. Further research may include more content specific questions, because here the container phrase "technology" was used. Also, the sample size should be increased to achieve more stable component structure.

Keywords: technology education, beliefs, pre-service teachers

INTRODUCTION

When we talk about science and technology education today, most people would agree that technology plays a vital role in modern societies. Although academics agree that there is a clear difference between science and technology (Moore, 2011; Pavlova, 2009), this may only be true if technology is also seen distinct from engineering. The STEM acronym can be used to highlight the difference between the domains. Yet, in many cases science dominates technology and engineering, or technology and engineering are interpreted as practical application of knowledge in natural sciences (see Renn et al., 2009).

What is more, in German-speaking Europe, technology and engineering are not seen as separate entities. The term technics (Technik) is used there and it comprises the creative re-assembly of
items as well as the use of digital devices in any context (e.g. Dolata & Werle, 2007). One can thus say that the term technics includes production knowledge and application knowledge. Both knowledges comprise problem-solving and value-added purposes. Where engineering may seek problem-solving on a productive level, technology and technology-use may help in automation or controlling systems. In educational contexts engineering can be seen as a content-related topic that allows to learn about the nature, functioning, or relevance of technics; technology can add to optimize educational interactions and learning, for example by means of tablets use for and in instruction.

An example, where both ideas – understanding and application – meet is digital technology. In digital technology engineering, the objective is to improve components, e.g. make them small or more efficient. In digital technology education, a teacher may use the engineered product for educational purposes, e.g. use tablet computers to visualize a phenomenon. Within this notion of technology, technology education is supposed to teach students the processes and techniques in engineering as well as the use of technical devices. In order to avoid confusion and to imply the notion of understanding and use of technology, we will refer to tech as an abbreviation for technology and engineering.

Tech education is of primary interest in terms of STEM education and future advances in technology and engineering. Yet, by now in Switzerland, there is no designated school subject that addresses tech education specifically. In the Swiss compulsory school system, technical design is a distinct subject, but tech, as we defined it in the above section, is distributed all over the curriculum and thus usually science teachers integrate technology into their instruction as an add-on if there is time left. Teachers of other subjects may not even consider tech instruction at all. What is more, tech is likely to be dropped even by science teachers. This is especially the case if teacher do not feel themselves competent enough or see other obstacles that justify skipping a laborious and complex topic (Peschel & Koch, 2014).

In this report we want to give an overview on the Swiss curriculum 21 and show the distribution of tech education. The distribution of tech education leads to the question of where, when and how Swiss teachers implement tech education. We will focus on pre-service teachers, because they are currently educated in the framework of the new curriculum.

A SWISS BACKGROUND

The current Swiss compulsory school system does not equip pupils with a solid basis of tech knowledge. But, currently the Swiss school curriculum is undergoing a change (so-called Lehrplan 21) where tech education is supposed to be taught at a basic level. The cantons Basel-Stadt and Basel-Land already use the new curriculum since the school year 2014/15 and, therefore, already educate pre-service teachers at the local university of teacher education (PH FHNW) according to the new curriculum.

As was stated in the previous section, there is no specific tech education in the new curriculum (see Figure 1). Tech is supposed to be integrated in various subjects, e.g. physics, history, arts, graphical/ textile and technical design.
One can see in Figure 1 that any tech education in the first cycle (Kindergarten and 1st/ 2nd grade) has to be implemented in an integrated way. Most likely it seems to be a part of Nature, man, and society or Technical design. In cycle two tech may also be included in Media, information and communication technology. In the third cycle the integrated subject Nature, man, and society fans out and gets more specific. Technology and engineering become a part of the natural sciences education. Yet still, tech seems to be more a part of natural sciences instead of a stand-alone subject. As a result, teachers might treat tech as a supplementary topic.

THEORETICAL BACKGROUND

The research question is in line with the idea that teachers who are interested in a topic (e.g. tech) would also tend to teach technology, because they feel self-confident and competent in using technology. Interest seems to determine study choices and initial career paths in STEM professions (Aeschlimann, Herzog, & Makarova, 2015; Ardies, De Maeyer, Gijbels, & van Keulen, 2015). In the context of interest Ng (2012) found that undergraduate students can productively use even unfamiliar digital devices. So, the question arises whether pre-service teachers do see the opportunity to implement tech issues in their future instruction. This prospective interpretation is of high value as it shows acute threats to future tech implementation. Jones, Buntting, and de Vries (2013) name teacher education as one central predictor of successful change in the translation of a new curriculum into praxis. In our context the innovative change is tech instruction. Pelgrum (2001) summarizes major obstacles of embedding ICT in educational praxis and school report that it is difficult to find and schedule time, lack of technical assistance/ support, weak infrastructure, low teacher qualification, and that it is too difficult with low achieving pupils. Here, we want to transfer this knowledge from ICT educational research to technology education research and build up on that in a quantitative, exploratory study.

Besides the use of tech for educational purposes, there is also the dimension to teach tech in an engineering-oriented way. Yet, little is known about the choice to become an engineer or tech teacher, because one cannot sign in for that subject at universities of teacher education. Berweger, Bieri Buschor, Keck Frei, and Kappler (2014) find that women enter engineering studies if they have a high self-efficacy in successful graduation, had a solid interest in mathematics and/ or physics, and had a positive attitude toward a post-graduate turnover.

RESEARCH QUESTION

As can be read in the above sections, Switzerland is undergoing curricular changes that affect every educational entity. Especially in-service teachers are supposed to implement more tech education in their instruction. Pre-service teacher's education at the universities of education also should offer classes that allow students to prepare for future demands. Yet, the question arises what and how university classes should introduce tech classes. Especially with reference to pedagogical content knowledge and other instruction-oriented variables, such as self-efficacy, interest or the quality of educational tech equipment that is available to teachers, we ask the question whether there are reasons for student teachers to keep the implementation of tech education at a minimum.
METHODS

We asked pre-service teachers to anticipate circumstances in which they would do tech instruction and about their beliefs of their own tech use. For this we formulated questionnaire items and had them rated on a 5-point Likert-scale (0: totally disagree, 4: totally agree). We tried to assess obstacles that hinder the implementation of technology education with 23 items. For example, we asked for the material equipment at their school, for the collegial support and exchange, own competence rating, as well as for external factors as parents’ approval and students’ prerequisites. On operational beliefs we formulated 15 items which comprise the use of and attitude toward tech (e.g. I am happy to just use tech devices; I could dis- and re-assemble my tech devices even blindfold; I love to play around with tech devices; Tech improves our life-standard in general).

In the sample were 69 pre-service students all mostly in their second year of undergraduate studies. 32% were future lower-secondary teachers, 68% future kindergarten and primary school teachers. They were evaluated in their second year of study.
We used SPSS 23 for statistical analyses and principal component analyses (PCA, Varimax-rotation, Eigen-value >1) to classify the items of the obstacles and operational beliefs. Orthogonality was optimized by eliminating items with cross-loadings above .32 (Tabachnick & Fidell, 2001). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and the Bartlett test were used to evaluate the appropriateness of the PCA. Individual components were judged regarding their unique item-component reliabilities (communalities > .40; Costello & Osborne, 2005). Components were scaled (Cronbach-alpha) and scale averages were compared with independent t-tests. Differences are reported using the effect size Cohen's d.

RESULTS

Exploratory component analysis, scale properties and correlations

Initial person-item ratios were fairly good at 5:1 (Costello & Osborne, 2005). The first PCA on the obstacles showed a seven component solution (KMO=.55), but the Bartlett test was significant and there were several large cross-loadings. Similar starting values were found in the operational beliefs (KMO=.75, Bartlett <.05, several cross-loadings).

After item-elimination a three-component solution resulted for obstacles, with loadings all beyond .50, communalities averaged at .70 and components hardly correlated. Also a final three-component solution for operational beliefs was found; KMO was .67 and communalities were at an average level of .70, the Bartlett test was still statistically significant.

The three components of obstacles were: Not enough collaborative support at school (4 items, $\alpha=.79$), Lack of teaching material available at school (2 items, $\alpha=.93$), and Pupil-caused obstacles (3 items, $\alpha=.62$). The three operational belief components were: Self-concept in technology education (4 items, $\alpha=.82$), Positive attitude toward technology (4 items, $\alpha=.69$), and Rather using than understanding technology (2 items, $\alpha=.72$).

Reliabilities are acceptable and standard deviations show that there is variance in answering the items and averages do not indicate any ceiling or bottom effects (see Table 1).

One can see in Table 1, that correlation coefficients between obstacles and belief components generally do not exceed a value of .44. Interesting are the correlations between collegial support and available material as well as available material with the use of technological devices. Also, a positive attitude is correlated with the demand of collegial support, just as is the relation between inter-personal assistance and the use of technology.

Group differences

Additionally, we compared primary/ kindergarten student teachers with lower-secondary ones. Independent sample t-tests and U-tests are reported in the Table 2).

Kindergarten/ primary student teachers are more optimistic that pupils can be taught tech whereas lower-secondary student teachers think pupils do not have enough pre-knowledge, they are not disciplined enough and that class-sizes are too huge ($d=.83$). At a level of $p<.05$ this effect is statistically significant.

Using a more liberal, exploratory interpretation of significance thresholds, there also occur relevant differences in the use-orientation and the self-concept. Lower levels students would
rather use than explain tech compared to lower-secondary student teachers (d=.47) and prospective lower-secondary teachers state a higher self-concept compared to kindergarten teachers (d=.38).

There are no significant differences in the attitude toward tech, the need of collegial support the quality of the equipment available at schools.

**Table 1: Descriptives, scale properties and Pearson inter-correlations of variables**

<table>
<thead>
<tr>
<th></th>
<th>AM (SD)</th>
<th>VE (1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Not enough collaborative support at school</td>
<td>2.62 (.86)</td>
<td>26%</td>
<td>.79 (N=4)</td>
<td>.44**</td>
<td>.31*</td>
<td>-.03</td>
<td>-.27*</td>
</tr>
<tr>
<td>(2) Lack of teaching material available at school</td>
<td>3.52 (1.05)</td>
<td>23%</td>
<td>.93 (N=2)</td>
<td>.24*</td>
<td>-.14</td>
<td>-.13</td>
<td>.27*</td>
</tr>
<tr>
<td>(3) Pupil-caused obstacles</td>
<td>2.50 (.96)</td>
<td>22%</td>
<td>.62 (N=3)</td>
<td>-.04</td>
<td>.06</td>
<td>-.03</td>
<td></td>
</tr>
<tr>
<td>(4) Self-concept in technology education</td>
<td>2.92 (.97)</td>
<td>26%</td>
<td>.82 (N=4)</td>
<td>.38**</td>
<td>-.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Positive attitude toward technology</td>
<td>3.59 (.71)</td>
<td>22%</td>
<td>.69 (N=4)</td>
<td>-.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6) Rather using than understanding technology</td>
<td>4.18 (.96)</td>
<td>17%</td>
<td>.72 (N=2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: all two-sided significance testing; + p<.10, *p<.05, **p<.01; Diagonal bold Cronbach-alpha value and N= number of items in the scale; VE: Variance explanation

**Table 2: Group difference testing**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Kindergarten (n=32)</th>
<th>Lower-secondary (n=21)</th>
<th>T-Test</th>
<th>Sig.</th>
<th>Sig. (n-par)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-concept</td>
<td>2.95 (.96)</td>
<td>3.30 (.88)</td>
<td>-1.35 (51)</td>
<td>p=.182, d=.38</td>
<td>p=.152</td>
</tr>
<tr>
<td>Positive attitude</td>
<td>3.66 (.70)</td>
<td>3.74 (.60)</td>
<td>-.40 (51)</td>
<td>p=.692</td>
<td>p=.840</td>
</tr>
<tr>
<td>Use-orientation</td>
<td>4.34 (.73)</td>
<td>3.91 (1.19)</td>
<td>1.51 (30.04)</td>
<td>p=.141, d=.47</td>
<td>p=.226</td>
</tr>
<tr>
<td>Collegial support</td>
<td>2.67 (.60)</td>
<td>2.44 (.88)</td>
<td>1.07 (46)</td>
<td>p=.291</td>
<td>p=.214</td>
</tr>
<tr>
<td>Equipment at school</td>
<td>3.48 (.94)</td>
<td>3.55 (1.22)</td>
<td>-.21 (50)</td>
<td>p=.832</td>
<td>p=.704</td>
</tr>
<tr>
<td>Pupil-related barriers</td>
<td>2.26 (.79)</td>
<td>2.98 (.98)</td>
<td>-2.92 (50)</td>
<td>p=.005, d=.83</td>
<td>p=.006</td>
</tr>
</tbody>
</table>

Notes: uneven df indicate that equal variances for t-test are not assumed; sig n-par= non-parametric significance testing (Mann-Whitney-U-Test)

**DISCUSSION**

In summary we see that collaboration at school is a major demand of future teachers when asked to use technology in their instruction. Their digital/technological nativity does not automatically result in self-confident _technology teaching_. This supports the idea that nativity has to be combined with literacy as is supported in Ng (2012). Additionally, those students who do know how to use a device would also implement this use in class, what seems to be true in kindergarten and primary schools. Student teachers in lower-secondary schools are more interested in details of technology and perhaps this detailed knowledge hinders them to initiate technology in classes, perhaps because they see the complexity and the need for thorough
preparation. This result should be used in future for more focused research on the effect of implementing and using technology in school and its pedagogical/ didactic embedding. Experimental study designs can reveal more systematic insights that can be transferred to field contexts. In the field also the effect of fostering collaboration should be studied. Yet, if one considers these results in an overarching perspective one could argue that all this is due to the individual perception of technology education. In our next project we will also address this issue and ask for individual definitions and opinions of on technology education. In further investigations we also intend to differentiate between experienced teachers, pre-service teachers, pure professionals (e.g. technicians) and teachers in professional vocational educational training.

Besides the results above, our study is limited in the following: We only focused on obstacles and reliabilities of scales could be higher. Also, further research may include more content specific questions, because here the container phrase tech was used. An increased sample size could also contribute to a stable component structure.

REFERENCES


HOW PRESCHOOL PRE-SERVICE TEACHERS DETECT CHILDREN’S IDEAS ABOUT SOCIAL AND SCIENCE TOPICS?

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Science Education and Social Science Education Department, Seville University, Spain

This study aims to establish the way in which groups of preschool pre-service teachers design and analyse an instrument to detect children’s ideas about science and social topics, after studying two coordinated subjects at University. With that purpose, a table of analysis is presented, we found that the instrument designed employs appropriate language for the age of the children, combines a reasonable number of open questions with other resources and tends to ask about meanings related to the mesocosm. However, difficulties are encountered when organizing the responses into a category system under which the levels follow clear criteria of complexity and there is coherence between the system created and the data obtained. Finally, even though pre-service teachers recognize the importance and usefulness of having knowledge of the ideas of the pupils, they do not appear to significantly take these ideas into account in the design of their proposals, which demonstrates the need to continue working with pre-service teachers on this matter.

Keywords: preschool pre-service teacher, children’s ideas, science and social topics.

INTRODUCTION

In recent decades there has been literature with studies on the ideas of preschool students related to different educational content, although it continues to be the stage upon which least research has been carried out (Kambouri, 2015; Kerr, Beggs & Murphy, 2006). The need is now recognized to have advance knowledge of those ideas before becoming involved in order to use them in the approach and help pupils to achieve meaningful learning. Therefore, in the initial teacher training for Early Childhood Education (Pringle, 2006) teaching how to design instruments which detect these ideas and analysing the data obtained must be taught. The focus of this study is to design and apply an analysis rubric on a) the quality of instruments for detecting children’s ideas designed by pre-service preschool teachers; b) the analysis of responses obtained, as well as c) the didactic implications that they draw from these.

Early childhood pupils' ideas about the content of knowledge of the social and natural environment

An educational approach that focuses on detecting and taking into account the pupils’ ideas could be contextualized as part of so-called democratic and participatory early childhood education (Allen, 2014; Avgitidou, Pnevmatikos & Likomitrou, 2013; Driver, Guesne & Tiberghien, 1985; Dayan & Ziv, 2012). Here, the pupil is given a voice, their viewpoints are taken into account, and consensus is reached with them on many everyday educational issues.

When designing an educational proposal in early childhood education, teachers need to know their pupils' prior ideas about the themes that are going to be taught later. Indeed, to achieve meaningful learning, the pupils should know, discuss, and reflect upon their own ideas.
Knowledge is built in the pupils' minds thanks to the interaction between their already existing mental models and new experiences and information. According to Sickel (2017), it is necessary to know the pupils' prior ideas and their way of seeing the world before beginning a teaching and learning process with them. In this way, it will be possible to construct shared meanings, and the teacher will be able to adjust the interventions to fit the needs of the pupils.

Cantó, Pro and Solbes (2016) state that there is a research deficit in early childhood science teaching. Despite there being fewer studies on early childhood children's prior ideas than on those of pupils at other educational levels (Kambouri, 2016), those studies still cover a great variety of topics related to the natural and social environment. There have also been reviews of studies in the literature on early childhood pupils' ideas that are related to scientific concepts (Kerr, Beggs & Murphy, 2006).

**Scientific education in early childhood education**

According to Cañal (2006), basic scientific education (BSE) is not something that is alien to young children's nature and everyday lives. Neither does it start out from scratch when it is introduced in early childhood education, but first develops spontaneously from the moment of birth in the out-of-school interaction with the environment. The main objective with BSE should be to enrich and interrelate child's spontaneous acquisitions and capacities in this field, encouraging their appropriate development through school tasks and sequences valid for that purpose.

Spanish legislation recognizes the transversal character of the scientific competence to be developed in early childhood education (BOE, 2007). The importance of taking the children's ideas into account when planning the teaching of early childhood education has already been commented on. But the reality of the classroom often shows that teachers do not always have time to identify the children's ideas, so that they assume a certain basic level of knowledge. The results reported by Kambouri (2016) from a study of early childhood teachers in the United Kingdom were very enlightening. Despite being aware of the importance of the theoretical diagnosis of their pupils' ideas, the participating teachers' actual practice was contradictory because usually they either did not identify the children's ideas or did not help them to correct those ideas. This may have been because most of the participants considered that scientific education at these ages should help in the development of skills rather than the understanding of concepts, as also has been defended by other authors (Cantó, Pro & Solbes, 2016). Half of the teachers considered it to be acceptable for a child to finish early childhood education with alternative ideas because they considered that it would not affect the child's learning and conceptual development. We believe that initial teacher training should try to change this panorama.

**Initial PECT training and science education**

Teachers tend to teach in the same way as they themselves were taught, and breaking this cycle requires good initial teacher training (Pringle, 2006). Working with real classroom experiences is essential to guide the student towards understanding and developing appropriate professional knowledge.
PECT have been studied by several authors (Akerson, Buzzelli & Donnelly, 2010; Kahriman, 2016; Saçkes & Trundle, 2014). The influence of PECT formation is really important, because it is perhaps more stable than it is often assumed to be (Smith, 1997), and the importance of quality education for individuals working with young children is widely accepted in the field of Early Childhood Education (Early & Winton, 2001).

Cruz-Guzmán, García-Carmona and Criado (2017) presented the profile of students doing the Early Childhood Education degree course at the Seville University, Spain. Most of them had a low preference for science. More than half had accessed the degree course via a study path without science subjects, but instead through social sciences, a humanities pre-university baccalaureate, or modules of professional training in education. Many had last studied science between the ages of 14 to 16, and had begun the degree course with an inadequate science background.

PECT have been asked by different authors about various educational themes, such as the promotion of children's active participation and decision-making, the role of the teacher, the way children learn, the reasons for schooling, the children's needs, pupil-teacher relationships, etc. (Avgitidou, Pnevmatikos & Likomitrou, 2013; Lin, Gorrell & Silvern, 2001). However, to the best of our knowledge, there has been no approach to PECT’s analysis of children's prior ideas about scientific themes, although we have found such studies at a different educational level or in early childhood education but with in-service teachers.

For example, Pringle (2006) studied how 56 prospective primary education teachers explored children's alternative ideas as a basis for planning their science teaching proposals. To this end, the student teachers designed a teaching and learning activity that sought to make the children's alternative ideas explicit so that they could be reformulated conjointly in a guided way. The objective was for the prospective teachers to experience in a profound way the planning and practice of a teaching activity in a constructivist classroom. It is noteworthy that the students, at the end of their study, thought that this was not realistic due to the lack of time to be able to implement large-scale activities for the identification of pupils' alternative conceptions. However, they did express excitement about the variety of ideas the children ha about the specific themes that had been addressed.

Kambouri (2016) analysed the data obtained from in-service early childhood teachers in relation to their beliefs and practices in the classroom related to their pupils' prior ideas. The results showed there to be a deficit in the temporal dedication to identifying the children's ideas when the teachers planned their proposals, as well as a need to improve their ongoing training because many of them had no previous scientific training before their education degree.

Goals of this communication

In this context, we consider it to be of absolute importance in the initial training of early childhood education teachers for them to learn how to detect and analyse their pupils' ideas, so that they "know how to", not just "know", and then can be able to include constructivist and inquiry-based methods in their classes. This study therefore was aimed at determining (a) the instruments that the ECPT design to discover what their pupils' ideas are about the content in the area of knowledge of the natural and social environment, (b) how they analyse the results
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they obtain, and (c) the didactic implications and usefulness of the results they get for their educational planning.

METHOD

Participants and Context

The participants were 38 students from the third year of preschool education, organized into 7 groups of 4-5 members. All of them were taking the courses Natural Environment Teaching for the stage 0 to 6 years and Knowledge of the Social Environment, which are carried out in coordination. On these courses pre-service teachers acquired the necessary knowledge to design an instrument to detect ideas previously held by children on a preschool curriculum topic, they applied it with a sample of 6 children of the same age, between 3 and 6 years old, analyzed the ideas of the children interviewed and wrote a report with open questions for their evaluation in the two courses. The responses of the children were not included in the reports due to a lack of space.

Analysis of the pre-service teachers’ reports

In order to analyze the quality of the work presented by the pre-service teachers a qualitative method was followed, for which an analysis rubric has been designed (Table 1), defining the categories 1.1, 3.2, 3.3, 4.1 and 4.2 as they emerged throughout this process and the rest of the categories are based on the work of Solís, Porlán, Martín del Pozo and Siqueira (2016) and Porlán, Martín del Pozo, Rivero, Harres, Azcárate and Pizzato (2011). The responses to the reports have been grouped into the different categories created, triangulating the data obtained and reviewing the coding between the three authors, organized in pairs for the analysis of the two sets of reports that were established. Subsequently, an agreement was reached on the questions where there were discrepancies (a low percentage), to such an extent that a 100% agreement was reached on the dubious responses.

RESULTS

The frequency of the three levels of formulation for each category analyzed are presented, for report (7 reports, Figure 1) and for question designed (88 questions, Figure 2). The results show that pre-service teachers predominantly choose topics which are either word-for-word curriculum topics (2/7) or fail to connect with the interests of the preschool students (3/7). 7/7 design instruments tend to combine a reasonable number of mainly open questions with other resources such as drawings, diagrams, etc. The data shows that the students do not always explicitly state the educational implications derived from the study carried out, and in designing their educational proposal, those that took the educational demand researched into account are in the minority (1/7). Nevertheless, the majority (5/6) consider the work carried out to be useful and feasible in future as a teacher.
The questions that the students include in their instruments employ language fairly in keeping with the age of the pupils interviewed (in 54% of cases), they usually look for meaning although we found a significant number of questions (23%) where the responses are with concrete data (names, dates, etc.) "How long does a season last?\)". In general, a 72% relate to the mesocosm, that which is perceptible or close to the pupil, "How do you know summer has arrived?\)", but they do not seek a theoretical justification of what is perceived (macrocosm or mesocosm). This may be due to the students' belief that children at the early childhood stage are unable to relate the mesocosm to the closer levels of the macrocosm and the microcosm (Level 3).
Figure 1. Frequency of formulation levels by category and by report. In total 7 reports

Figure 2. Frequency of formulation levels by category and by question. In total 88 questions.

In 44% of the cases, the objectives of the questions considered tend to be clear and in line with the proposals, nonetheless, with a frequency of 33%, the objectives do not correspond to what is really being asked (level 1, e.g., "How long does the stomach take to digest food?" Objective: "To see whether they relate the resting time after having eaten a meal with the actual time it takes the stomach to digest it."), the questions are either not well formulated or are simply not relevant to the topic being studied. The objective either repeats the question affirmatively or does not specify the desired school content (39%, Level 2) (e.g. Question: "Do you know what recycling is? What is it for?" Objective: "To see if the child understands the concept of recycling as well as its usefulness.").

The results obtained with respect to the analysis performed by the pre-service teachers demonstrate the difficulty they find with the process carried out. In this way, even though we find responses in which levels of complexity are formulated following some clear criteria (level
3, 25%), the ones which do not always go up in accordance with the level of their complexity or they do not specify the knowledge for each category (Level 2) are slightly more predominant (28%). Here it is shown level 2 example. In response to the question "Is recycling good or bad? Why?", the levels determined were: I. Do not answer. II. They respond but do not give reasons for their response. III. They respond providing reasons to support their response.

In the same way, although in many cases the devised category system makes sense according to the data obtained, the systems where not all the categories created are related to or make sense according to the responses or the data analyzed is predominantly higher (33%).

The final dimension analysed concerns the educational value of the work carried out. In relation to the category 4.1, the PECT seldom declare that they will take into account the demand for learning that was investigated in their educational proposal design (Level 3, Example 1), although in 3/7 of the reports it is possible to sense an educational implication in their conclusions (Level 2, Example 2).

Example 1. Bearing in mind the previous data about the children's prior ideas, and thus about the knowledge they have about recycling, this was used as the base for the development of a project about this theme. The prior ideas obtained after interviewing the children are going to be taken into account in developing a series of activities for our project "Recycling" that are based on the different levels which they have attained (Report Group 12. Level 3).

Example 2. The completion of this study can be of help to us in the future as we have learned to analyse the children's prior ideas and from this, we shall be able to teach the chosen theme taking into account their previous knowledge (Report Group 7. Level 2).

More positively, in regard to the category 4.2, in 5 of the 7 reports, the PECT consider the work they did to be useful and applicable for their future as teachers (Level 3), and only a minority consider it to be useful but too complicated to implement, or do not openly declare its transferability (Level 2). Below we present two fragments extracted from the reports in which the students give their opinions regarding the transfer of the work they carried out:

We believe this is a good way of working with the children's prior ideas, and that it can be of use to us as teachers in the future as well as now as students (Report Group 5. Level 3).

We consider it to be appropriate and original to know what knowledge our young pupils have before going deeper into a particular theme and to take advantage of the great imagination and the many great responses they can provide us with. However, we note that the process of collecting data through the tables and matrix so as to be able to analyse the children's ideas is quite a complicated process which takes a long time to see the levels the children have reached, so therefore it would be difficult to implement in a class (Report Group 15. Level 2).

**DISCUSSION AND CONCLUSIONS**

This study has allowed us to verify that prospective teachers have difficulty in selecting themes that go beyond what is set out in the curriculum and are more directly linked to pupils' everyday reality. They remain anchored in traditional curricular content, and are unable to break away
and propose topics that may be more attractive to the pupils. We find that there exists a certain 
reluctance to break with traditional teaching, coinciding with the idea defended by Pringle 
(2006) that teachers tend to teach in the same way they themselves had been taught. It is 
therefore essential to make a break with this model in initial teacher training, and provide our 
students with the skills and strategies that can lead them to create their own teaching model.

Regarding the design of the instrument to detect children’s ideas, the prospective teachers show 
a great capacity to adapt to the children's language and to make use of different resources to 
facet late their pupils’ contact with and understanding of the topics. In accordance with Solis, 
Porlán, Martin del Pozo and Siqueira (2016), in this way they surpass the so-called level of 
amademic culture to that of the culture of age, using a language that is closer and more 
approachable for early childhood pupils. This aspect is particularly favourable because it 
demonstrates the PECT’s ability to be understood by their pupils and to be able to design 
resources that are attractive for them.

It is also noticeable that the questions the PECT put to the children relate mainly to the 
mesocosm. This may be linked, on the one hand, to the difficulty they often have in 
understanding scientific content (Cruz-Guzmán, García-Carmona & Criado, 2017; Timur, 
2012) and, on the other, to the consideration that some content can not be dealt with in early 
childhood education as the pupils at this stage are not prepared for it (Kambouri, 2016; Cantó, 
Pro & Solbes, 2016). Initial teacher training is once more the key to overcoming these 
obstacles. Prospective teachers must improve their scientific knowledge because, unless they 
master the subject they have to teach, they are not actually going to be able to teach it in an 
innovative way. We therefore consider that it is important to give greater weight to science 
subjects in initial teacher training so that they can compensate this deficiency in the scientific 
background with which they entered university.

In our study, the prospective teachers find it very hard to analyse the pupils' ideas. There 
fundamentally stands out the difficulty they had in categorizing the responses, tending to create 
closed categories that they generally link to answers that are "right" or "wrong". This may 
again be related to the dominance of a traditional teaching model in which there are no 
alternative responses, closed and pre-defined concepts predominate, and "misconceptions" are 
not seen as ideas that can be made to evolve during learning. The PECT’s lack of mastery of 
the content (Kerr, Beggs & Murphy, 2006) makes it particularly difficult for them to determine 
categories and levels of complexity in the children's responses.

If prospective teachers encounter these obstacles at this stage of their training, in the future it 
will be difficult for them to take their pupils' ideas into account when planning their teaching 
because, if they are unable to organize the responses they get from the pupils and determine 
the different levels or stages of knowledge these represent then they will not be able to offer 
the pupils the means to advance to higher levels. In this regard, we consider it essential to 
implement a process of feedback with the prospective teachers during this type of practical 
work they do in their courses. Once they have prepared a system of categories and begin to 
analyse their data, by reflection with them we may be able to provide them instruments with 
which they can correct their mistakes, i.e., give them advice on the scientific content involved, 
on classification techniques, on restructuring the system they have created, and on using low-
inference descriptors (Latorre, 2003). In this way, we would be helping them to overcome the obstacles they encounter, guiding them in their real and effective consideration of these ideas in planning their future educational proposal.

In addition to everything mentioned above, it should be noted that, at the theoretical level, the prospective teachers seem to be clear that the work they carried out should have a direct impact on the design of the educational proposal they make. This, however, is restricted to the declarative plane, reflecting the dominance of theoretical didactic knowledge. We therefore consider that it is necessary to work with the prospective teachers in direct contact with early childhood pupils so that our students can learn about the children's actual ideas and ways of thinking, and try to connect their aforementioned didactic knowledge with practical classroom reality. Maybe in this way the abandonment of constructivist methods that many in-service teachers present could be avoided. Kambouri (2016) notes the lack of time that practising teachers dedicate to considering their pupils' ideas, and hence the low educational implication of those ideas.

Finally, it is notable that the prospective teachers value very positively the work they carried out, considering it to be useful and applicable for their professional practice. They particularly value the learning they derived from direct contact with the children and their ideas, the recognition of their own capacity to listen, and the satisfaction they felt from taking on the role of teacher during the development of the work. In this sense, the present results coincide with those of Pringle (2006) with regard to the positive assessment of the approach to the children's conceptions, but differ in that the prospective primary teachers of her study found that activities designed to determine pupils' ideas were unrealistic due to the lack of time available.

Initial teacher training must therefore advance by offering prospective teachers the opportunity to gain depth in their own scientific knowledge and by facilitating their direct contact with the reality of the early childhood classroom.

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PROFESSIONALIZATION OF FUTURE CHEMISTRY TEACHERS FOR TEACHING IN INCLUSIVE CLASSROOMS

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Inclusive schooling brings new challenges for teachers, for which they need to be prepared. This paper introduces a university seminar that aims to professionalize future chemistry teachers for teaching in inclusive classrooms. The seminar’s contents and the results of its evaluation are presented and discussed. For this, the Universal Design for Learning (UDL) serves as a guiding concept. The evaluation does not only show that the future teachers assess the seminar as attractive but also indicate a significant increase regarding their attitudes, willingness, and self-efficacy concerning inclusion as well as their skills in designing lesson plans according to the UDL. Additionally, they can implement what they have learnt at school to some extent. The students rate the future teachers’ classrooms very positive.

Keywords: inclusion, teacher training, universal design for learning

INTRODUCTION

Since the ratification of the UN Convention on the Rights of Persons with Disabilities (United Nations, 2006), inclusion is a much-discussed issue. However, its successful implementation still requires a long process of various changes to the educational system. Hence, insights into the requirements of the realization of inclusive lessons are necessary. It is a new challenge for the teachers to develop a teaching practice, which supports every student in accordance with his or her individual skills, while also taking (special) educational needs of the students into account. Therefore, the teacher training provides an essential basis for implementing inclusive education at schools (Amrhein & Dziak-Mahler, 2014; Florian & Rouse, 2009). Consequently, it is the goal of this project to develop and to evaluate a seminar that prepares future chemistry teachers for teaching in inclusive classrooms.

THEORETICAL BACKGROUND

Inclusion in the teacher training

Even though inclusion is already reality in German classrooms, teachers and future teachers do not feel well prepared for the new challenges that come with it (Amrhein & Dziak-Mahler, 2014; Lambe & Bones, 2006). That is particularly due to the fact that universities show little efforts to prepare future teachers for inclusion (Körner, 2010). A study in Germany revealed that inclusion is often just part of courses in general pedagogies; it is still rare that inclusion is taught in connection with the specific subject or teaching methodology (Monitor Lehrerbildung, 2015). Therefore, future teachers gain some general knowledge about inclusion, but they do not learn how to implement it in subject-related classrooms.

To meet the requirements of inclusive teacher training, Forlin (2010, p. 8) proposes a “Whole Faculty Approach (WFA)”: The university’s different departments, divisions and discipline areas should collaborate to build up a “common understanding of what constitutes an inclusive
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curriculum or what the aims should be in furthering this” (Forlin, 2010, p. 8). Recently, the German government tried to promote the implementation of inclusion in its teacher training. For this, the Federal Ministry for Education and Research (BMBF) supports projects of universities that aim to implement such whole faculty approaches (Bundesministerium für Bildung und Forschung, 2016). Comparable efforts are made internationally as well. For example, in 2009 the European Agency for Development in Special Needs Education started the triennial project Teacher Education for Inclusion (TE4I) to work out essential teacher competences for inclusive education. These competences were organized and structured as the Profile of Inclusive Teachers (European Agency for Development in Special Needs Education, 2012). However, there is still no evidence-based concept to develop those competences.

Universal Design for Learning

Within this study, the Universal Design for Learning (UDL) serves as a guiding concept. It is a framework for designing classrooms, which are accessible for all students by reducing construct-irrelevant barriers (CAST, 2011; Rose & Meyer, 2002). Drawing from brain research, the core of UDL consists of three principles that demand three kinds of flexibility:

I. “To support recognition learning, provide multiple means of representation – that is, offer flexible ways to present what we teach and learn.

II. To support strategic learning, provide multiple means of action and expression – that it, flexible options for how we learn and express what we know.

III. To support affective learning, provide multiple means of engagement – that is, flexible options for generation and sustaining motivation, the why of learning.” (Hall, Meyer, & Rose, 2012, p. 2)

Each principle is subdivided into three guidelines with three to five checkpoints each. These guidelines are tools to support teachers in the instructional planning phases. They help identifying potential barriers in materials and methods and offer fitting solutions to ensure that all students can learn in the best possible way (Lapinski, Gravel, & Rose, 2012).

Overall, UDL maintains the policy “Essential for Some, Good for All” (Meyer, Rose, & Gordon, 2014, p. 84): Not all students need such flexibility in the classroom to meet their individual skills but everyone benefits from it.

THE INTERVENTION

The developed seminar “Preparation for teaching chemistry in inclusive classrooms” is the preparation seminar for the internship semester. The internship semester contains school practice and is part of the master program of the studies. Therefore, the seminar shall prepare for this internship semester and is mandatory for all future teachers in chemistry education.

In the seminar, the students deal with different aspects of teaching in inclusive classrooms, both theoretically and practically. Table 1 shows all seminar topics.
Table 1. Seminar’s contents and thematic blocks. Written in grey are the times of measurements.

<table>
<thead>
<tr>
<th>Session no.</th>
<th>Content</th>
<th>Thematic block</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. + 2.</td>
<td>Introduction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>First time of measurements</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Planning chemistry in inclusive classrooms</td>
<td>I. Basics of teaching in inclusive classrooms</td>
</tr>
<tr>
<td>4.</td>
<td>The Universal Design for Learning</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>The history of learning disabilities*</td>
<td>II. Basics of special educational needs</td>
</tr>
<tr>
<td>6.</td>
<td>Learning disability and successful learning in school*</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Development of learning tasks for heterogeneous learning groups</td>
<td></td>
</tr>
<tr>
<td>8. + 9.</td>
<td>Student-based experiments in inclusive classrooms</td>
<td>III. Practical implementation</td>
</tr>
<tr>
<td>10.</td>
<td>Easy language*</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Cooperative learning in inclusive chemistry classrooms</td>
<td>IV. Methodological basics</td>
</tr>
<tr>
<td>12.</td>
<td>Dealing with behavioural problems in inclusive classrooms</td>
<td></td>
</tr>
<tr>
<td>13. + 14.</td>
<td>Discussion about chances and limits of inclusive classes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Second time of measurements</td>
<td></td>
</tr>
</tbody>
</table>

* Sessions held by a lecturer from the special needs department

The seminar was cooperatively created by the chairs of chemistry education as well as the special needs department and the seminar sessions are organised as team teaching. The seminar sessions signed with a star are held by a lecturer from the special needs department and focus on students with learning disabilities. The reason for this focus is that in Germany, learning disability is the most common disability of special needs students and those students very often go to inclusive classes (KMK, 2016a; KMK, 2016b). A lecturer from the chair of chemistry education manages the other seminar sessions. Therefore, the students can deal with both, special educational aspects of teaching and learning as well as subject related aspects concerning inclusion. However, in all sessions both lecturers are present, so every subject can be discussed from both points of view. Moreover, four thematic blocks subdivide the seminar.

Normally, one session is structured as follows: It starts with an introduction, mainly realized with a Power-Point-presentation. After that, the students can deal with the presented topics in groups independently. At the end, they present their results.

In the seminar, the UDL serves as overarching concept and guideline. Therefore, the introduction of the UDL as a general pedagogical framework for inclusive teaching happens in session 4 and all other seminar topics refer to it. For example, the lecture in the session “Student-based experiments in inclusive classrooms” presents a hands-on learning environment which is designed to be mostly universally accessible using the UDL. This learning environment, as a specific example, shall point out opportunities and steps, which can increase the universal access in hands-on learning environments. After that, the students get time to develop a hands-on learning environment for inclusive classrooms on their own in groups.
RESEARCH QUESTIONS

Adapted to the evaluation steps by Kirkpatrick (1979), the developed seminar is evaluated on the basis of the following levels: (1) attractiveness, (2) cognitive changes, (3) implementation at school and (4) effect on the students. The research questions are based on these four levels:

Attractiveness: Q1): How do the future teachers assess the seminar?

Cognitive changes:

Q2): Which impact does the seminar have on the
   a) attitudes concerning inclusion?
   b) self-efficacy expectations concerning inclusion?
   c) willingness to teach in inclusive classrooms?

Q3) Do the future teachers improve their skills in designing lesson plans according to the UDL?

Implementation at school: Q4): Are the future teachers able to put into practice at school what they have learnt in the seminar?

Effects on the students: Q5): Which effect do the implemented lessons have on the students in the classrooms?

STUDY DESIGN AND METHOD

The study is an intervention study with a pre-post-follow-up-design (Error! Reference source not found.). Moreover, the analysis of a comparison group shall ensure that some of the measured effects can be traced back to the seminar and not to other factors, such as the test rerun.

During the first two sessions of the intervention group, the first measurement takes place. The future teachers’ attitudes, willingness, and self-efficacy concerning inclusion are tested by paper-and-pencil-tests (6-point Likert-scale from 1 = I completely agree to 6 = I completely disagree; \( \alpha_{\text{Attitudes}} = .900, \alpha_{\text{Willingness}} = .904, \alpha_{\text{Self-efficacy}} = .894 \)). Moreover, to measure their skills in designing lesson plans according to the UDL, the future teachers must plan lessons for inclusive chemistry classrooms. This analysis is made by using an encoding manual (4-point Likert-scale from 1 = no to 4 = yes; ICC\textsubscript{unjust} = .857). After that, the intervention with eleven sessions follows. During the intervention, a survey (5-point Likert scale from 1 = I completely agree to 6 = I completely disagree; \( \alpha = .879 \)) measures the quality of four thematic blocks. The future teachers’ work behaviour during two working phases is filmed and assessed by an encoding manual (\( \kappa \) between .709 and .851).

During the last two seminar sessions, the second measurement takes place. Besides the attitudes, willingness, and self-efficacy tests as well as the lesson plans, this time of measurement includes a survey to measure the seminar’s overall assessment (5-point Likert-scale from 1 = I completely agree to 6 = I completely disagree; \( \alpha = .837 \)), focused on the quality of the working phases and lecturers’ delivery. After the seminar, the future teachers can implement what they have learnt in the subsequent internship semester. During this internship semester, the future teachers have an accompanying seminar for three days at university.
## Figure 1. Study Design

<table>
<thead>
<tr>
<th>Intervention group (IG)</th>
<th>Comparable group (CG)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seminar</strong></td>
<td></td>
</tr>
<tr>
<td>First time of measurement</td>
<td>First time of measurement</td>
</tr>
<tr>
<td>First two seminar sessions</td>
<td>First time of measurement</td>
</tr>
<tr>
<td><strong>Intervention</strong></td>
<td></td>
</tr>
<tr>
<td>Electronic seminar division, twice a week</td>
<td></td>
</tr>
<tr>
<td>„Preparation for teaching chemistry in inclusive classrooms“</td>
<td>Implementation of a general subject-related didactical seminar</td>
</tr>
<tr>
<td>Measurement of the quality of thematic blocks</td>
<td></td>
</tr>
<tr>
<td>Videography of two seminar working phases</td>
<td></td>
</tr>
<tr>
<td>Second time of measurement</td>
<td></td>
</tr>
<tr>
<td>Last two seminar sessions</td>
<td>Second time of measurement</td>
</tr>
<tr>
<td><strong>Second sessions of the accompanying course</strong></td>
<td></td>
</tr>
<tr>
<td>Planning of lessons in inclusive classrooms by the teacher students</td>
<td></td>
</tr>
<tr>
<td><strong>Internship semester</strong></td>
<td></td>
</tr>
<tr>
<td>Implementation at school</td>
<td></td>
</tr>
<tr>
<td>Implementation of inclusive classrooms by the teacher students</td>
<td></td>
</tr>
<tr>
<td>Videography of the lessons</td>
<td></td>
</tr>
<tr>
<td>Conduct of interviews with the teacher students</td>
<td></td>
</tr>
<tr>
<td>Conduct of interviews with the students</td>
<td></td>
</tr>
<tr>
<td>Third time of measurement</td>
<td></td>
</tr>
<tr>
<td>Third sessions of the accompanying course</td>
<td></td>
</tr>
<tr>
<td>Survey of the attitudes, willingness and self-efficacy</td>
<td></td>
</tr>
<tr>
<td><strong>Survey of the attitudes, willingness and self-efficacy</strong></td>
<td></td>
</tr>
<tr>
<td>Planning of lessons for inclusive chemistry classrooms by the teacher students</td>
<td></td>
</tr>
<tr>
<td>Survey of the seminar’s overall assessment</td>
<td></td>
</tr>
</tbody>
</table>

| | | |
|-------------------------|-----------------------|
| | | |
In the first session of this seminar, the future teachers can ask questions and develop lesson plans for their inclusive classrooms with their fellows. Then, the future teachers have to implement their developed lesson plans at school. To evaluate the implementation at school, three aspects are analyzed: One of these is the future teachers’ written lesson plans. These are analyzed by the same encoding manual which is used to assess the future teachers’ skills in designing lesson plans according to the UDL during the seminar (ICC\text{unjust} = .840). The second aspect of this evaluation is their developed work sheets, analyzed by assessment criteria (4-point Likert-scale from \(1 = \text{not met}\) to \(4 = \text{met}\); ICC\text{unjust} = .923). Thirdly, the videos of the implementation at school are analyzed by using an encoding manual (\(\kappa\) between .764 and .980) as well. Additionally, guided interviews with the future teachers survey their subjective assessment of their implemented inclusive lessons after the implementation. These interviews are analyzed by the means of an encoding manual (4-point Likert-scale from \(1 = \text{incorrect}\) to \(4 = \text{correct}\); ICC\text{unjust} = .959). Furthermore, guided interviews with three students per class – preferably students with different performance levels – are used to measure the effects on the students regarding the lessons’ universal access experienced by the students. For this, encoding rules (4-point Likert-scale from \(1 = \text{incorrect}\) to \(4 = \text{correct}\); ICC\text{unjust} = .959) are used as well. In the last session of the accompanying seminar, there is the third time of measurement to evaluate the seminars’ long-term impact on the future teachers’ attitudes, willingness, and self-efficacy.

Overall, this process has already been completely conducted two times in the past while a third seminar turn was analyzed without the implementation at school in the internship semester. Figure 1 shows the study’s time-course.

![Study's time-course](image)

The comparison group consists of future teachers from a different, but comparable university, which participate in their preparation seminar for their internship semester. Their seminar is a subject-related teaching methodology seminar with no focus on inclusive education. In the second and penultimate session, the survey measures attitudes, willingness and self-efficacy as well as the future teachers’ previous experiences concerning inclusion of the future teachers in the comparison group.

**RESULTS**

This chapter will present the study’s results, following the four evaluation steps. Overall, 39 future teachers participated in the developed seminar and 18 future teachers completed the internship semester. Eleven future teachers formed the comparison group. Therefore, it is a small sample size, which is why the results should be treated carefully.
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Attractiveness

The future teachers’ perception of the quality of the thematic blocks and of the working phases as well as lectures served to assess the seminar’s attractiveness.

Table 2 lists the results of the seminar quality questionnaire. As the means show, the future students feel very positive about the quality of all thematic blocks.

Table 2. Seminar quality of the four thematic blocks and the aggregated data of all blocks (Total). The descriptive statistics of the seminar quality survey from $1 = \text{very incorrect}$ (negative) to $5 = \text{very correct}$ (positive) are shown.

<table>
<thead>
<tr>
<th>Thematic block</th>
<th>$n$</th>
<th>$M$</th>
<th>$SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block I</td>
<td>37</td>
<td>4.09</td>
<td>0.46</td>
</tr>
<tr>
<td>Block II</td>
<td>36</td>
<td>3.72</td>
<td>0.74</td>
</tr>
<tr>
<td>Block III</td>
<td>32</td>
<td>4.24</td>
<td>0.41</td>
</tr>
<tr>
<td>Block IV</td>
<td>33</td>
<td>4.27</td>
<td>0.38</td>
</tr>
<tr>
<td>Total</td>
<td>138</td>
<td>4.07</td>
<td>0.56</td>
</tr>
</tbody>
</table>

However, there are also some differences in the future teachers’ assessment noticeable. The second block exhibits a lower mean than the others. A univariate analysis of variance (ANOVA) with repeated measures confirms this difference ($F = 8.56, p < .001, \eta^2 = .290, n = 22$). Applying the post hoc test demonstrates that Block II is rated significantly worse than Block III and IV (Table 3).

Table 3. Seminar quality of the thematic blocks: Pair-wise comparison by post hoc test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Block</th>
<th>$n$</th>
<th>Average difference</th>
<th>Standard error</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminar quality</td>
<td>I</td>
<td>22</td>
<td>.317</td>
<td>.122</td>
<td>.103</td>
</tr>
<tr>
<td>Seminar quality</td>
<td>II</td>
<td>22</td>
<td>-.095</td>
<td>.083</td>
<td>1.000</td>
</tr>
<tr>
<td>Seminar quality</td>
<td>III</td>
<td>22</td>
<td>-.186</td>
<td>.117</td>
<td>.770</td>
</tr>
<tr>
<td>Seminar quality</td>
<td>IV</td>
<td>22</td>
<td>-.412</td>
<td>.086</td>
<td>.001</td>
</tr>
<tr>
<td>Seminar quality</td>
<td>II</td>
<td>22</td>
<td>-.502</td>
<td>.117</td>
<td>.002</td>
</tr>
<tr>
<td>Seminar quality</td>
<td>III</td>
<td>22</td>
<td>-.091</td>
<td>.102</td>
<td>1.000</td>
</tr>
</tbody>
</table>

At the seminar’s end, a survey measures the quality of the working phases and the performance of the two lecturers. The means in Table 4 show that the future teachers assess the working phases and both lecturers as positive.

Overall, concerning the first research question the results indicate that the future teachers assess the seminar very positively.
Table 4 Assessment of the working phases and lecturers’ performances (Lecturer CE = Lecture from chemical education department; Lecturer SN = Lecture from special needs department). The descriptive statistics of the seminar overall assessment survey from 1 = very incorrect (negative) to 5 = very correct (positive are shown.

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery Lecturer CE</td>
<td>37</td>
<td>4.78</td>
<td>0.34</td>
</tr>
<tr>
<td>Delivery Lecturer SN</td>
<td>37</td>
<td>4.55</td>
<td>0.51</td>
</tr>
<tr>
<td>Working phases</td>
<td>37</td>
<td>4.51</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Cognitive Changes

The future teachers’ attitudes, willingness and self-efficacy expectations concerning inclusion serve as the first parameters to analyze cognitive changes. For that, a survey measures these three parameters at the beginning (pre) and at the end (post) of the seminar as well as at the end of the internship semester (follow-up). A graphical overview of the results serves Figure 2. An immediate and a long-term increase is visible.

A paired t test confirms this observation (Table 5). The seminar was able to achieve a significant positive change in the three parameters both immediately and in the long term.

In addition, a comparison group shall ensure that no other factors, for example the test rerun, cause the measured effects regarding these changes. Figure 3 serves as a graphical overview of the means of the attitudes, willingness and self-efficacy before and after the seminar of the intervention and comparison group. It shows a slight decrease of the three parameters in the comparison group. This suggests that the three parameters increase in the intervention group more than in the comparison group.

An unpaired t test of the residuals confirms that other factors do not cause the measured significant changes (Table 6).
Table 5. Immediate (Pre-Post) and long-term (Pre-Follow-up) changes of the attitudes, willingness and self-efficacy from 1 = very incorrect (negative or small) to 6 = very correct (positive or high). Comparison by paired *t* test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time of measurement</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t Test</th>
<th>t</th>
<th>p</th>
<th>δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitudes</td>
<td>Pre</td>
<td>37</td>
<td>4.28</td>
<td>0.63</td>
<td>-2.92</td>
<td>.006</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td></td>
<td>4.52</td>
<td>0.62</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre</td>
<td>18</td>
<td>4.19</td>
<td>0.62</td>
<td>-3.64</td>
<td>.002</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Follow-up</td>
<td></td>
<td>4.59</td>
<td>0.73</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Willingness</td>
<td>Pre</td>
<td>37</td>
<td>4.06</td>
<td>1.25</td>
<td>-2.90</td>
<td>.006</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td></td>
<td>4.46</td>
<td>1.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre</td>
<td>18</td>
<td>3.94</td>
<td>1.10</td>
<td>-2.38</td>
<td>.029</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Follow-up</td>
<td></td>
<td>4.44</td>
<td>0.93</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>Pre</td>
<td>37</td>
<td>3.64</td>
<td>0.81</td>
<td>-7.06</td>
<td>&lt; .001</td>
<td>1.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td></td>
<td>4.59</td>
<td>0.49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre</td>
<td>18</td>
<td>3.26</td>
<td>.074</td>
<td>-6.78</td>
<td>&lt; .001</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Follow-up</td>
<td></td>
<td>4.59</td>
<td>0.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Presentation of the means of the attitudes, willingness and self-efficacy before (pre) and after (post) the seminar of the intervention group (IG, *n* = 37) and the comparison group (CG, *n* = 11). *p < .05: *; *p < .01: **; *p < .001: ***.

Table 6. Differences between the future teachers of the intervention (IG) and comparison (CG) group in the changes of attitudes, willingness and self-efficacy (residuals). Comparison by unpaired *t* test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>t Test</th>
<th>t</th>
<th>p</th>
<th>δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitudes</td>
<td>IG</td>
<td>37</td>
<td>0.26</td>
<td>0.87</td>
<td>3.73</td>
<td>.001</td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CG</td>
<td>11</td>
<td>-0.86</td>
<td>0.89</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Willingness</td>
<td>IG</td>
<td>37</td>
<td>0.26</td>
<td>0.78</td>
<td>3.784</td>
<td>&lt; .001</td>
<td>1.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CG</td>
<td>11</td>
<td>-0.87</td>
<td>1.15</td>
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</tr>
<tr>
<td>Self-efficacy</td>
<td>IG</td>
<td>37</td>
<td>0.40</td>
<td>0.62</td>
<td>7.89</td>
<td>&lt; .001</td>
<td>2.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CG</td>
<td>11</td>
<td>-1.36</td>
<td>0.76</td>
<td></td>
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</tbody>
</table>
Concerning the second research question, the results indicate that the seminar has a positive impact on the future teachers’ attitudes, willingness, and self-efficacy.

As a second parameter to analyze the cognitive changes, the future teachers’ skills in designing lesson plans according to the UDL before and after the seminar are analyzed. For this, the future teachers had to develop lesson plans before and after the seminar. These lesson plans are evaluated based on the implementation of UDL-elements. The comparison of the future teachers’ skills before and after the seminar shows a significant improvement ($t = -12.20$, $p < .001$, $\delta = 2.01$, $n = 37$).

**Implementation at school**

There is a big difference between knowing principles as well as techniques and using them. Therefore, the implementation of the seminar’s contents at school in the subsequent internship semester is also measured.

The future teachers had to plan inclusive lessons using what they have learnt in the seminar. In this context, they developed lesson plans as well as work sheets and they tried to implement their lesson plans. Their efforts were videotaped. By analyzing these three aspects according to the elements of the UDL, the results show that the future teachers implemented what they have learnt to some extent. For example, the analysis of the lesson plans happens by using the same encoding manual that was already used to analyze the lesson plans before and after the seminar. With a maximal value of four, the future teachers achieve an average of $M = 2.44$ ($SD = 0.32$, $n = 17$). This shows they can still enhance the quality of the implementation. In addition, the analysis of the videos reveals great differences among the future teachers regarding the quality of their implementation at school.

Immediately after the implementation, interviews with the future teachers indicate that they rate their gained experiences at school as positive and the UDL was helpful for the development and implementation of inclusive lessons.

According to the fourth research question, the data show that the future teachers are able to put into practice what they have learnt but the quality of the implementation can be enhanced.

**Effects on the students**

Interviews with three students per class detect the effects on the students. These interviews are conducted immediately after the future teachers’ inclusive lessons. In these interviews, the students assess how accessible the future teachers’ classroom was for them. With a maximal value of four, the students assess the accessibility with an average of $M = 3.33$ ($SD = 0.37$, $n = 50$). This result indicates that the inclusive classrooms implemented by the future teachers are accessible to the students.

**DISCUSSION**

This study identifies some possibilities to prepare future chemistry teachers for teaching in inclusive classrooms. The results show that the future teachers improve their attitudes, willingness and self-efficacy concerning inclusion as well as their skills in designing lesson plans according to the UDL. In addition, the future teachers are able to implement what they
have learnt and the students assess these implemented classrooms as accessible for them. Nevertheless, the transfer of knowledge into practice seems to cause some problems for the future teachers since the implementation in school can still be improved. However, this is not surprising, as their teacher training is not completed yet. The future teachers have to take their exams at university and after that finish a traineeship, which takes one and a half year.

These results reveal possible improvements. To improve the transfer from theory into practice video vignettes showing critical situations in inclusive chemistry classrooms could be implemented into the seminar. In doing so, the future teachers could gain some realistic insights in the inclusive classrooms. They could discuss it and work out some alternative behaviours.

Since the UDL is a framework of the general pedagogy, other departments can use this seminar conception with subject-related adaptions. This has already occurred in the subjects English, Music and Physical Education at TU Dortmund University. This constitutes one step towards the WFA (Forlin, 2010).

Overall, there are more courses and seminars necessary to prepare future (chemistry) teachers for teaching in inclusive classrooms. This requires the cooperation of the whole university in designing a common understanding of inclusion and shared concepts future teachers can work with. For that, the developed seminar can provide some indications.

ACKNOWLEDGEMENT

I want to thank my research group at TU Dortmund for their support with my Ph.D.-project and the participating students and future teachers.

REFERENCES


PROFESSIONALIZATION OF PRE-SERVICE CHEMISTRY TEACHERS FOR THE COMPETENT USE OF ASSESSMENT

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TU Dortmund University, Chair of Chemical Education, Dortmund, Germany

Since 2005, the right of each student for individual support has been anchored in Germany (Schulgesetz für den Land Nordrhein-Westfalen, 2005). Therefore, it is important that teachers regularly analyze their teaching in order to adapt future lessons to the current learning level of the students and to give individual support. This has been particularly important since 2006. At this time, Germany signed the UN Convention of the Rights of Persons with Disabilities and is therefore committed to introduce an inclusive education system (United Nations, 2006). With the increasing heterogeneity in German classrooms, a formative diagnostic assessment of the current learning level is indispensable. Therefore, it is necessary to make diagnostic tests universally accessible or modify the task level. The aim of this project is to professionalize future chemistry teachers in dealing with these new challenges and to show them how to implement inclusive diagnosis in their classes. For this reason, a seminar was developed in which the teacher students learn how to formulate and evaluate learning objectives. The seminar is located in the master program of the studies. They get to know different task formats and how to adapt them to heterogeneous learning groups with the help of test accommodations and modifications. Additionally, the Universal Design for Assessment is used for support (Lovett & Lewandowski, 2015). Hereby, learning objectives and diagnostic tests are not only taught theoretically, but are also created independently by the teacher students. A checkup of what has been learnt takes place in the subsequent internship semester. There, the teacher students apply in the classroom what they have learnt in the seminar. In order to evaluate the effectiveness of the seminar, we used pre- and post-tests and the implementation in the internship semester is evaluated. In this paper, we report the first results of the main study.

Keywords: teacher training, assessment, inclusion

MOTIVATION

Since 2005, every student in the state of North Rhine Westphalia (Germany) has the right to individual support (Schulgesetz für das Land Nordrhein-Westfalen, 2005). In order to fulfill this obligation and to be able to ensure adequate individual support, teachers have to diagnose the learning outcomes of their students. Despite the demands for diagnosis and individual support, school performance has only been improved to a limited extent as international school performance comparisons (TIMSS, IGLU) show. Hence, an increase in the diagnostic competencies of teachers (Fischer et al., 2014) is required.

A further challenge for teachers is posed in the form of the UN Disability Equality Convention, where Germany agreed to convert its school system into an inclusive one (United Nations, 2006). Handling these two demands has become a law of teacher training in Germany, e.g. in Northrhine Westfalia (LABG, 2009). For this reason, universities are obliged to improve diagnostic competencies in the teacher-training. Therefore, we developed and evaluated a university seminar that deals with this topic.
THEORETICAL BACKGROUND

Inclusive teaching requires regular pedagogical diagnosis (Prengel, 2013). For this purpose, a formative form of assessment is useful. This method enables to recognize students’ current learning needs and, therefore, adapt the following lessons to them accordingly (OECD, 2005). As a consequence, formative assessment primarily aims at the improvement of teaching and learning in the classroom (Black & William, 2009). Accordingly, the main element of the seminar developed is to specify learning objectives and to check the individual progress of the learners towards these goals (OECD, 2005).

Furthermore, information about the use of formative diagnostic tests in inclusive classrooms is given to the teacher students. If some students in heterogeneous classes are unable to participate in the test under regular conditions, test accommodations concerning the environment or the layout are recommended. An overview of the aspects that should be observed is provided by the Universal Design for Assessment (UDA) (Lovett & Lewandowski, 2015). Lovett and Lewandowski adapted the Principles of Universal Design (Story, Mueller & Mace, 1998) for creating tests. In many studies the effects of different alterations in the test layout or test environment were investigated. For example, a study by Kettler et. al. (2012) tested the effects of reducing barriers in test layouts, they were able to show that students with and without disabilities received higher scores. Furthermore, Shinn and Ofiesh (2012) created an overview of the types of test alterations that reduce influences of disabilities. If test accommodations are not sufficient to participate in the diagnostic test due to the special education level, it is possible to use modifications by creating different content levels (Kettler et. al., 2012). This means that students who are overburdened or subchallenged by the regular performance level will receive a diagnostic test with an appropriate level of performance.

METHOD

The procedure of the main study with about 25 students is based on the results of a pilot study. In the following illustrations, it is only the main study is referred to. The seminar consists of seven seminar sessions, in which the contents for the formulation of learning objectives and how to evaluate them are taught to the teacher students. In the subsequent internship semester, they can practice what they have learnt in the seminar in the classroom.

We evaluated the seminar on four levels based on the theory of Kirkpatrick and Kirkpatrick (2006). This way, the appreciation of the seminar, the cognitive change, the practical implementation, and the effect on the learners are measured.

To evaluate the appreciation of the seminar, we used a test of attractiveness after the seminar (open questions, 5 Items; 5-point-Likert-scale, 26 Items, α = .884).

For the evaluation of the cognitive change we surveyed the teacher students three times: Before, and after the seminar, as well as after the internship semester. At each time, we used a competence test for measuring the skills in handling learning objectives and diagnostic tests (16 Items, coding manual: ICC unjust = .845). Additionally, a test for measuring the attitude, self-efficacy, and willingness of the teacher students was conducted before and after the seminar (5-point-Likert-scale; 21 Items, α = .889).
After the internship semester, we used a coding manual (ICC unjust = .765) to analyze the diagnostic test that had been created by the teacher students. We measured this for the level of practical implementation.

To gather the effects on the learners, the teacher students applied a questionnaire. The questionnaire asked the learners about to their opinion on the diagnostic test and the degree of difficulty (5-point-Likert-scale, 5 Items).

**CONTENTS OF THE SEMINAR UNIT**

In the seminar unit "Diagnostic tests in chemistry classes", students learn the theoretical structure of learning objectives, diagnostic tests and individual task types. In addition, they learn special features for usage in an inclusive classroom. These theoretical constructs are put into practice by the teacher students in each individual session, e.g. by creating their own diagnostic tests in the working periods of the seminar. Thus, a seminar is always composed of a theoretical input through Power-Point-presentations and practical working periods, which are characterized by a variety of methods. All results will be presented by the teacher students to each other, explained and discussed with the other teacher students. The focus of the seminar is on three topics which are repeatedly linked with each other. These includes the formulation of learning objectives according to Mager (1977), test accommodations in test design and test environments according to Lovett and Lewandowski (2015) as well as the modification (Kettler et al., 2012) of individual task types. The aim is to prepare teacher students as comprehensively as possible for various special educational needs. The individual seminar sessions are listed in Table 1 and are explained in more detail below.

**Table 1. Content of the seminar**

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Learning status diagnostics for inclusive classrooms – Conceptualization</td>
</tr>
<tr>
<td>2.</td>
<td>Learning status diagnostics for inclusive classrooms – Formulation of learning goals</td>
</tr>
<tr>
<td>3.</td>
<td>Assessment in inclusive classrooms</td>
</tr>
<tr>
<td>4.</td>
<td>Closed questions for inclusive classrooms (e.g. multiple-choice item, matching task, …)</td>
</tr>
<tr>
<td>5.</td>
<td>Semi-opened questions for inclusive classrooms (e.g. cloze, concept-cartoon, …)</td>
</tr>
<tr>
<td>6.</td>
<td>Open-ended questions for inclusive classrooms (e.g. short-answer item, interpretative task, …)</td>
</tr>
<tr>
<td>7.</td>
<td>Exercise unit – Learning goals &amp; assessment in inclusive classrooms</td>
</tr>
</tbody>
</table>
Session 1

The seminar unit starts directly with a task, which serves to establish a personal relation to the importance of diagnosis for the students. In this way, a change of the inner attitude towards the significance of pedagogical diagnostics for their own teaching should be achieved. For this purpose, we present the teacher students fictitious statements, similar to those they know from their own school days. These fictitious statements are worded through the perspective of students that either lack any diagnosis by their teacher or are diagnosed incorrectly. After a guided conversation, there is a Power-Point-presentation on diagnostics and the close connection between diagnosis and individual support. In order to clarify and differentiate the most important concepts on the subject of learning objectives and diagnostic tests, the method of group puzzle is used. On the basis of a pre-defined mind map in DINA-3-size and matching texts, the teacher students become experts in one area and impart the newly acquired knowledge to the other teacher students, while they can record everything in keywords on the mind-map-printout.

Session 2

The second seminar session deals with the formulation of learning objectives. The concepts already learned are repeated at the beginning of a classroom conversation. This is followed by a presentation on the various functions of learning objectives and the formulation according to Mager (1977). This gives a comprehensive impression as a basis and can be well developed later in the teacher training. Furthermore, the subdivisions according to Mager (1977) are linked with the behavioral and content dimension according to Gage and Berliner (1996) and a schema is provided for formulation. The Power-Point-presentation is interrupted by short questions and work phases in which, for example, words that can be used as operators have to be assigned to the different requirements (KMK, 2013) by actively sorting the terms on the blackboard by the teacher students. After the informative input, the teacher students have to formulate learning objectives independently and assign them to the terms learnt in the first seminar session.

Session 3

The third seminar session is dedicated to the use of diagnostic tests in inclusive learning classrooms. By using the Think-Pair-Share method, we work out which particularities are to be taken into account when formulating learning objectives in lessons with inclusive students. After that follows a link between the Universal Design for Learning (CAST, 2011) and the related model of Universal Design for Assessment (UDA) (Lovett & Lewandowski, 2015). The UDA mostly represents the possibilities of test accommodation, which are explained in detail in the seminar. The aim is to create a test for all learners in order to achieve the maximum possible fairness. A summary of the principles is given in Table 2. In order to grasp the guidelines adopted by Universal Design and applied to tests (Story, Mueller & Mace, 1998), teacher students work in groups on different texts. In the end, each group formulates a guideline and a teaching example and presents it to the whole group. As a supplementary model to the test accommodation, the modification is to be considered which aims to offer a differentiated diagnostic test at different levels (Kettler et al., 2012). The model of the modification is briefly
explained, but not in full detail, as numerous examples will follow in the following three seminar sessions.

Table 2. Principles of UDA (Lovett & Lewandowski, 2015, pp. 213-216)

<table>
<thead>
<tr>
<th>Number</th>
<th>Principle</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>Equitable Use</td>
</tr>
<tr>
<td></td>
<td>This principle encourages the design of assessments that are fair, identical wherever possible, and accessible to all persons.</td>
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<tr>
<td>2.</td>
<td>Flexibility in Use</td>
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<td></td>
<td>This principle encourages creativity in the way test materials are presented and responses collected.</td>
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<tr>
<td>3.</td>
<td>Simple and Intuitive Use</td>
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<td>This principle encourages test designs that are elegant in their simplicity. Test designs should not be burdensome, punitive, or excessively long.</td>
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<tr>
<td>4.</td>
<td>Perceptible Information</td>
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<td></td>
<td>This principle encourages test designs to maximize legibility and comprehensibility.</td>
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<tr>
<td>5.</td>
<td>Tolerance of Error</td>
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<td></td>
<td>This principle encourages tests that can still be administered properly when something goes wrong.</td>
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<tr>
<td>6.</td>
<td>Low Physical Effort</td>
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<td>The intent of this principle is to foster test designs that minimize nonessential physical effort in order to allow maximum energy and attention to the cognitive aspects of the test.</td>
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<tr>
<td>7.</td>
<td>Size and Space for Approach and Use</td>
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<td></td>
<td>This principle serves to remind us that examinees vary in body size, hand size, reach, visual acuity, mobility, and posture.</td>
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</table>

Sessions 4 to 6

The contents of the following three seminar sessions are structured in a similar way as each seminar session deals with a different task format. The teacher students get to know a total of 15 different task types which can be classified into three common task formats: closed, semi-open and open. The teaching method changes in each session. In addition, at the beginning of each of the three seminar sessions, the task format is briefly introduced and at the end, all advantages and disadvantages are collected in the plenary session. In seminar session four, five types of tasks are presented in a closed task format. The structure, the criteria and the possibilities of modification are explained for each task type. This is accompanied by specific example tasks. Afterwards, the teacher students create their own tasks in small groups and differentiate them on three levels. They use the self-defined learning goals of the second seminar session. Laptops and textbooks are made available to the teacher students. In order to provide feedback for all participants, the results are exchanged and feedback is given to each
other. Finally, the teacher students discuss selected examples in the plenary session. The focus of the fifth seminar session is on semi-open task formats. This time, the topic is worked out by the teacher students. In pairs of two, they receive posters on which they find a sample task and the name of the task type. They have to find criteria and develop modifications independently. In addition, the assigned example task is to be differentiated in three levels. The seminar session ends with a gallery walk to present all results. Seminar session six is very similar to the fourth seminar session, but with the subject of the closed questions. It is supplemented by a summary of all modification options.

**Session 7**

The last seminar session is a practice unit in which the teacher students have to reapply their acquired knowledge and link it thematically to new knowledge. Laptops, textbooks, curricula and materials from the other seminar sessions are available. The assignment requires the teacher students to choose a topic and to use the curriculum to formulate learning objectives. On the basis of these learning objectives, appropriate diagnostic tests have to be developed. Each task format should be represented once. When creating the diagnostic instrument, the teacher students have to take a given setting of a class composition into account and adapt the diagnostic test to the individual characteristics of the students. In this seminar session, the teacher students receive support from the lecturer and open questions can be answered.

**RESULTS**

The first results of the main study are presented below. So far, not all of the collected data have been evaluated. Therefore, the following results are preliminary.

**Cognitive Change**

The teacher students significantly improved their ability to handle learning objectives and diagnostic tests in inclusive classrooms ($p < .015, \delta = 1.331, n = 9$).

The self-efficacy, attitude and willingness of the teacher students concerning the use of diagnostic tests in the inclusive classrooms are significantly improved (Self-efficacy: $p < .001, \delta = 1.20, n = 25$; Attitude: $p = .002, \delta = 0.71, n = 25$; Willingness: $p = .004, \delta = 0.64, n = 25$) (Figure 1).

**Appreciation of the seminar**

The seminar is perceived as attractive by the teacher students ($M = 4.48$, negative to 5 = positive, $n = 25$).
DISCUSSION AND CONCLUSIONS

Impact of the seminar unit
The first impression of the main study corresponds to our expectation as the seminar improves the teacher students’ competence, self-efficacy, attitude and willingness significantly. Especially the self-efficacy has been improved to a great extent. Moreover, the teacher students consider the seminar as attractive.

Practical implementation
Subsequently, we will analyze the diagnostic tests, which have been conducted by the teacher students in the internship semester.

Effects on the leaners
Furthermore, the questionnaires for the students about to their opinion on the diagnostic test and the degree of difficulty will be surveyed.

ACKNOWLEDGEMENT
Finally, I would like to thank my working group for the support and all the participating teacher students and students for their cooperation.

REFERENCES


STUDENT PHYSICS TEACHERS’ ORIENTATIONS

Jens Klinghammer, Thorid Rabe and Olaf Krey
Martin Luther University of Halle-Wittenberg, Halle (Saale), Germany

Assuming that orientations determine how (future) teachers think and act, an insight into student physics teachers’ orientations seems to be important. Orientations are basic mental structures of implicit knowledge. Student teachers’ orientations towards teaching and learning physics are primarily influenced by physics lessons they experienced in their own school time. Practical experiences as part of pre-service teacher training can irritate these orientations. Therefore, this case-based study (N = 17) aims at the reconstruction of the student physics teachers’ “frameworks of orientations” concerning teaching and learning physics in the context of a first teaching experience, the so-called school-practical training. Narrative interviews have been conducted and the documentary method is applied for the interpretation of the interview transcripts.

Keywords: implicit knowledge, practical training, documentary method

INTRODUCTION

Science education research suggests what Korthagen (1993) summarises as: “teachers teach the way they have been taught, and not as they have been taught to teach” (p. 324). Pre-service physics teachers’ lesson planning and classroom acting seem to be strongly influenced by what they experienced as pupils during their school time (e.g. Fischler, 2000). Based on these experiences made in numerous lessons, student teachers already have a specific image of teaching and learning within their subject matter before they enter university (Gustafson & Rowell, 1995). This experience-based image of physics teaching can be described as practical experience-based implicit knowledge, also called atheoretical knowledge by Mannheim (1954) or tacit knowledge by Polanyi (1966).

Because this experience-based implicit knowledge seems to be highly relevant to lesson planning and particularly to classroom behaviour, there is the risk that student physics teachers reproduce formerly self-experienced physics teaching. For this reason, the question, “Why do teachers who go through science teacher preparation programmes aimed at reform-minded instruction still teach the way they were taught?”, represents a big issue in science teacher education (Abell, 2008, p. 1413).

Therefore, it has to be taken into account, that student teachers learning in university is related to their experience-based implicit knowledge of teaching and learning physics. Throughout the university teacher training programme the student teachers gain theoretical professional knowledge that might be in contradiction to this implicit knowledge of teaching and learning physics. The necessity of thinking experience-based implicit knowledge as a part of the teacher's knowledge becomes obvious (Helsper, 2002).

THEORETICAL BACKGROUND - IMPLICIT KNOWLEDGE

Assuming that there is a link between (pre-service) teacher’s cognition and their classroom activities, the investigation of pre-service (science) teachers’ knowledge seems to be important
Recent science education research on teacher professionalization attempts to map the relationships between the professional knowledge of (pre-service) physics teachers and their actions in physics teaching as well as the student learning achievement in physics lessons (e.g., Fischer, Borowski, & Tepner, 2012).

In German science education research, Cauet’s (2016) study in this area raises the question of whether studies so far test relevant knowledge. The results, that neither “teachers’ content knowledge (CK) nor their pedagogical content knowledge (PCK) correlated significantly with their support of students’ cognitive activation in the classroom”, indicate that the explicable knowledge gathered in professional knowledge tests has limited measurable relevance to physics teachers’ action in science classroom (Cauet, Liepertz, Borowski, & Fischer, 2015, p. 462). Furthermore, the tested physics teachers’ professional knowledge does not “explain any variance of student learning gains” (ibid.). Consistent with these results, Vogelsang’s (2014) research on (pre-service) physics teachers’ professional knowledge and their performances in science classroom suggests, that there is “a very small correlation between the level of competence (or professional knowledge) and actual teaching quality – some evidence even implies that there is no correlation at all” (Vogelsang et al., 2016, p. 36). Although it usually is assumed in the cognitive psychological approach of expertise research (Baumert & Kunter, 2013), Vogelsang (2014) even doubts the general assumption of the transformation of explicit knowledge into teaching action. Therefore, he proposes the analysis of the actual action-guiding resources in the sense of Neuweg’s (2011) knowledge II (Vogelsang, 2014).

Neuweg (2011) distinguishes three forms of teacher knowledge. Knowledge I represents explicit (professional) knowledge in an "objective sense", acquired in teacher education (ibid., p. 452, see Figure 1). Knowledge II comprises explicit and implicit knowledge in a "subjective sense" of action-guiding mental structures (ibid.). Knowledge III frames knowledge in a sense of "competence", which can be reconstructed by an outside observer through the analysis of action episodes (ibid., see Figure 1).

Figure 1. Forms of teacher knowledge according to Neuweg (2011, p. 453, translated by the authors)

The focus of previous research on professional knowledge of (pre-service) physics teachers in Germany can be classified as research on explicable (theoretical) knowledge I. Fischler (2011) criticises, that in “the current mainstream of research projects on teachers’ professional
development under a cognitive psychological perspective, the ideas of Polanyi, Schön, and of Neuweg […] play only a marginal role” (p. 45). The proposed consideration of the action-guiding mental structures (knowledge II), in particular the investigation of the tacit (Polanyi, 1966) and implicit (Neuweg, 2004) dimension of this knowledge, represents a desideratum in science education research. The implicit knowledge of (pre-service) physics teachers about teaching and learning physics has hardly been investigated so far.

Besides the mainstream research on teacher professionalization under a cognitive psychological perspective, there are approaches that underline the importance of implicit knowledge. Other - in German science education research not widely considered - lines of research, like the structural approach to teacher professionalism, emphasise this desideratum, too. Instead of considering the competencies of professionals, the structural approach focuses on typical “structural” problems of practice (in our case teaching physics) that professionals (in our case pre-service teachers) have to deal with (Bonnet & Hericks, 2014). In the context of the structural approach to teacher professionalism, Helsper (2002) refers to the necessity to consider biographical, experience-based and implicit knowledge as a part of the teacher's knowledge. From this perspective of teacher professionalism, it is rewarding to reconstruct the action-guiding knowledge that structures the practice of teaching physics. Moreover, typical subject specific problems of teaching physics that professional science teachers have to deal with can be examined.

**Methodological conclusions - reconstructive research approach**

The nature of implicit knowledge described by Neuweg (2004) and Polanyi (1966) entails methodological consequences. The first “experience-dependence aspect” indicates that implicit knowledge is conceptualised as experience-based knowledge (Neuweg, 2008, p. 729). From a learning perspective, the experience-dependence suggests that implicit knowledge rather is acquired through socialization than through verbal instruction (Neuweg, 2004). Therefore, a constructivist-structuralist socialization perspective according to Pierre Bourdieu (1977) seems appropriate to understand the nature of implicit knowledge (Hummrich & Kramer, 2017). For this reason, Bourdieu’s (1977) theory of habitus is an important theoretical framework within this study.

The statement “we can know more than we can tell” (Polanyi, 1966, p. 4) summarizes a second characteristic feature of implicit knowledge, called “non-verbalisable aspect” (Neuweg, 2008, p. 727). According to Michael Polanyi’s (1966) knowledge theory (*tacit knowing view*), implicit knowledge is that knowledge “which manifests itself in behavior in a wider sense, that is, in the processes of perception, judgement, anticipation, thought, decision-making or action, and which is not, not completely or not adequately explicable […] by the subject” (Neuweg, 2008, p. 725). From a methodological point of view, the non-verbalisable aspect is not compatible with frequently used subsuming-logical research approaches like quantitative research methods as well as methods of qualitative content analysis. To investigate the implicit knowledge of (pre-service) physics teachers about teaching and learning physics, these often applied methodologies in science education research are not appropriate.
This study considers the identified methodological constraints by using a qualitative-reconstructive research approach. Based on a praxeological approach referring to Karl Mannheim’s (1954) sociology of knowledge, the reconstruction of “social practices in order to reveal their meanings, significances, effects, interdependencies etc.” allows analysing the atheoretical and implicit knowledge, which is embedded in the social practices itself (Herbert & Kraus, 2013, p. 8). This analytic perspective includes a shift from the question what happens to how reality is constituted (ibid.).

A research methodology based on Bourdieu’s (1977) habitus concept and Mannheim’s (1954) sociology of knowledge is the documentary method (Bohnsack, 2010). The documentary method allows the reconstruction of the “implicit knowledge that underlies everyday practice and gives an orientation to habitualized actions” (Bohnsack, Pfaff & Weller, 2010, p. 20). The reconstruction of the implicit knowledge by interpreting social practice (praxeological approach) includes the assumption that implicit knowledge is documented in the way of speaking about the social practice. To investigate the nature of this action-guiding and implicit knowledge, the documentary method with the concept of the “framework of orientation” is suitable to analyse pre-service physics teachers’ narrations about teaching and learning physics. In the following, the term "framework of orientation" refers to the structure of implicit knowledge at a specific point of the individual biography (Helsper, Kramer, Brademann & Ziems, 2007).

In German educational science, only little research using the documentary method is done (Bohnsack, Pfaff & Weller, 2010). Within the German science education community, only a few researchers have successfully applied this praxeological approach. Sander and Höttecke (2016) chose a qualitative approach based on the documentary method and explored the tacit dimensions of pupils’ judgment and decision-making on socio-scientific issues. Krüger (2017) analysed interviews with pupils by using the documentary method to reconstruct pupils’ frameworks of orientations about the diachronic nature of science. Ruhrig and Höttecke (2015) interviewed science teachers to reconstruct science teachers’ orientational frameworks when dealing with uncertain evidence in science teaching.

This study takes place in the context of a practical training. In the perspective of the structural approach to teacher professionalism, practical training is considered appropriate to irritate experienced routines as well as the embedded action-guiding knowledge and orientations (Kramer, 2013). In the course of a practical training, within critical teaching experiences crises can occur. (Implicit) knowledge can be result of a crisis solution and belongs to the sphere of routines which have either already proven themselves or whose probation is expected to be promising (Oevermann, 2006). If this (implicit) knowledge no longer proves to be successful in a new practical experience, a crisis will arise in which new orientations will be developed and proved. An initial transformation of (implicit) knowledge is therefore structurally linked to the condition of crisis or at least critical teaching experiences (Oevermann, 1991). Following this, critical teaching experiences as crises can be important to irritate implicit knowledge and orientations. In Germany, the first opportunity to gain teaching experience in the course of university pre-service teacher education usually is a practical experience called the school-practical training. As seen from a research-oriented perspective, the school-practical training
as such a potentially critical teaching experience offers an opportunity to investigate the student physics teachers’ action-guiding frameworks of orientations and their potential changes in the context of this practical training.

**Research questions**

This case-based study aims at the reconstruction of the student physics teachers’ “frameworks of orientations” in the context of the school-practical training. The following research question will be investigated:

What “frameworks of orientations” concerning teaching and learning physics can be reconstructed?

**RESEARCH DESIGN - CASE-BASED STUDY**

The design of the case-based study is orientated towards the school-practical training (see Figure 2). A special feature of this particular practical training is the close supervision by science education experts. The school-practical training consists of a preparation seminar at the beginning, followed by two individual planning consultations with the science education expert and two physics lessons taught by each student teacher with subsequent feedback from the other student teachers and the science education expert. In addition to this, the student teachers join several hours of classroom observation during the other student teachers physics lessons. At the end, there is a seminar to reflect the experiences made in this practical training (see Figure 2). Usually a period of three months passes between the preparation seminar and the seminar to reflect the experiences.

**Sample**

All participants study at the Martin Luther University of Halle-Wittenberg in order to become physics teachers at secondary schools.

While the sample of the first survey period (summer term 2015) comprises six student physics teachers, the sample of the second survey period (summer term 2016) consists of eleven student physics teachers (see Figure 2). Overall, the sample of 17 participants includes five women and twelve men.

At our University, the school-practical training can be completed twice in the course of university pre-service teacher study. Ten participants attend their first school-practical training (4th semester) and usually have had no practical experience before. Seven participants join the school-practical training for the second time (usually 8th semester) and have previously done longer school internships.

**Narrative interviews**

Two narrative interviews (each lasting about 60 min) were conducted with every participant. The first interview (see Figure 2, blue) takes place after the preparation seminar whereas the second interview (see Figure 2, red) was recorded after the second physics lesson taught by that particular student physics teacher.
In the first interview, the student’s self-made drawing of a physics teaching situation is used as an interview stimulus. The drawing has been made in the course of the preparation seminar in response to the task: “Draw yourself as a physics teacher in a self-chosen teaching situation.” A few days later, the first interview (blue) takes place (see Figure 2). In this interview, the student physics teachers talk about their physics class experiences during their school time and about the physics teaching situation in their own drawing.

In the course of the school-practical training, the second physics lesson was recorded. Scenes taken from this videotaped physics lesson had been used as interview stimuli. The second interview (red) was conducted a few days after that second lesson (see Figure 2). First of all the interviewees talk about their teaching experiences in general. After that, in the sense of stimulated recall interviews (Calderhead, 1981), the students narrate about specific teaching situations in the videotaped lessons.

Each part of the interview starts with open questions to encourage the interviewee to talk about their own experiences (King & Horrocks, 2010). This procedure is recommended assuming that these detailed narrations about the experiences offer the possibility to reconstruct action-guiding orientations (Nohl, 2010). At the end, more structured questions are used (Flick, 2014).
Figure 3. The steps of the documentary method (based on Trautrim, Grant, Cunliffe & Wong, 2012, edited by the authors)

**Documentary method**

For the interpretation and analysis of the interview transcripts, the documentary method is applied. The documentary method allows access to the student physics teachers’ implicit knowledge, which is embedded in the practice of teaching physics itself as well as, which is most important here, in the practice of speaking about teaching physics (Bohnsack, 2010).

Figure 3 illustrates the steps of the documentary method. The essential steps are described in the following (see Fig 3). The data to be analysed are the transcribed narrative interviews. In the first step, the formulating interpretation refers to the analysis of what is said (Nohl, 2010). The researcher examines topic changes and rephrases what is said in the text. In doing so, the investigation of the theoretical knowledge is possible. In addition, this step leads to a distancing and alienation from the material. A second step is necessary to investigate the implicit knowledge beyond.

The reflecting interpretation is the second step to investigate how something is said (ibid.). The researcher explores how the topic is treated. Assuming that how we say something is influenced by our orientations towards the topic, the reconstruction of “how” leads to the deeper meaning of the word and the underlying framework of the topic. By doing so, the exploration of the *modus operandi* and its underlying unconscious mental structures is possible. The researcher has to examine in which framework the topic is dealt with. Therefore, the “framework of orientation is the central subject of documentary interpretation” (Bohnsack, 2010, p. 110).

By these two separate steps, the researcher changes the analytic stance and goes beyond the explicit meaning of communication to examine the implicit dimension of talk (ibid.).

The third step is the comparative analysis (Nohl, 2010) (see Figure 3). The comparative analysis investigates how the different interviewees responded to the same questions and in which diverse ways they tackled the issue. At the end, different typologies can be generated.
EXEMPLARY INTERPRETATION

Of course, no detailed documentary interpretation can be presented in this paper. However, it is possible to give at least a brief superficial insight into the data material and suggest an idea of interpretation. Due to the translation, the original wording and especially its meaning cannot be reproduced exactly. While reading the exemplary interpretation, this should be kept in mind.

Simon - the actor on a theater stage

The short interview transcript (see Figure 4) is part of Simon’s first interview (see Figure 2, blue). Simon’s drawing of himself as a physics teacher in a teaching situation three days before is used as a stimulus in the interview. Simon explicates what was going on in his mind when he created his drawing.

In the following, the steps regarding the interpretation of the teacher’s role in Simon’s narration are shown briefly. The interpretation suggests that Simon can be described as an actor on a theater stage. The first step is the formulating interpretation to analyse what is said: He made the students come closer, so they can see better. He added that he was not standing so impersonally in the front to follow his lesson plan. Instead, he involved his students and asked questions. At this level, aspects of Simon’s explicit theoretical knowledge are pointed out.

Within the next step, the reflecting interpretation is used to analyse how something is said. The analysis of the verbs related to the teacher or the students is very meaningful. Whereas Simon as the teacher “made”, “is standing”, “follow[s] through” and “involves”, the students only “see” and are “made” to “come closer” to the front desk by the teacher (see Figure 4). The analysis suggests that the teacher is more active than the students are. The students are passive and see the experiment on the teacher’s desk. A second valuable strategy is the analysis of the implicit relation between teacher and students. The students have to “come closer”, which implies that there was a distance between teacher and students before (see Figure 4). There seems to be some kind of a natural distance between teacher and students. Moreover, it is beneficial to analyse special words, which are unusually used in a specific context. The use of “in an impersonal way” is very unusual in German language and supports the idea of a natural distance between Simon and his students. A first idea of the interpretation could be that Simon controls the action and the students are passive in this situation as well as there is a kind of natural distance between teacher and learner.

Of course, this is a short transcript and a small data basis. That is why the documentary method requires a more detailed look at many other interview sequences. Due to limited space in this
paper, only one more sequence is presented. This second scene takes place only a few minutes after the excerpt mentioned above. In this second short transcript, Simon explains how his drawing developed (see Figure 5). The first step again is the formulating interpretation of what is said: Simon has drawn the table and the experiment, because this is “what's actually going on in this scene” (see Figure 5). He has drawn the blackboard and himself as a teacher. Simon has drawn the students around the experiment, from an arts perspective the “audience is drawn at the end”, followed by the speech bubbles.

The next step (again) is the reflecting interpretation to develop an idea of Simon’s implicit orientations. The analysis of the order of the drawn items is very useful. Students were drawn almost at the end. They seem to be less important than the table, the experiment, the blackboard and the teacher (see Figure 5). Here again, it is a valuable strategy to analyse striking words. Simon used the word “audience” related to the students. If you think of an “audience”, a conceivable interpretation implies a group of people, which is listening or watching in a passive way. So, the students seem to be entertained by the teacher like an audience by a stage actor.

“Well, I first have drawn the table and the experiment, because this is you know * uhm, what's actually going on in this scene, an experiment which the students see, next I have drawn uhm the blackboard in the background * and uhm me as a teacher, [...] and afterwards I have drawn the students around it, uhm * yes, just from an * arts * perspective, you know, that the * audience is drawn at the end. Yes and at the end I only added the speech bubbles, because I * still had time.” [00:37:37]

Figure 5. Second short part of Simon’s interview transcript. The little stars (*) are short breaks.

Now, there are more hints, which strengthen the first interpretation. According to the documentary method, other interview sequences have to be analysed to prove this interpretation. These two transcripts offer at least an idea of the origin of this interpretation about the teacher’s role in Simon’s narrations. A conceivable interpretation suggests that Simon can be described as an actor on a theater stage. He as teacher seems to be in the center, controls the situation and the attention. The students as learners appears to be a group of people, which is listening or watching like an audience in a passive way. There is some kind of natural distance between teacher and the entertained students. Therefore, Simon can be described by the metaphor of an actor on a theater stage with his students as the audience.

**Outlook**

The previous analysis perspective in the interpretation of Simon’s narrations focuses on the orientations about the teacher’s role. In the context of the comparative analysis (see Figure 3), the investigation of other participants allows to reconstruct different orientations concerning this analysis perspective. By doing so, various contrasting concepts of the teacher’s role can be described. Due to limited space in this paper, only one more example called Niklas will be mentioned. Whereas Simon’s implicit orientation about the teacher’s role can be described as an actor on a theatre stage, Niklas’ role seems to be more like a technician, who keeps the engine (the lesson) going. Niklas as teacher rather not permanent structures, designs or adapts individual teaching situations, because physics lessons seem to follow natural fixed rules and are not very complex. He only intervenes in a physics lesson, when the automatically running lesson get stuck. If Niklas has fixed a problematic situation, the lesson goes on. Like cogs in a
machine, the lesson seems to continue independently and appears to be no longer dependent on Niklas. This second example is intended to illustrate that thru the comparative analysis different implicit orientations about the teacher’s role can be contrasted.

Besides orientations about the teacher’s role, other analysis perspectives like the orientations about the student’s role as well as about the teacher’s handling of students’ questions can be focussed. In addition, it seems to be rewarding to reconstruct the orientations referring to how student physics teachers deal with unexpected situations and with uncertain experimental results. Moreover, their orientations about the role of experiments in teaching physics as well as about the relation between physics and mathematics can be analysed. Furthermore, it appears to be worthwhile to investigate the orientations regarding to how student physics teachers manage complexity of teaching situations and negotiate epistemic authority. By analysing these perspectives, the frameworks of orientations concerning teaching and learning physics can be reconstructed.

In addition to this, a second research question will be addressed in this ongoing study. The transcripts of the second narrative interviews (see Figure 2, red) are used to answer the following research question: To what extent do the “frameworks of orientations” alter during the school-practical training? The second part of the study faces the question whether in the context of the school-practical training an irritation of the action-guiding frameworks of orientations can be reconstructed. The transformation of the individual “framework of orientation” will depend on whether the relatively short practical training provides sufficient opportunities for crisis and coverage (in the sense of Kramer, 2013).

**DISCUSSION**

In summary, our first results indicate that it is rewarding to analyse narrative interview sequences of student physics teachers by using the documentary method. As shown rudimentarily by using the examples Simon and Niklas, it is possible to reconstruct contrasting characteristics in several analytic perspectives, which as whole form different action-guiding frameworks of orientations about teaching and learning physics. The reconstruction of the frameworks of orientations allows access to the underlying implicit knowledge that, so the assumption, primarily structures the teaching of (student) physics teachers. By doing so, insights into the unconsciously implicit knowledge beyond the explicit (professional) knowledge can now be described.

In further research it is necessary to discuss similarities and differences in the theoretical conceptions of implicit knowledge (Neuweg, 2011), tacit knowledge (Polanyi, 1966), a-theoretical knowledge (Mannheim, 1954), incorporated knowledge or habitus (Bourdieu, 1977) and frameworks of orientations (Bohnsack, 2010) in more detail.

Moreover, it also has to be discussed whether the methodological theory behind the documentary method entitles such a longitudinal perspective as used to answer the second research question in this case-based study. This study consequently faces the methodical question whether changes in the “frameworks of orientations” can be reconstructed at all. However, the documentary method seems to be suitable to reconstruct the unconsciously implicit knowledge of student physics teachers about teaching and learning physics.
The implicit knowledge base of (pre-service) science teachers about teaching and learning physics has hardly been investigated so far. For this reason, foundational research has to be done in the field of implicit knowledge of (pre-service) science teachers. Moreover, the assumption that this experience-based implicit knowledge is highly relevant to lesson planning and particularly to classroom acting, has to be investigated and proved in science education research. This may provide an insight into the problem, why teachers who go through science teacher preparation programmes aimed at reform-minded instruction still teach the way they were taught (Abell, 2008).

From a theoretical perspective of the structural approach to teacher professionalism, typical structural subject specific problems of teaching physics that (pre-service) science teachers have to deal with can be examined. Furthermore, this study also underlines Neuweg’s (2011) argumentation regarding the different forms of teacher knowledge. The consideration of his ideas about teacher knowledge lead to a desideratum in the cognitive psychological model of teachers’ professional competence (Baumert & Kunter, 2013). It has to be extended by implicit knowledge as a sociological gained construct. At the moment, we are far away from a satisfactory model of teachers’ complex professional competences, their development as well as their impact and interaction in real teaching situations. For this reason, there is still a lot to be done in this field of science education research.

REFERENCES


Strand 13


MODELING INQUIRY-ORIENTED INSTRUCTION OF BEGINNING SECONDARY SCIENCE TEACHERS

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New national science education standards, the Next Generation Science Standards, in the United States (US) promote inquiry-based instruction through an integrated emphasis on scientific practices and disciplinary content. Thus, it is important for beginning science teachers to reach proficient implementation of reformed teaching practices by the end of their induction phase in order to become effective science teachers. Yet, extant science education research studies on development of beginning teachers’ classroom practices is rare. In this study, we collected data from a longitudinal study of science teachers from two teacher preparation programs - a bachelor’s program with teacher candidates who had less than a major in science and a 14-month master’s degree program with candidates who had at least a major in science - in a large, Midwestern university in the US. These data were used to examine the impact of observation-level and teacher-level characteristics on the likelihood of an observed science lesson being at or below a proficient inquiry level on the Electronic Quality of Inquiry Protocol (EQUIP) instrument. Using observation-level and teacher-level data, two-level hierarchical generalized linear models were built to investigate the relationship between proficiency in inquiry-oriented instruction and the predictor variables at both levels. The parameters estimated in the best fitting model for the data indicate that observation-level variables do not significantly predict the likelihood of an observed science lesson being at or below a proficiency level on the EQUIP scale. Among the teacher-level characteristics, only the teacher preparation program was found to be statistically significant. Controlling for all other variables in the best-fitting model, the likelihood of an observed lesson being taught at the proficient inquiry level was significantly higher for teachers with a stronger science background who graduated from the master’s program. Limitations of the study and future research directions are discussed.

Keywords: secondary science teachers, inquiry-oriented instruction, multilevel generalized linear models

INTRODUCTION

An inquiry-based approach to teaching and learning for science education reform has been promoted in science teacher preparation programs in response to science education policy, research literature, and standards frameworks for teaching science in the US since the early 1990s (NGSS Lead States, 2013; NRC, 1996). Supovitz, Mayer, and Kahle (2000) defined inquiry-oriented instruction as a “student-centered pedagogy that uses purposeful extended investigations set in the context of real-life problems as both a means for increasing student capacities and as a feedback loop for increasing teachers’ insights into student thought processes” (p.332). Teachers need to be well-versed in inquiry-based instruction to promote student learning of science through experiential, active learning that employs scientific practices, or thinking like a scientist (NRC, 2000). Yet, an examination of the literature on the preparation of science teachers reveals that little is known about new teachers’ induction period; we need more research on how secondary science is taught by beginning science teachers (Bianchini,
Unfortunately, even the existing research (e.g., Luft, Firestone, Wong, Ortega, Adams, & Bang, 2011) has failed to improve our understanding of the effectiveness of teacher preparation for the purpose of reformed-based science teaching.

This study sought to add to the knowledge base on teacher preparation and growth over time by modeling how beginning science teachers’ use of inquiry-based science instruction develops throughout the first four years of in-service teaching. Using 455 coded classroom observations of 51 science teachers from two teacher education programs in a large, Midwestern university, the effects of observation-level variables and teacher-level variables on the level of reformed science instruction was examined. Since the data are hierarchically organized (i.e., class observations nested within teachers), multilevel models were used to properly account for the hierarchical (correlated) nesting of data (Hox, 2002; Raudenbush & Bryk, 2002; Snijders & Bosker, 2012).

We specifically investigated the relationship between observation-level variables (i.e., time, level of observed lesson (HS vs. MS), length of observed lesson (block vs. regular), and mode of observation (video vs. real-time)) and teacher-level characteristics (i.e., teacher’s sex and education program) on the likelihood of an observed science lesson being at or below proficient use of inquiry in an observation instrument used to measure the level of inquiry-based instruction. Using observation-level (Level 1) and teacher-level (Level 2) data, hierarchical generalized linear models were built to investigate the relationship between proficiency in inquiry-based instruction and the predictor variables at both levels. The following research questions were posed in this study: (1) What is the likelihood of a science lesson being at or below proficient inquiry instruction levels taught by a typical science teacher? (2) Does the likelihood of being at or below each proficiency level vary across science teachers? (3) What is the relationship between the time of observation and the likelihood of an observed lesson being at or below a proficiency level while controlling for observation- and teacher-level characteristics? and, (4) What is the relationship between the teacher education program and the likelihood of an observed lesson being at or below a proficiency level while controlling for observation- and teacher-level characteristics?

METHOD

We collected data as part of a longitudinal study of beginning science teachers’ professional practice using four cohorts of students who completed an intensive, 14-month graduate teacher certification program at a large, Midwestern university (Lewis, Musson, Pedersen, 2013). The intensive program prepares science majors and professionals to become highly qualified K-12 science teachers. This study builds upon prior exploratory work (Lewis & Musson, 2013) and the specific teacher education program details shown in Table 1 are described and presented elsewhere (Lewis, McCarty, and Musson, 2014; Lewis, Rivero, Musson, Lu, & Lucas, 2016). Science teachers who completed a bachelor’s degree in secondary science education from the same university were also recruited to serve as a comparison group.
Table 1. Comparison of bachelor’s and master’s degree secondary science teacher preparation coursework.

<table>
<thead>
<tr>
<th>Program</th>
<th>Bachelor’s Degree</th>
<th>Master’s Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content Prerequisites</td>
<td><strong>Pre-professional Education Coursework:</strong> Foundations of Education; Adolescent Psychology + Practicum</td>
<td><strong>Prior to Acceptance:</strong> Undergraduate major in one area of science; some MA students have graduate-level coursework or advanced degree</td>
</tr>
<tr>
<td></td>
<td><strong>MA Coursework:</strong> Reading in the Content Area (Cohort 3-7); History and Nature of Science (Cohorts 1-2 only); Teaching ELLs in the Content Area; Intro to Educational Research; Curriculum Theory; Teacher Action Research Project</td>
<td></td>
</tr>
<tr>
<td>Common Coursework</td>
<td>Accommodating Exceptional Learners; Adolescent Development / Human Cognition; Science Teaching Methods (two classes, each with a practicum experience); Multicultural Education / Pluralistic Society</td>
<td></td>
</tr>
<tr>
<td>Resulting Degree</td>
<td>BA Secondary Science Education, with State Content Area Teaching Endorsement</td>
<td>MA with Emphasis in Science Teaching, with State Content Area Teaching Endorsement</td>
</tr>
</tbody>
</table>

Over four years, five researchers observed and coded lessons using the Electronic Quality of Inquiry Protocol (EQUIP) instrument (Marshall, Horton, Smart, & Llewellyn, 2008) to measure the level of inquiry-based instruction in middle and high school science classrooms. By design, every teacher participant was targeted to be observed up to six times within one academic year. The validated EQUIP instrument has 19 items; each item employs a scale of 1 to 4 to describe the level of inquiry-oriented instruction in an observed science lesson. Level 1, the lowest level in the scale, corresponds to “pre-inquiry” (a teacher-centered classroom, i.e., lecture-based) and Level 4, the highest level, to “exemplary inquiry” (an open-ended and engaging student-centered classroom). For instance, in terms of instructional strategies, a teacher may be observed to “predominantly lecture to cover content” (Level 1) or “occasionally lecture but used classroom activities that promoted strong conceptual understanding” (Level 4). In this study, the EQUIP score for an observed lesson corresponds to the median score for all the 19 items in the instrument. We assume that the four-item outcomes form an underlying latent variable that is inquiry-oriented instruction behavior.

The data has a two-level structure with a set of classroom observations conducted over time that are nested within teachers. The variation of outcomes within subjects over time is at the lowest level (Level 1) and the variation of the underlying mean outcomes between subjects is at level two (Singer, 1998). Since the data gathered via the EQUIP instrument are categorical, ordinal data, multilevel generalized linear models (GLM) were used in modeling the data. The data are multinomial, violating standard linear mixed model assumptions such as normality and homogeneity of variance (Hox, 2002). In contrast with hierarchical linear models (HLM) that
has continuous, approximately normally distributed outcomes, GLMs are appropriate for many kinds of non-normally distributed outcomes (e.g., binary, unordered categorical, ordered categorical, counts, censored, zero-inflated, and continuous but skewed data). The models were estimated and interpreted using SAS PROC GLIMMIX. The variables included in the models are shown in Table 2.

Table 2. Frequency count distribution of science lesson observations and teachers.

<table>
<thead>
<tr>
<th>Variables Included in the Models</th>
<th>Science Lesson Observations ((n=455))</th>
<th>Teachers ((J=51))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observation-level (Level 1)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 1</td>
<td>174 (38%)</td>
<td></td>
</tr>
<tr>
<td>Year 2</td>
<td>149 (33%)</td>
<td></td>
</tr>
<tr>
<td>Year 3</td>
<td>100 (22%)</td>
<td></td>
</tr>
<tr>
<td>Year 4</td>
<td>32 (7%)</td>
<td></td>
</tr>
<tr>
<td>Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High School</td>
<td>350 (77%)</td>
<td></td>
</tr>
<tr>
<td>Middle School</td>
<td>105 (23%)</td>
<td></td>
</tr>
<tr>
<td>Length of Observed Lesson</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block (90 minutes)</td>
<td>111 (24%)</td>
<td></td>
</tr>
<tr>
<td>Regular (50 minutes)</td>
<td>344 (76%)</td>
<td></td>
</tr>
<tr>
<td>Mode of Observation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td>78 (17%)</td>
<td></td>
</tr>
<tr>
<td>Real-time</td>
<td>377 (83%)</td>
<td></td>
</tr>
<tr>
<td><strong>Teacher-level (Level 2)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>31 (61%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>20 (39%)</td>
<td></td>
</tr>
<tr>
<td>Teacher Education Program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bachelor’s program</td>
<td>13 (25%)</td>
<td></td>
</tr>
<tr>
<td>Master’s program</td>
<td>38 (75%)</td>
<td></td>
</tr>
</tbody>
</table>

At the observation level, the variables included in the model are time of the observation in years, the level of the observed lesson (i.e., high school vs. middle school), the length of the observed lesson (i.e., block vs. regular), and mode of the observation (video vs. real-time). In this study, the time of observation refers to the post-program year of teaching when the observation was done. A lesson could be observed in the high school level (Grades 9-12) or middle school (Grades 7-8). It could be designed for a block period (90 minutes) or a regular period (50 minute). The mode of observation could be through the use of a video sent by a participating teacher or via a real-time observation, which could be done in-person or through a teleconferencing software such as Skype or FaceTime. Program and sex were included in the models as teacher-level variables. The program refers to the teacher education program completed by the teacher (i.e., bachelor’s degree vs. master’s degree in science teaching). Both teacher education programs are offered in the same college of the university and graduates from both programs were endorsed to teach science.
The outcome variables from the EQUIP scale are polytomous, ordinal-type. In SAS PROC GLIMMIX, a multinomial distribution and a cumulative logit link were used to allow for the computation of the cumulative odds for each EQUIP category (i.e., 1=Pre-inquiry, 2=Developing inquiry, 3=Proficient inquiry, 4=Exemplary inquiry), or the odds that an outcome would be at most, in that category (O’Connell, Goldstein, Rogers, & Peng, 2008). In this study, we were interested in the probability of being at or below a proficiency level defined in the EQUIP scale and in the influence of observation (Level-1) and teacher (Level-2) characteristics on this probability for each category. The conceptualization of the models in a generalized linear framework is represented by a set of equations in the next section.

RESULTS

Three proportional odds logistic models were estimated with the EQUIP data. In all of the models, the default convergence criterion (GCONV=1E-8) was satisfied. Table 3 shows the distribution of EQUIP scores for all observations from the response profile generated by SAS PROC GLIMMIX. The scores were distributed in the first three categories of the EQUIP scale, but not the fourth.

<table>
<thead>
<tr>
<th>EQUIP category</th>
<th>Frequency (n (%))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – Pre-inquiry</td>
<td>85 (19%)</td>
</tr>
<tr>
<td>2 – Developing inquiry</td>
<td>291 (64%)</td>
</tr>
<tr>
<td>3 – Proficient inquiry</td>
<td>79 (17%)</td>
</tr>
<tr>
<td>4 – Exemplary inquiry</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

The ordinal empty means, random intercept only model, is represented by two logit-based model equations (1). When dealing with polytomous outcomes, multiple logits are simultaneously estimated (M-1 logits, where M=the number of outcome categories). For the case of three outcomes as shown in Table 3, two logits are simultaneously estimated by the model.

\[
\eta_{1ij} = \log \left( \frac{p(R_{ij}=1)}{1-p(R_{ij}=1)} \right) = \gamma_{001} + U_{0j}; \eta_{2ij} = \log \left( \frac{p(R_{ij}=2)}{1-p(R_{ij}=2)} \right) = \gamma_{002} + U_{0j}
\]

(1)

The two intercepts in the model represent the log odds of an observation in a typical teacher being at or below the first two levels of inquiry-based instruction (i.e., pre-inquiry and developing inquiry) in the EQUIP scale. These log odds can be used to calculate the probabilities of being at or below each proficiency level by using the following equation (2) wherein \( \phi_{ij} \) stands for cumulative probability.

\[
\phi_{ij} = \frac{e^{\eta_{ij}}}{1+e^{\eta_{ij}}}
\]

(2)

Parameter estimates for Model 1 are shown in Table 4. Using the model equations, the log odds of being at the pre-inquiry level for an observed science lesson in a typical teacher is -1.58, resulting in a probability of 0.17. Similarly, the log odds of being at or below the developing inquiry level is 1.98, resulting in a cumulative probability of 0.88. Finally, the cumulative
probability of being at or below the proficient inquiry level adds to 1. To calculate the actual probabilities of being at each level, cumulative probabilities of adjacent categories are subtracted from one another. As a result, the predicted probability of an observed lesson being at the pre-inquiry level for a typical teacher is 0.17, 0.71 at the developing inquiry level, and 0.12 at the proficient inquiry level.

Table 4. Estimates for two-level generalized linear models of inquiry-based instruction.

<table>
<thead>
<tr>
<th>Fixed Effects</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Unconditional model)</td>
<td>(Model 1 + Observation-level fixed effects)</td>
<td>(Model 2 + Teacher-level fixed effects)</td>
</tr>
<tr>
<td>Intercept 1 (Pre-Inquiry)</td>
<td>-1.58* (0.19)</td>
<td>-1.34* (0.41)</td>
<td>-0.21 (0.52)</td>
</tr>
<tr>
<td>Intercept 2 (Developing Inquiry)</td>
<td>1.98* (0.21)</td>
<td>2.24* (0.45)</td>
<td>3.37* (0.56)</td>
</tr>
<tr>
<td>Time (in years)</td>
<td>-0.18 (0.12)</td>
<td>-0.20 (0.11)</td>
<td></td>
</tr>
<tr>
<td>Level (HS=1, MS=0)</td>
<td>0.11 (0.39)</td>
<td>0.32 (0.35)</td>
<td></td>
</tr>
<tr>
<td>Length of Observed Lesson (Block=1, Regular=0)</td>
<td>-0.48 (0.35)</td>
<td>-0.42 (0.32)</td>
<td></td>
</tr>
<tr>
<td>Mode of Observation (Video=1, Real-time=0)</td>
<td>0.15 (0.36)</td>
<td>0.14 (0.33)</td>
<td></td>
</tr>
<tr>
<td>Sex (Female=1, Male=0)</td>
<td></td>
<td></td>
<td>-0.12 (0.30)</td>
</tr>
<tr>
<td>Teacher Education Program (MAst = 1, BSEd = 0)</td>
<td></td>
<td></td>
<td>-1.51* (0.38)</td>
</tr>
</tbody>
</table>

| Error Variance                     |                              |                              |                                  |
| Intercept                          | 0.92* (0.34)                 | 0.89* (0.36)                 | 0.51* (0.24)                      |

| Model Fit                          |                              |                              |                                  |
| -2 Log Likelihood                  | 787.04                       | 780.92                       | 767.00**                        |

Note:*p<.05; **=likelihood ratio test significant; Values based on SAS PROC GLIMMIX. Entries show parameter estimates with standard errors in parentheses; Estimation Method=Laplace.

\(^a\)Best fitting model

The empty, unconditional model with no predictors provides an overall estimate of the intraclass correlation (i.e. ICC = \(\tau_{00} / (\tau_{00} + 3.29) = 0.92 / (0.92 + 3.29) = 0.22\)). In multilevel GLMs, there is assumed to be no error at Level-1, therefore, a modification was needed to calculate the ICC. This modification assumes that the outcome originates from an unknown latent continuous variable with a Level-1 residual that follows a logistic distribution with a
mean of 0 and a variance of 3.29 (Snijders & Bosker, 2012). Therefore, 3.29 was used as the Level-1 error variance in calculating the ICC. The ICC indicates that approximately 22% of the variability of being at or below a proficiency level in the EQUIP scale is accounted for by the teachers in the study, leaving 78% of the variability to be accounted for by the observations or other unknown factors. However, it should be noted that the ICC is somewhat problematic to interpret due to non-constant residual variance. Model 1 also indicates that there is a statistically significant amount of variability in the log odds of being at or below a proficiency level between teachers \(\tau_{00} = 0.92; z(50) = 2.75, p < .05\).

Model 2 includes the fixed effect estimates for observation-level variables (i.e., time, level, the length of the observed lesson, and mode of observation). The fixed effect estimates illustrate the relationship between an observation-level characteristic and the log odds of being at or below a proficiency level in the EQUIP scale. The value of each fixed effect estimate remains constant across logits although there are two estimates for the intercepts. This means that the fixed effects are assumed to be the same for each cumulative odds ratio. Model 3 was similar to Model 2 with the addition of teacher-level fixed effects. Table 4 presents a summary of the results and estimates for all three models considered in the model-building process as well as model fit information.

We compared the three models in terms of fit in order to decide the best fitting model for these data. Based on the changes in the -2 Log Likelihood between nested models, Model 3 is the best fitting model for these data; it fits significantly better than Model 2 \(\chi^2(2) = 13.92, p < .001\) and also better than Model 1 \(\chi^2(6) = 6.12, p < .05\). The addition of teacher-level variables improved model fit.

**DISCUSSION**

To address our research questions, the parameter estimates from the best-fitting model (Model 3) were used. The first research question requires finding the likelihood of being at or below each proficiency level in inquiry-based instruction for an observed lesson taught by a typical science teacher. Using Model 3, we found that the probability of an observed lesson being at the pre-inquiry level for a typical teacher was 0.45; 0.52 at the developing inquiry level, and 0.03 at the proficient inquiry level. These predicted probabilities are interpreted based upon all variables in the model being equal to zero. As a follow-up, in our second research question, we were interested to know if the likelihood of being at or below each proficiency level varied across science teachers. Looking at the the error variance estimate for the random intercept, Model 3 indicates that there is a statistically significant amount of variability in the log odds of being at or below a proficiency level between teachers \(\tau_{00} = 0.51; z(48) = 2.08, p < .05\). The probability of being at or below a proficiency level varies considerably across teachers.

For our third research question, we found that there was no statistically significant relationship between the time of observation and the likelihood of an observed lesson being at or below a proficiency level while controlling for observation- and teacher-level characteristics. The final, fourth research question refers to the relationship between teachers’ education program and the likelihood of an observed lesson being at or below a proficiency level while controlling for observation- and teacher-level characteristics. To answer this question, we used the parameter
estimate for teacher education program ($b=-1.51$, $p<.05$), which indicated a negative, statistically significant relationship between teachers’ education program and the likelihood of an observed lesson being at or below a proficiency level. Specifically, as we move from a lesson taught by a science teacher with a bachelor’s degree in secondary science education to a lesson taught by a teacher with a master’s degree with an undergraduate degree in an area of science, the likelihood of an observed lesson being at the proficient level increases.

To make a more meaningful interpretation, we calculated the corresponding predicted probabilities for observed lessons taught by teachers in different preparation programs and controlled for other observation- and teacher-level characteristics. Using Model 3 parameter estimates in Table 3, the log odds of an observed lesson taught by a teacher graduate of the master’s degree program (program=1) being at or below the pre-inquiry level is 0.18, resulting in a probability of 0.15. Similarly, the log odds of being at or below the developing inquiry level is 6.43, resulting in a cumulative probability of 0.87. From these values, we found that the probability of an observed lesson being at the pre-inquiry level for a graduate of the master’s program is 0.15; 0.71 at the developing inquiry level, and 0.13 at the proficient inquiry level. These predicted probabilities are interpreted for the case of program=1 and all other variables in the model being equal to zero. This means that the predicted probability of an observed lesson (at the beginning of Year 1, taught in middle school on a regular schedule by a male teacher with a master’s degree, and observed in-person) to be at the pre-inquiry level is 0.15. For a teacher with a bachelor’s degree, the predicted probability of an observed lesson being at the lowest proficiency level is 0.45. Thus, controlling for all other observation- and teacher-level characteristics, an observed lesson taught by a graduate of the bachelor’s program has a higher probability of being at the lowest proficiency level in the EQUIP scale compared to a lesson taught by a graduate of the master’s program. In other words, the master’s level teachers enacted reformed-based science teaching more frequently.

Figure 1 compares teachers by teacher education program in terms of the change in probability of EQUIP score outcomes across years of teaching. For both groups, the likelihood of an observed science lesson to be teacher-centered or being in the lowest level of the EQUIP scale decreases as the teachers gain more experience. However, teachers from the master’s program start at a higher level; they are more likely to create and implement more inquiry-based lessons and continue to improve as they gain teaching experience. Thus, teachers with a master’s degree in science teaching appear to show accelerated growth in the in the used of inquiry-based teaching practices compared to teachers with only a bachelor’s degree in secondary education with science endorsement.

These findings imply that differences in teacher education affect the long-term development of inquiry practices in the first four years of teaching. However, there are several limitations that need to be taken into account when interpreting these results. Adding new observation data from the fifth year of the longitudinal study could increase the precision of the models. It could also allow us to better understand and describe the growth of beginning teachers since the first 5 years are commonly considered to encompass the notion of beginning teaching (Loughran, 2014). The findings regarding the particular ramifications of the teacher education programs are also context-dependent; the results may only be transferable to similar program designs.
Also, several background variables such as age, science credits hours, and work experience could be contributing to differences in the performance of inquiry-oriented science teaching. Finally, there were several factors that were not considered in building the models that may have a significant impact on the enactment of inquiry-based instruction such as size and diversity (i.e., racial diversity and socioeconomic status) of the students in the observed lessons, the amount of in-service teacher professional development activities, subject matter knowledge, and teacher beliefs and self-efficacy in teaching.

Although it appears that lessons taught by graduates of the bachelor’s program have a higher likelihood of being in the lowest level of the EQUIP scale corresponding to a more teacher-centered approach, it should be noted that the features of the two teacher education programs were not systematically investigated.

Teachers from the master’s program could have a stronger science content knowledge due to their completed science degree prior to taking a graduate-level master’s program on teaching. Also, they were older and may have worked as a science professional which may have led to the development and mastery of science process skills that are important in the teaching of science as well as their understanding of the nature of science. More studies that explore how
the master’s level program accelerates new science teachers’ growth would be productive (Lewis, Rivero, Musson, Lu, & Lucas, 2015).

In this exploratory study, the variables were entered in aggregate into the models. Thus, the modeling process did not consider specific predictors alone and as a result there may be possible interactions within the models. More complex hierarchical models that use longitudinal data on teachers, schools, and school districts are needed to capture the intricacies of teacher change.

CONCLUSIONS

This study examined the effect of observation-level variables (i.e., time, lesson (HS vs. MS), length of observed lesson (block vs. regular) and mode of observation (video vs real-time)) and teacher-level characteristics (i.e., teacher’s sex and education program) on the likelihood of an observed science lesson being at or below a proficiency level in the EQUIP scale. Using observation-level (Level 1) and teacher-level (Level 2) data, we built two-level hierarchical generalized models to investigate the relationship between proficiency in inquiry-based instruction and the predictor variables at both levels. The parameters estimated in the best fitting model for the data indicate that observation-level variables do not significantly impact the likelihood of an observed science lesson being at or below a proficiency level in the EQUIP scale. Among the teacher-level characteristics, only the teacher preparation program was found to be statistically significant. Controlling for all other variables in the full model, the likelihood of an observed lesson being at the lowest proficiency level is significantly lower for teachers who graduated from the master’s program. These findings imply that differences in teacher education preparation determine the future development of reformed science teaching. Future research that identifies aspects of instruction (e.g., discourse, assessment, instructional strategies, curriculum design) that display the least growth during the induction period would be useful in designing and improving programs for teacher professional development. Finally, it is important to build other models to explore which variables account for the unexplained variance in the enacted teaching practices of beginning secondary science teachers.

ACKNOWLEDGEMENTS

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NGSS Lead States (2013). Next generation science standards: For states, By states. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.


The purpose of this study was to investigate the effect of the active participated material development process on the Prospective Science Teacher (PST)s’ astronomy self-efficacy beliefs. The study was carried out using mixed-methods research. PSTs’ astronomy self-efficacy beliefs were examined using qualitative and quantitative data in detail. The study group was composed of 27 junior PSTs from a State University from the West Black Sea area in Turkey. The study group were determined purposively. The data collecting tools used were the Astronomy Self-Efficacy Belief (ASEB) scale and reflective journals written by PSTs. The ASEB scale was applied twice to the PSTs, at the beginning of the active participated material development process and at the end of the process. The reflective journals were written by PSTs during the material development process. The quantitative data obtained from the ASEB scale were analysed with paired t-test in the SPSS 23.00 statistical packet program. The qualitative data obtained from journals were analysed according to content analysis. Qualitative data were coded and themes and sub-themes created from these codes. Providing validity of the qualitative data codes were created by two researchers in the consensus. Also the percentage of consistency between two researchers' coding were calculated for providing reliability of the qualitative data. Quantitative results revealed that a significant difference was observed in favour of the post-test average scores. Additionally, there was significant difference in favour of the post-test average scores of the PSTs’ personal science teaching efficacy belief; however, there was not a significant difference between pre-test and post-test average scores of the PSTs’ personal science teaching outcome expectancies. Analysis of the journals revealed three inter-related sub-themes affecting PSTs’ astronomy self-efficacy beliefs, labelled as: Technological knowledge, Pedagogical knowledge and Content knowledge. These sub-themes describe participants’ views of their quality PST training and thinking about active participated material development process. Educational outcomes were discussed in relationship with study findings.

Keywords: astronomy education, astronomy self-efficacy beliefs, prospective science teacher education.

INTRODUCTION

Teachers’ self-efficacy beliefs have a crucial role in preparing teachers for effectively overcoming the challenges posed by reform initiatives to prioritize quality science teaching in the elementary classrooms, and in the implementation of necessary reform-based pedagogical strategies (Smith & Southerland, 2007; Thomson, DiFrancesca, Carrier & Lee, 2017). It is important that teachers feel capable of successfully implementing reform strategies in their classroom. Teachers' personal efficacy beliefs affected their job satisfaction and students' academic achievement (Caprara, Barbaranelli, Steca & Malone, 2006). Teachers' self-efficacy beliefs affect the quality of the learning environments they prepare to promote the level of academic progress their students’ achieve (Bandura, 1993). Innovative strategies globally in
science programs have shown up in elementary science programs in Turkey, too. One of the emphasized topics in the innovative science instructional program is astronomy. In other words, astronomy is at the forefront in the elementary science program in Turkey (URL-1, 2018). In conjunction with this, is the belief that improving of the science teachers’ astronomy self-efficacy beliefs are very important. So it is seen as a need to make efforts to improve the astronomy self-efficacy beliefs of the prospective science teachers during the undergraduate education process. There are studies to determine PSTs’ astronomy self-efficacy beliefs in the literature (Gunes, 2010), but studies on efforts to develop PSTs’ astronomy self-efficacy beliefs are limited in the literature (Ceylan & Bozkurt, 2017). Also it was determined that prospective teachers (Trumper, 2001; Frede, 2006; Gürbüz, 2016) and even teachers have alternative concepts related to astronomy topics and concepts (Brunsell & Marcks, 2004; Kikas, 2004). Teachers are able to reflect alternative concepts to their students (Bradley & Mosimege, 1998; Yağbasan & Gülcicek, 2003). It is very important and necessary for the teachers to have adequate knowledge of the field in order to improve the conceptual meaning of the students in a clear way from the alternative concepts and to educate them equipped with the knowledge of the field during their undergraduate education. A teacher with sufficient scientific knowledge may be more successful at solving alternative concepts that students have. However, it emerges that science teachers need to be aware of some specific teaching techniques and methods in order to help their students to remedy alternative concepts (Küçüközer, 2004). At this point, it is believed that the prospective teachers should have knowledge about the special teaching methods and techniques and they should apply them for these methods and techniques. Cerrah-Özsevgeç (2007) found that active participated material development process was effective in completing the lack of knowledge and remedying alternative concepts of prospective biology teachers. Cerrah-Özsevgeç, Ayas and Özsevgeç (2010) determined that handbook preparation process was effective in prospective biology teachers' understanding of the endocrine system. However, the effect of the active participated material development process on prospective science teachers' astronomy self-efficacy beliefs is not known. The aim of this study was to investigate the effect of the active participated material development process on prospective science teachers' astronomy self-efficacy beliefs.

**METHOD**

The study was carried out according to mixed-research method. In this study both quantitative (scale) and qualitative (journals) data were collected, and the study employed was a sequential explanatory mixed-methods design (Creswell et al. 2003), which consisted of collecting quantitative data and then qualitative data to help explain or elaborate on the quantitative results. According to a sequential explanatory design, collection and analysis of quantitative data was followed by the collection and analysis of qualitative data, with priority being given to the quantitative data; the qualitative data help further explain the results from the quantitative data and analysis. Participants’ astronomy self-efficacy beliefs were examined using both qualitative and quantitative data in detail. The participants of this study were 27 third grade Prospective Science Teacher (PST)s from a state university at west Black Sea area in Turkey. The data collecting tools used were the Astronomy Self-Efficacy Belief (ASEB) scale and reflective journals written by PSTs. ASEB scale was developed by Riggs and Enochs (1990)
and translated into Turkish by Ozkan, Tekkaya and Cakiroglu (2002). The scale is a quintet Likert type scale composed of 23 items and two sub-factors which are Personal Science Teaching Efficacy Belief (PSTEB) and Science Teaching Outcome Expectancy (STOE) (cited in Gunes, 2010). Gunes (2010) calculated Cronbach alpha reliability coefficient of PSTEB sub-factor as .87 and Cronbach alpha reliability coefficient of the STOE sub-factor as .78. In this study the calculated Cronbach alpha reliability coefficient of ASEB scale was .77, Cronbach alpha reliability coefficient of PSTEB sub-factor was .82 and Cronbach alpha reliability coefficient of the STOE sub-factor was .70. These findings showed that the ASEB scale had reliability. The ASEB scale was applied to participants twice, at the beginning of the active participated material development process as pre-test and at the end of the process as post-test. Participants wrote reflective journals during the active participated material development process.

The quantitative data obtained from the ASEB scale were analysed with paired samples t-test in the SPSS 23.00 statistical packet program. The qualitative data obtained from reflective journals were analysed according to content analysis. Data were coded and themes and sub-themes created from codes. Providing validity of the qualitative data codes were created by two researchers in the consensus. Also the percentage of consistency between two researchers' coding were calculated for providing reliability of the qualitative data. The percentage of consistency between two researchers' coding were calculated as 90%. Quotes from participants’ statements in their reflective journals were presented for providing of the qualitative data validity.

The PSTs have studied instructional technologies and material development courses in the third grade at the undergraduate program. They learn information such as the importance of material development, material development principles, and kinds of instructional materials as theoretical lectures. And they prepare lesson plans, working sheets, graphic materials (concept, knowledge, mind map), concept cartoons, and develop three-dimensional materials.

In this study the PSTs prepared concept, knowledge, mind maps and concept cartoons according to gains of the “The Solar System and Beyond” unit at the elementary school 7th grade science curriculum. This unit consists of celestial bodies (3 gains), solar system (2 gains), and space researches (4 gains) issues (MNE, 2013). In the future the PSTs will teach astronomy issues elementary school 7th grade students according to these gains. The data collecting process and teaching sequence through ten weeks of this study is presented in Figure 1. Examples of concept, knowledge, mind maps and concept cartoons of the PSTs are shown in Appendix 1.

**FINDINGS**

Findings obtained from the astronomy self-efficacy belief scale are shown in Table 1.

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>X̄</th>
<th>S</th>
<th>sd</th>
<th>t</th>
<th>p</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>27</td>
<td>3.52</td>
<td>.343</td>
<td>26</td>
<td>-2.217</td>
<td>.036</td>
<td>.086</td>
</tr>
<tr>
<td>Post-test</td>
<td>27</td>
<td>3.67</td>
<td>.366</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1755
<table>
<thead>
<tr>
<th>Week</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. week</td>
<td></td>
</tr>
</tbody>
</table>
- Astronomy Self Efficacy Belief (ASEB) scale were applied as pre-test (1 hour).
- PSTs were informed about reflective journal writing (2 hours).
- Importance of the teaching technology and material development were discussed in the teaching (1 hour).  

2. week |  
- Teaching technologies and communication were discussed (2 hours).
- Teaching tools were introduced by lecturer (2 hours).

3. week |  
- Kinds of teaching materials was introduced (2+2 hours).

4. week |  
- Teacher qualities were discussed in Teaching technologies and material development process (2 hours).
- The use of computers and computers in education was discussed (1 hour).
- How to use of the web 2.0 tools, which are map tools (glify, mindmeister, text2mindmap) and concept cartoons tools (Pixton, Tondoo, storyboardthat), were discussed as instructional purposes. PSTs learned and practised web 2.0 tools computer lessons 1 and 2 in second grade (1 hour).

5. week |  
- Work sheet was introduced and sample applications were made. PSTs prepared their work sheets related science issue which they determined form elementary school science curriculum (2 hours)
- PSTs prepared lesson plans. (2 hours).

6. week |  
- The PSTs draw their concept maps on the extracurricular time.
- The PSTs mailed concept maps to lecturer.
- The PSTs’ concept maps were examined and feedback was given to them by lecturer.
- PSTs wrote reflective journals about their feelings, what they learn, things they cannot learn in drawing concept map process.

7. week |  
- Hierarchical and non-hierarchical concept map was introduced to PSTs and PSTs draw concept maps guided by lecturer. (2+2 hours)
- Gains in the “The Solar System and Beyond” unit at the elementary school 7th grade science curriculum were given to the PSTs.
- Lecturer assigned to the PSTs the task of drawing concept maps containing all the gains until next week.
- Lecturer wanted reflective journal writing of the PSTs.

8. week |  
- Knowledge map was introduced to PSTs and PSTs draw knowledge maps guided by lecturer. (2+2 hours)
- Gains in the “The Solar System and Beyond” unit at the elementary school 7th grade science curriculum were given to the PSTs.
- Lecturer assigned to the PSTs the task of drawing knowledge maps containing all the gains until next week.
- Lecturer wanted reflective journal writing of the PSTs.

9. week |  
- Mind map was introduced to PSTs and PSTs draw mind maps guided by lecturer. (2+2 hours)
- Gains in the “The Solar System and Beyond” unit at the elementary school 7th grade science curriculum were given to the PSTs.
- Lecturer assigned to the PSTs the task of drawing mind maps containing all the gains until next week.
- Lecturer wanted reflective journal writing of the PSTs.

10. week |  
- Concept cartoon was introduced to PSTs and PSTs prepared concept cartoons guided by lecturer. (2+2 hours)
- Gains in the “The Solar System and Beyond” unit at the elementary school 7th grade science curriculum were given to the PSTs.
- Lecturer assigned to the PSTs the task of preparing concept cartoons containing all the gains until next week.
- Lecturer wanted reflective journal writing of the PSTs.

- The PSTs prepared their concept cartoons on the extracurricular time.
- The PSTs mailed concept cartoons to lecturer.
- The PSTs’ concept cartoons were examined and feedback was given to them by lecturer.
- PSTs wrote reflective journals about their feelings, what they learn, things they cannot learn in the preparing concept cartoons process.

- Lecturer received the final version of the concept, knowledge, mind maps and concept cartoons from the PSTs.
- Astronomy Self-Efficacy Belief (ASEB) scale were applied as post-test (1 hour).
- Lecturer received the reflective journals from the PSTs.

**Figure 1. The data collecting process and teaching sequence through ten weeks of this study**

[Image of Figure 1: Strand 13, showing the timeline of activities and lectures over ten weeks.]

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When Table 1 was considered that there was significant difference between the pre-test and post-test points \( t_{(26)} = -2.217, p < .05 \). The average of the pre-test and the post-test show a significant difference in favour of the post-test. When was examined the pre-test and post-test score averages, it was observed that the pre-test score average of participants is \( \bar{X} = 3.52 \); whereas the post-test score average is \( \bar{X} = 3.67 \). Besides, \( \eta^2 \) effect values of astronomy self-efficacy belief scale scores of the participants are medium effect values, which support this condition.

According to Table 2, when the pre-test and post-test average scores of PSTs’ personal science teaching efficacy belief were compared using the paired sample t test, a statistically significant difference was observed in favour of the post-test personal science teaching efficacy belief sub-factor average scores of the working group \( t_{(20)} = -4.491, p < .05 \). When the pre-test and post-test personal science teaching efficacy belief sub-factor score averages were examined, it was observed that the pre-test score average of participants is \( \bar{X} = 3.42 \), whereas the post-test score average is \( \bar{X} = 3.72 \). Besides, \( \eta^2 \) effect values of astronomy self-efficacy belief scale scores of the participants were high effect values, which support this condition. Also when the pre-test and post-test average scores of participants’ science teaching outcome expectancy were compared using the dependent t test, a statistically significant difference wasn’t observed in between pre-test and post-test science teaching outcome expectancy sub-factor average scores of the PSTs \( t_{(25)} = -.680, p > .05 \). When the pre-test and post-test science teaching outcome expectancy sub-factor score averages were examined, it was observed that the pre-test score average of participants is \( \bar{X} = 3.63 \), and the post-test score average is \( \bar{X} = 3.69 \). Besides, \( \eta^2 \) effect values of astronomy self-efficacy belief scale scores of the participants were small effect values, which support this condition.

**Table 2. The statistic findings obtained from paired sample t test of the personal science teaching efficacy belief (PSTEB) and the science teaching outcome expectancy (STOE) sub-factors of the astronomy self-efficacy belief scale**

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>( \bar{X} )</th>
<th>S</th>
<th>sd</th>
<th>t</th>
<th>p</th>
<th>( \eta^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest PSTEB</td>
<td>21</td>
<td>3.42</td>
<td>.486</td>
<td>20</td>
<td>-4.491</td>
<td>.000</td>
<td>.335</td>
</tr>
<tr>
<td>Posttest PSTEB</td>
<td>21</td>
<td>3.72</td>
<td>.427</td>
<td>25</td>
<td>-.680</td>
<td>.503</td>
<td>.009</td>
</tr>
<tr>
<td>Pretest STOE</td>
<td>26</td>
<td>3.63</td>
<td>.376</td>
<td>25</td>
<td>.503</td>
<td>.009</td>
<td>.009</td>
</tr>
<tr>
<td>Posttest STOE</td>
<td>26</td>
<td>3.69</td>
<td>.443</td>
<td>25</td>
<td>.503</td>
<td>.009</td>
<td>.009</td>
</tr>
</tbody>
</table>

Findings obtained from the reflective journals were presented in Figure 2. When Figure 2 was examined, it is seen that PSTs stated their ideas about the active participated material development process at the content knowledge (CK), pedagogical knowledge (PK), technological knowledge (TK) sub-themes in the Technological Pedagogical Content Knowledge (TPCK) themes.

Quoted from the statements in the reflective journals of two PSTs for the TK sub-theme:

“We decided to use Gliffy program as the group when preparing the concept map. But it was a bit difficult for me to use this program. Because, I’ve never used this program before. Then I learned to use the program (1)”

“...Preparing the concept map is quite difficult in the technological environment. However, hand-crafted maps provide convenience even if they take time (5)”.
Quoted from the statements in the reflective journals of three PSTs for the CK sub-theme:

“I realized that I have many misconceptions when I prepared the concept map. After I prepared the map, I removed my misconceptions (1)”.  

“...I learned that the comet I know as a star is not a star... (3)”.  

Quoted from the statements in the reflective journals of three PSTs for the PK sub-theme:

“I learned to take into consideration students' thoughts while preparing concept cartoons. I learned what misconceptions students might have... (1)”  

“I learned to prepare maps for gains ...(5)”.  

“It helped me to understand students’ misconceptions. We will take into consideration these misconceptions in their mind as we teach our students in the future when we are teachers. Concept cartoons are mostly based on misconceptions. But the information on other maps is heavily weighted. The pupil teaches more (11)”.

Figure 2. Data obtained from participants’ views about graphical materials preparing process  

“...I had some problems while I was preparing maps due to my lack of content knowledge or because of my misconceptions ☹ But, by doing research I completed my lack of content knowledge and removed to my misconceptions ... (9)”
RESULTS/CONCLUSIONS-RECOMMENDATIONS

In this study, the active participated material development process has been effective in the improvement of PSTs’ ASEB. This case is hopeful. The PSTs’ previous efficacy beliefs are likely to predict their future efficacy beliefs (Thomson et al., 2017). There was positive and significant relation between PSTs’ astronomy conceptual knowledge with astronomy self-efficacy beliefs (Gunes, 2010). Besides, the active participated material development process has been effective in the improvement of PSTs’ content knowledge (CK), pedagogical knowledge (PK), technological knowledge (TK) and Technological Pedagogical Content Knowledge (TPCK). CK, PK and TK are complex and interconnected (Thomson et al., 2017). As well as this result is very important to predict their future STOE beliefs. There is a significant relationship between elementary pre-service teachers’ science pedagogical content knowledge and science outcome efficacy (Thomson et al., 2017).

Cerrah-Özsevgeç (2007) and Cerrah-Özsevgeç, Ayas and Özsevgeç (2010) found that the active participated material development process was effective on remedying prospective teachers’ misconceptions and lack of content knowledge. These studies also showed that this process improved the prospective teachers’ pedagogical content knowledge. Results in this study are parallel with the results of other studies in the literature. According to the results of this research it might suggest that the effect of the active participated material development process in another science issues should be search on students’ and prospective teachers’ self-efficacy beliefs.

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URL-1 http://mufredat.meb.gov.tr/Dosyalar/2017726121110793-REV_SON_2017717141158599-04FEN%20B%C4%B0L%C4%B0MLER%C4%B0%203-81.pdf has been downloaded at 17.01.2018.

Appendix 1*. Examples concept, knowledge, mind maps and concept cartoons of the PSTs

*They were translated into English by the researchers

![Mind map of PST concepts](image1)

![Knowledge map of PST concepts](image2)
Strand 13

Figure 1. An example Mind Map of the PSTs

Figure 4. An example concept cartoon of the PSTs
INQUIRY AND MODELING IN PRE-SERVICE TEACHER TRAINING TO IMPROVE SCIENTIFIC, EPISTEMIC, PEDAGOGICAL KNOWLEDGE, AND EMOTIONAL SELF-REGULATION

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The need to promote "scientific practices" as they help students to elaborate an appropriate image of scientific activity, requires training competent teachers to teach them in Elementary school classrooms. To achieve this, we focus the initial training on promoting an evolution in the “spontaneous teachers’ thoughts”, by engaging them actively in those practices and reflecting on the learning process, in order to develop: Descriptive and explanatory Scientific Content knowledge, inquiry process understanding, Epistemic knowledge, Pedagogical knowledge and emotional and learning self-regulation. The design of part of the course “Science Education I” which includes two inquiry cycles (descriptive and explanatory-predictive both related to Sun-Earth movements), is presented and the multiple instruments designed to evaluate its effectiveness are shown. Preliminary results from student teachers’ discussions reveal the important role of accurate descriptive knowledge to construct a model. Moreover, the responses given in the self-learning regulation activities show they recognize an enhancement in their epistemic and scientific content knowledge. These results, among others, seem to indicate the efficiency of the proposal design in promoting the teachers’ professional development.

Keywords: pre-service teacher training, sun-earth, model-based inquiry

INTRODUCTION

The NRC (2012) emphasizes the need to promote "scientific practices" in response to the huge flood of proposals reduced to hands-on activities without considering the importance of minds-on activities. Osborne (2014) attributes this problem to the confusion of the goal of science with the goal of learning science consisting of building an understanding of the ideas about the world surrounding us, and the lack of a common understanding of what inquiry means.

If we aim to promote scientific practices in Elementary schools, it is necessary to train competent teachers to incorporate them in their instruction. A prospective teacher’s personal view of teaching science is a strong predictor of a prospective teacher’s actual practice of teaching science (Crawford, 2007). Therefore, an important aspect of preparing teachers to teach scientific practices be to provide them with experiences that will change their view of teaching science into one with includes the scientific, epistemic, pedagogical aspects as well. With this purpose, we address initial training as a process of changing the spontaneous teachers’ thoughts consisting of conceptions, ideas… about science, nature of science and science teaching and learning, which, to be plausible, it requires learning experiences alternative to their previous experiences that serve as a reference to teach science (Martínez-
Chico, 2013) while they are learning by doing (Haefner & Zembal-Saul, 2004), and reflect on the learning process experienced.

To facilitate the promotion of scientific practices in Elementary schools, the kind of knowledge children have which is descriptive-experiential, close, immediate-, and their own explanations about the world, as well as the competencies which they are to develop such as “explaining phenomena scientifically” what includes the ability to describe or interpret phenomena and predict changes should not be ignored (OCDE, 2016).

Considering all these aspects, to enhance the pre-service Elementary School teachers (PET)’ competence to teach science we focus on promoting: Descriptive and explanatory Science content knowledge, Inquiry process understanding, Epistemic knowledge, Pedagogical knowledge. Furthermore, as science-based learning processes are not merely cognitive but are highly charged with feelings and self-regulation, we cannot ignore the common negative emotions towards science and teaching science (Evagorou et al., 2014), and therefore, the training should be extended to the affective dimensions (Brígido et al. 2010).

As research has shown that inquiry-based teaching practices have a positive effect on student learning, particularly students’ engagement in the cognitive dimensions of inquiry and teacher-led inquiry activities (OCDE, 2016), we focus the initial teacher training on Inquiry-Based Science Education, an approach drawn from constructivist learning, facing the need to express and discuss students’ misconceptions and the need for students to understand the epistemic basis of science (Osborne, 2014).

In this paper we summarize a teaching sequence in which PETs experience two inquiry cycles on Sun-Earth movements, with an integrated theory-practice approach, trying to overcome the common critics from teachers that consider initial training programs too abstract and theoretical (Darling-Hammond & Bransford, 2005). Another purpose of our research is to obtain evidence of the activity sequence effectiveness and the different instruments used aiming to explore the evolution on PET’ Scientific content knowledge, inquiry process understanding and epistemic knowledge, pedagogical knowledge and self-learning and emotions perceptions when they engage in scientific practices to construct both, descriptive and explanatory knowledge.

Specifically, the research questions we address in this paper are:

- How effective is this design to construct scientific knowledge (descriptive & models)? Is the construction of descriptive knowledge useful for modelling?
- How do they perceive their learning of scientific contents and epistemic knowledge? Do their perceptions correspond to what they have learnt?
- Which emotions do they recognize having felt throughout the proposal?

**METHODOLOGY**

**Context of the Study and Participants**

The participants of the study were 175 pre-service teachers (PETs), studying to become elementary school teachers at a University in the south of Spain. All the participants were in their 2nd year enrolled in the Science Education I course, which lasted 30 weeks.
The purpose of the course is to train the PET on science education, initiating them into the scientific practices through learning experiences as learners, as thinkers and as designers, to engage their future students with scientific practices. None of the elementary pre-service teachers had a background in science.

Part of the course which has been presented (Table 1) was implemented at the beginning of the course 2016/17, over 25 in-class hours. For some activities (A9 and A10), the participants were expected to work in small groups (4–5 PSTs).

**Activity Sequence**

Part of the course presented (Table 1) includes both: An Inquiry-based cycle (to construct descriptive knowledge about how sunlight hours change throughout the year) and a Model-Based Inquiry cycle (to explain the descriptive knowledge previously constructed), including times for self-regulation by analyzing what and how they have learned and felt (underlined activities).

The science content matter chosen for this study is Celestial Motion from an Earth-Based Perspective. The election of this topic is due to different reasons: it is useful for teachers to have a clear understanding of the subject matter that they are teaching (NRC, 2007) and this specific science content is a fairly repeated part of the curriculum and text books; to construct a proper view of Science, apart from considering the current understanding of natural systems, the process whereby that body of knowledge has been established and is being continually extended, refined, and revised, must be consider (NRC, 2007), and this subject matter offers the possibility of understanding both; the contents around those ideas help us weed out peripheral ideas and instruction that focuses on the rote memorization of disconnected facts, as a result of presenting the contents in an unproblematic, abstract and decontextualized form for students (Plummer & Krajcik, 2010); the common lack of understanding of these concepts may hinder students’ progress towards more advanced understanding in the domain (Plummer & Krajcik, 2010); prior research has demonstrated that neither children nor adults hold a scientific understanding of the big ideas of astronomy and different misconceptions are perpetuated by everyday sayings, the school, the teachers discourse, etc. (Atwood & Atwood, 1996; Trumper, 2001; Plummer & Krajcik, 2010); by working from another reference system different from the traditional one, students learn to change their own perspective, starting from a close perspective, according to a reference system focused on our situation (flat horizon in a specific locality of the Earth), and advancing towards the perspective of "looking from outside the Sun-Earth System" (side view of the Earth), reflecting on the progression followed. With this we allow the difficulty of looking from the earth, habitual difficulty in most children and adults as Plummer, Zahm, and Rice (2010) show and we avoid the inconsistency of ideas promoted by the "forced" introduction of concepts that do not serve to explain the observations (such as the use of the heliocentric model to explain the variation of the Sun's hours throughout the year).
**Table 1. Activities included in the inquiry cycles**

<table>
<thead>
<tr>
<th>Activity statement</th>
<th>Comments</th>
<th>Purpose of the activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity 1. What has changed from the days before and the days after September 22?</strong></td>
<td>With this activity we try to embed the scientific contents in the ongoing experiences of the learners, creating opportunities for them to approach these contents, contextualizing in a real-world situation. Learning occurs from the classroom through the real practice experience and vice versa, so that students get involved in looking for explanations of known phenomena. As PETs will probably use verbal language to express their ideas, in the sharing it will become evident that this language is insufficient and, if no group has done so before, the teacher proposes expressing their ideas through graphic language highlighting their usefulness (in this case, to represent the change of a variable over time).</td>
<td>Promote PETs’ engagement in scientific questions</td>
</tr>
<tr>
<td><strong>Activity 2. Does the number of sunlight hours change in Almeria? How do they change?</strong></td>
<td>A desirable quality in every teacher is to understand what the learners want to express, without making judgments about whether the ideas are correct or not from the beginning. Therefore, after each student has drawn their graph, they can be given a short script to analyse the ideas of their peers: Does the magnitude change? Which is the maximum/minimum value and on what day does it reach it? Which times does the magnitude increase each day? Which periods does the magnitude decrease each day? Is the rate of change constant? When is it greater? When is it smaller? It is important they realize this activity is not about judging whether their partners say is correct, but about learning to understand what they mean.</td>
<td>Ideas interpretation and identification of misconceptions</td>
</tr>
<tr>
<td><strong>Activity 3. Interpret each graph that your classmates present and describe what they think.</strong></td>
<td>One of the scientific practices that should be promoted is ‘Engaging in argument from evidence’ (NRC, 2012). PETs are asked to suggest different ways to contrast their hypothesis. It is expected that they answer the corresponding magnitude (hours of sunlight) should be measured every day in Almeria, but to obtain an approximate graph it is not necessary, it is enough to measure one day per month. It is convenient to ask them to express how they would measure that magnitude on a specific day. Once their ideas are expressed and discussed, we propose, if they didn’t do it before, to use data of the sunrise and sunset in Almeria from other research groups (collective dimension of scientific work), thus, we show that evidence does not always have to come from experimental data.</td>
<td>Look for evidence (considering not only experimental designs, but also reliable information searching)</td>
</tr>
<tr>
<td><strong>Activity 4. Which evidence can we look for to confirm or reject our response? Write down what you plan to do and how you are going to present the results.</strong></td>
<td>After performing the look for evidence PETs compare the results with what they thought initially. The sharing will take place at the beginning of the next class. It is important that they identify the differences and emphasize that the change of their ideas is now supported by evidence, characteristic of scientific activity. The work done allows us to know how the duration of the day in Almeria changes throughout the year. After analysing the graphs carefully, the educator reviews and unifies the results considering the light refraction in the atmosphere, identifying the changes in Hours of sunlight: - The 1st semester (winter and spring) the number of sunlight hours increases and the 2nd (summer and autumn) decreases, - In winter and autumn there are less than 12 sunlight hours, while in spring and summer there are more than 12 hours, -The change occurs at a higher rate near the equinox days and changes very little near the solstice days, -There is symmetry with respect to June 21 and December 21 Some activities are proposed to apply the contents learnt.</td>
<td>Analyse data and adapt descriptions or explanations Identify differences between previous thoughts and results</td>
</tr>
<tr>
<td><strong>Activity 5. Communicate your results: Indicate where the evidence was found, present results, and list the modifications you incorporated to what you thought initially.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Activity 6. Unifies results and perform application activities.</strong></td>
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<td></td>
</tr>
</tbody>
</table>
Activity 7. If December 21 is the shortest day of the year, why is it not the coldest day? If June 21 is the longest day of the year, why not the hottest day?

We will refer to the thermal inertia. We all know that we do not take off our coat as soon as we turn on the heating or put it on as soon as we turn it off, that is, the temperature of the environment does not immediately reflect the amount of energy that is provided (especially in environments with abundant water, as is the case of the surface of the Earth). The main reason for this conception is the association between hours of light and temperature. So, if in summer each day is hotter until, for example, August 10, we can expect that until that day there will be increasingly hours of sunlight. The origin of this idea is therefore sensory, social, and perhaps school (examples of textbooks are shown).

Analysis of the justification of their initial models. Identification of misconceptions

Activity 8. Learning and emotional self-regulation questionnaire is issued.

Learning and emotions self-reflection of is performed. Students reflect on science learning and on the felt emotions based on this experienced sequence.

Self-regulation on experienced learning and emotions

Activity 9. Would it not have been easier and quicker for the teacher to explain the right ideas from the beginning?

Reflection on students' conceptions, constructivist view of learning and differences between the everyday epistemology used by people and scientific epistemology are performed.

Throughout the activities carried out, some ideas that do not coincide with the scientific ones have been revealed and its possible origin has been discussed. We can remember some of those ideas or misconceptions, asking why we think that way, and how to promote meaningful learning of science content.

Reflection on students’ learning and the teaching approach followed

**Inquiry cycle to construct explanatory knowledge**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Comments</th>
<th>Purpose of the activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 10. How does the number of sunlight hours change in ...?</td>
<td>PETs begin by making predictions about how the number of hours of sunlight changes throughout the year in different locations on the globe. They are asked about self-confidence in giving their answers, finding low levels of self-confidence. Next, we reflect on epistemic aspects. Until no, we have constructed descriptive knowledge based on evidence, but science does not only focus on collecting empirical data in a particular way, about what happens in each locality. Science uses models to explain what is already well known (for example, what happens in Almeria) and to make predictions whose veracity can be contrasted (for example, what happens in other locations). Throughout the next activities we will construct a model that allows us to explain these worked contents and make predictions.</td>
<td>Formulation of scientific questions Predictions Communication and expression of ideas</td>
</tr>
<tr>
<td>Activity 11. Use (audio-recorded) verbal language, drawings, and models to expose your understanding of how the sun and earth move in a way which explains that in Almeria: on December 21, there are &lt;12 sunlight hours; on March 21 there are 12 sunlight hours; on June 21, there are &gt;12 sunlight hours. Activity 12. What can each model explain and what cannot? (recorded session)</td>
<td>In small groups, the students record their discussion and conclusions, which can be supported with pictures, drawings, videos... To help them express their ideas, some porexpan balls are provided to use them as if they were the Earth. It is expected that they reproduce what they remember of their stage as schoolchildren, as for example that the Earth moves around the Sun, it is even possible that they assume a certain inclination on the Earth's axis, or that they draw the image that their book or their teacher showed, representing the trajectory of the Earth as a very flattened ellipse with the Sun in one of the foci of the ellipse... In any case, their models will be insufficient to explain the known changes in the number of sunlight hours... It is important to discuss the inadequacies found in each of the proposed models. We then conclude that we need to construct a model.</td>
<td>Communication and expression of ideas (initial models) Evaluation of models</td>
</tr>
<tr>
<td>Activity 13.1</td>
<td>What should the position of the Earth and the Sun be on the equinox day so that there is 12 sunlight hours in Almeria?</td>
<td></td>
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<td>---------------</td>
<td>------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Activity 13.2</td>
<td>What should the position of the Earth and the Sun be on December 21 so that in Almeria there is less than 12 sunlight hours?</td>
<td></td>
</tr>
<tr>
<td>Activity 13.3</td>
<td>What should the position of the Earth and the Sun be on June 21 so that there is more than 12 sunlight hours in Almeria?</td>
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</table>

After discussing the insufficiencies of models mainly based on the Sun-Earth distance, we discussed some elements that we will consider when constructing our model (based on evidence): the observer will be located outside the Earth to be able to consider what it happens in all locations; we will consider the Earth as a spherical body that rotates around an imaginary vertical axis that passes through the Poles; the rays reach the earth's surface parallel. Therefore, the sunlight always divides the planet into two equal parts (semispheres), one illuminated and the other not.

Then, PETs are invited to use the porexpan balls, to try to improve their models to explain what happens in Almeria in the equinoxes and solstices regarding to sunlight hours. How should the rays arrive? From above? What would happen if they arrived from above? And if they come from below? Should they arrive inclined? What would happen if they arrived inclined? Raising questions of this type we intend to orient PETs in the construction of the model. Among all the class, we construct a static model about the relative position of the Sun and the Earth in the four singular days of the year:

<table>
<thead>
<tr>
<th>Activity 14</th>
<th>The constructed model explains the changes in the sunlight hours in Almeria. Does it allow us to make predictions of what will happen in other locations?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 15</td>
<td>Compare your predictions with those you did before constructing the model (A10) and identify the main differences.</td>
</tr>
<tr>
<td>Activity 16</td>
<td>What were your answers based on at the beginning?</td>
</tr>
<tr>
<td>Activity 17</td>
<td>How can you know if the predictions are correct? Look for evidence using the USNO website and simulations.</td>
</tr>
<tr>
<td>Activity 18</td>
<td>Learning and emotional self-regulation questionnaire. Reflection on the results of the two questionnaires (A8 and A18).</td>
</tr>
</tbody>
</table>

Using a model to explain phenomena

<table>
<thead>
<tr>
<th>Activity 18</th>
<th>Learning and emotional self-regulation questionnaire. Reflection on the results of the two questionnaires (A8 and A18).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 17</td>
<td>How can you know if the predictions are correct? Look for evidence using the USNO website and simulations.</td>
</tr>
<tr>
<td>Activity 16</td>
<td>What were your answers based on at the beginning?</td>
</tr>
<tr>
<td>Activity 15</td>
<td>Compare your predictions with those you did before constructing the model (A10) and identify the main differences.</td>
</tr>
<tr>
<td>Activity 14</td>
<td>The constructed model explains the changes in the sunlight hours in Almeria. Does it allow us to make predictions of what will happen in other locations?</td>
</tr>
</tbody>
</table>

Self-regulation on experienced learning and emotions

Learning and emotions self-reflection is performed. Students reflect on science learning and on the felt emotions based on this sequence experienced.
When the implementation of the activities begun, the PETs did not have any previous experience with inquiry, modeling, or scientific practices.

**Data Collection**

To check the effectiveness of our training course on the different aspects stated before, we have designed different instruments shown in Table 2 which also work as learning activities, as they contribute to promote their pedagogical content knowledge. Some collected data (underlined) have already been analyzed (Martinez-Chico, 2013; Martínez-Chico, López-Gay, & Jiménez-Liso, 2013), and other results are commented on below (in bold).

<table>
<thead>
<tr>
<th>Evaluated aspects</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific content knowledge acquired (descriptions and models)</td>
<td>PSTs’ responses to activities (graphs, descriptions, explanations)</td>
</tr>
<tr>
<td>Inquiry process understanding and epistemic knowledge</td>
<td>Didactic conceptions questionnaire</td>
</tr>
<tr>
<td>Pedagogical knowledge (science learning and teaching)</td>
<td>Didactic conceptions questionnaire</td>
</tr>
<tr>
<td>Self-learning and Emotions perceptions</td>
<td>Learning &amp; emotional self-regulation questionnaire</td>
</tr>
</tbody>
</table>

In the following sections the data analysis and the presentation of results is addressed, but only those related to the PSTs' audio-recorded discussions and Learning & emotional self-regulation questionnaire, which are the focus of this work. The questionnaire can be found in: https://drive.google.com/file/d/0B3nyVea6LJeDM0hlYUtQbWQtUVU/view?usp=sharing.

**Data Analysis**

All data were open-coded, considering themes that related to the evaluated aspects. Specifically, the reflections in PSTs’ discussion analysis (alongside activities A10 and A11) were analyzed looking for themes on the role of the descriptive knowledge when PSTs construct an explanatory model. From the open-coding of the responses on PSTs’ audio-recorded discussions the findings presented in the next section were found.

With the double aim of knowing the evolution in their perceived scientific content knowledge and the emotions experienced along the sequence, PSTs' responses to a Learning & emotional self-regulation questionnaire implemented in activities A8 and A19 have been analyzed.

**FINDINGS**

**Findings from PSTs’ audio-recorded discussions**

The PSTs’ discussion analysis shows the important role of the descriptive knowledge when they construct an explanatory model.

This activity sequence design allows them to move from inconsistent towards a model to explain a precise knowledge of reality.
Usually, they state inconsistent models from their ideas on the Earth's elliptical Orbit around the Sun to explain the seasons because of the distance between the Sun and the Earth, which causes them to enter a loop in which some misconceptions lead them to an erroneous model that explains erroneous descriptive knowledge.

Nevertheless, when they try to construct the model to explain a precise knowledge of reality (descriptive knowledge previously constructed -about sunlight hours-) they introduce partial modifications to their initial models such as 'the inclination' of the Earth's axis, and they argue on its validity (or not) according to the descriptive knowledge they already have. This process leads them to identify the insufficiency of their initial models, particularly when explaining the existence of days with more than 12 sunlight hours.

**Findings from PSTs’ responses to a Learning & Emotional Self-regulation questionnaire**

The analysis of PSTs' responses to a Learning & emotional self-regulation questionnaire implemented in activities A8 and A19, shows an evolution in their perceived scientific content knowledge (Figure 1).

Results show a high effect size on all items, which means that they acknowledge to have learnt about scientific contents and epistemology (>2) such as identifying the insufficiency of a model to explain the existence of seasons, or the evidence needed to test the constructed model.

The most remarkable results are those related to the use of the Sun-Earth model to explain and make predictions. These results about their self-learning perceptions can be complemented with PSTs’ responses (predictions about sunlight hours) before and after constructing the Sun-Earth model (A9, A16), which indicates an enhanced explicative and predictive knowledge.

Most of the emotions that PSTs recognize to have felt when learning are "positive". Furthermore, concerning the evolution in PSTs’ emotions, a clear reinforcement of "positive" emotions (interest, concentration, and confidence) is found although there is also an increase in insecurity.
DISCUSSION AND CONCLUSIONS

A teacher training proposal focused on scientific practices through a Model-Based Inquiry approach, that includes learning self-regulation moments, structured in two inquiry-based cycles (in order to construct descriptive knowledge and a model to explain it) is presented.

Different instruments have been designed to check the effect of the course, and some findings related to scientific content and epistemic knowledge acquired and learning recognition are presented. On one hand, it has become clear the important role of the descriptive knowledge to construct a model. On the other hand, student teachers realize they improve their knowledge mainly of constructing and using models to explain and predict, something that coincides with their learning outcome. Moreover, the emotions felt are mainly positive, except for the case of insecurity, something that can be interpreted as normal (as a necessary emotion in the learning process) and that must be recognized by students as such in order for them to be able to regulate it.

These results, amongst others (obtained through the instruments presented in Table 2), allow us to consider the training proposal as an appropriate option as it facilitates professional development to teach scientific practices. Teacher training can be focused on different aspects (argumentation, modelling, inquiry…), but due to time limitations we are forced to focus on only one. Therefore, we opt to focus on inquiry-based learning which we have observed to be much more efficient given that it allows the construction of descriptive knowledge and models, epistemic and pedagogical knowledge. Engaging in scientific practices supports the development of the most appropriate understandings of science and scientific inquiry, and that PET become more accepting of approaches to teaching science (Haefner & Zembal–Saul, 2004). Nevertheless, implications include considering teaching designs performed by prospective elementary teachers to support the development of robust professional knowledge.

ACKNOWLEDGEMENT


REFERENCES


METHODOLOGICAL GUIDELINES FOR POTENTIATING ENVIRONMENTAL EDUCATION IN TEACHING TRAINING

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This research is a result of the innovation project, PIE 15-141, "Environmental Education in University Teaching Training" at the University of Málaga, whose main objective is to mobilize the cognitive, attitudinal, affective and conative dimensions of environmental awareness in Preservice Secondary Science Teacher Training Program and of the Grade of Primary and Child Education Teacher and with the intention of developing in the students the capacity to create, design and to specify learning situations whose axis is the environmental education. Based on a qualitative methodological analysis of the proposals of individually developed didactic interventions, in the different groups that constitute the work sample, a series of difficulties are detected to identify nearby environmental problems, belonging to its immediate environment, and didactic deficiencies to propose and design activities related to those problems. These results determine the need to generate methodological recommendations contextualized or methodological implications that will be addressed with the purpose of further progress in this project. In this way, a second assessment will be carried out following the application of the new guidelines, the report of which will be part of another communication. This work is part of the 'R & D Excellence' project EDU2013-41952-P, funded by the Spanish Ministry of Economy and Finance through its 2013 research call.

Keywords: environmental education, teacher training, didactic orientations.

INTRODUCTION

Environmental Education for future teachers has a determining aspect, since among the particular characteristics of Environmental Education, its axiological component stands out. When education professionals have been involved in an environmental training dynamic they have shown difficulties to: identify sources of knowledge, recognize and assess environmentally worrisome situations as well as limitations to exemplify own actions favorable to the environment. However, as positive aspects, future teachers have shown a predisposition toward environmental education as a generator of environmental awareness, since they consider it a mobilizer of sensitivity and respect, at the same time they point to the school as the place where it is most easily generated (Acebal, 2010).

On the other hand, there is a determination in their own formation, initial and permanent, as necessary to transmit from the master model, the necessary values for the development of competences of environmentally committed citizens (Acebal, Brero and Sampietro, 2015). In analyzes carried out on curricular perspectives for the training of trainers in environmental education, emphasis is placed on the need to incorporate the environmental perspective in vocational training (Sauvé, 2003).

Recent international publications coincide in previous statements such as the case of Shiang-Yao (2015) who states "teachers have satisfactory levels of knowledge and attitudes of the environment, but have low levels of environmental action that promote dissemination in them".
Other researchers have highlighted the existence of a personal teaching epistemology constructed through experience, first as a student and then as a teacher, which mediates the attitudes and behaviors presented by the teacher in class. This personal teaching epistemology can be an obstacle to didactic change but it must also be considered the starting point for new didactic constructions (Tobin and Espinet, 1989; Carretero and Limón, 1996).

Teachers with their initial personal epistemology must appropriately take on the existing didactic knowledge and for that they must be involved in the reconstruction of this knowledge. Thus, a training model consistent with these constructivist approaches will use the metaphor of teachers (in initial or ongoing training) as new researchers working in teams replicating didactic research directed, in an initial phase, by an expert researcher (the tutor, adviser or coordinator) in those investigations (Furió, 1994a, Furió and Gil, 1999). The didactic change of the teaching staff that includes the Environmental Education, has to be conceived as continuous and "natural" in the "learning to teach science", and essential for their professional development. This implies that teachers must be prepared not only to teach science but also to work collectively and self-assess their task. And this will only be possible if education is planned as a didactic hypothesis that tries to solve school failure and is tested through appropriate designs as in any research (Furió, 1994).

This research considers the study plans of the new degrees in the field of the European Higher Education Area (EHEA), which represent an important change in traditional methods of teaching and learning. Among the most significant aspects, subject to this change, are the development of competencies and the role of evaluation in the educational process (Blanco-Fernández, 2010; Zabalza, 2003). Habitually, the teacher training activities should set out tasks and learning situations as a rehearsal to which the teachers will have to carry out as part of their teaching tasks (Carrascosa, Martínez, Furió and Guisasola, 2008).

Perrenoud (2004) talks about ten new competences, proposed based on the Geneva reference in 1996, considering that they are priorities based on their coherence with the new role demanded of teachers, the evolution of continuing education and educational reforms that are being implemented in different countries. Starting from the concept of competence that the author manages as a capacity to mobilize several cognitive resources to deal with a type of situations, it establishes several aspects or considerations, one of which it is pertinent to underline: professional competences are created, in formation, but also at the expense of the daily task of the practitioner, from one work situation to another. That way, the ten families of proposed competences are:

1. Organize and animate learning situations,
2. Manage the progression of learning,
3. Develop and evolve differentiation devices,
4. Involve students in their learning and in their work,
5. Work as a team,
6. Participate in the management of the school,
7. Inform and involve parents,
8. Use new technologies,
9. Face the duties and ethical dilemmas of the profession,
10. Organize their own continuous training.
These are some of the skills that all teachers must develop and are directly related to the subjects or subjects they have to teach. That is to say, the development of these competences will be closely related to the didactic knowledge of the contents held by the teaching staff (Shulman, 1986 and 1993) and, therefore, their teaching and learning acquires special relevance in the specific subjects of the degrees involved in this work.

Perrenoud's competences are closely related to some of the curricula included in Preservice Secondary Science Teacher Training Program and Grade in Early Childhood and Primary Education Teachers at the University of Malaga, such as:

- Plan, develop and evaluate the teaching and learning process, promoting educational processes that facilitate the acquisition of the competences of the respective teachings, taking into account the level and previous training of the students as well as the orientation of the same, both individually and in collaboration with other teachers and professionals of the center (General competence).

- Develop and apply didactic methodologies, both group and customized, adapted to the diversity of students (General competence).

- Know strategies and evaluation techniques and understand the evaluation as an instrument of regulation and encouragement to the effort (Competence collected in the subject "Learning and teaching of the subjects of the specialties").

As stated at the beginning of this section, one of the most novel and complex aspects of the European Higher Education Area (EHEA) is the role of evaluation in the teaching and learning process (Brown and Glasner, 2003). Through educational evaluation, in addition to informing students about their strengths and weaknesses to correct errors and consolidate successes, the awareness of competency acquisition can be developed through self-evaluation activities focused on reflection and regulation (Valero and Díaz de Cerio, 2005).

It is important that the teachers in formation know and use self-evaluation techniques and strategies as an instrument of reflection and regulation of their own learning. The development of these competences in the teaching staff will undoubtedly result in their competences to promote them, in turn, in their students.

This research gives continuity to a line of work already started in the Knowledge Area of Experimental Sciences, related to the teaching and evaluation of the competences of teachers in training (Arjona, España and Márquez, 2008; Rueda, Acebal and Brero, 2010; Sacristán and España, 2010). It is integrated into a framework where some other lines of research that are carried out in the department are related, such as: environmental awareness and its relationship in the training of teachers, innovative methodologies in science to promote attitudinal change, environmental identity/multiculturalism, the formation of critical thinking from the didactic of Social Sciences.

As innovative aspects, the coordination of the mentioned subjects according to each grade or post-grade is proposed to program and develop in a coherent and integrated way training activities that ultimately result in the acquisition of environmental attitudes that promote the predisposition to contextualize intervention situations education for environmental education.
In this research we highlight aspects such as:

The consideration of Environmental Education as a generator of training and evaluation activities, from the interdisciplinary consideration that favor the multiplier effect, so necessary, in the different levels of the educational system.

The integration of a good number of subjects of several specialties of Preservice Secondary Science Teacher Training Program and Grade of Early Childhood and Primary Teachers, involving a high number of students.

The promotion of self-evaluation of students and their relationship with the development of important competences for future teachers of secondary education, high school, infant and primary education.

The promotion of coordination among the teachers of the areas involved, this being an aspect pending improvement.

The interdisciplinarity as an idea is totally coherent with the principles of Environmental Education and, for its part, the need for intra and interdisciplinary coordination is a permanent demand of the undergraduate and postgraduate students and faculty.

**WORK DESCRIPTION**

The development of this research work coincides with the first stage of the Educational Innovation Project PIE15-141 of the University of Malaga, "Environmental Education in teacher training", and which takes place during two consecutive school years.

This work was carried out during the academic courses 2015-2016 and 2016-2017 in the subjects related to the design and development of programming and training activities; the biology and geology curriculum; teaching innovation and initiation to educational research in the areas of Preservice Secondary Science Teacher Training Program at the University of Málaga and in Experimental Sciences Teaching and Teaching of Sciences in Grade in Early Childhood and Primary Education of the University of Malaga.

**Objectives**

- Identify the difficulties for the design of teaching-learning activities around Environmental Education.
- Encourage the empowerment of an environmental awareness of teachers committed to their immediate and global environment to determine educational actions consistent with environmental education.
- Design meaningful methodological guidelines that provoke the necessary change for the assessment and adoption of interdisciplinary and cooperative work strategies among the teaching staff.
- Design evaluation resources to enhance the self-assessment and regulation of student learning.
Methodology

Initially, a questionnaire was developed to assess different dimensions: cognitive, evaluative and behavioral aspects; capacity to identify environmental problems and the relationship between environmental problems and teaching contents that generate their inclusion in the design of educational activities (Figure 1).

This questionnaire was agreed and validated within the teaching team of the project. Subsequently, the students’ responses were analyzed and evaluated, from which didactic orientations were developed.

<table>
<thead>
<tr>
<th>INITIAL QUESTIONNAIRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What do you understand by Environmental Education? What types of content do you think are typical of EA?</td>
</tr>
<tr>
<td>2. What do you think an environmental educator should know? What deficiencies do you think you have as an environmental educator?</td>
</tr>
<tr>
<td>3. Evaluate your habitual behaviors, depending on whether they are positive or negative, towards the environment and express them in the following table in order of importance.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Positive behavior</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative behaviors</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

4. Complete the following table according to the importance of each case and cite some possible solution to these problems.

<table>
<thead>
<tr>
<th>Local environmental problems</th>
<th>Proposed solution</th>
<th>Global environmental problems</th>
<th>Proposed solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

5. Design an educational activity for one of the environmental problems identified, to carry out with the students of a course of their choice.

Figure 1. Questionnaire own elaboration.
In this research we will focus on the analysis of the answers that refer to two questions of the questionnaire:

1. Identify at least three local environmental problems.
2. Design educational activities for each environmental problem identified to carry out with students a course of your choice.

The sample of students consists of 181 students from various groups of teachers in training corresponding to the degrees of Teachers of Early Childhood, Primary and Secondary Education.

ANALYSIS OF RESULTS AND CONCLUSIONS

From the analysis of the answers to the first question, four environmental problems are identified only, highlighting the reference to waste in relation to others. The other problems mentioned are, in order of greater or lesser frequency, transport, water, biodiversity.

Concerning the second question, practically all of the activities proposed are not detailed in a didactic way, but only in a brief manner. The development of objectives or competences, methodology or specific tasks to students is not considered.

Description of the categories of problems and types of related educational activities.

The category of Waste, 80.11%, includes all those references to solid urban waste that the students denominates in a different way. The majority refers to garbage both domestic and in public spaces.

The Transport, 8.28%, agglutinates the answers that correspond mainly to the use of the own car or public transport.

The Water, 6.08%, groups answers mostly related to irresponsible consumption of the same.

Finally, Biodiversity, 4.97%, gathers mostly references to exotic pets as invasive species and hunting. (Table 1)

Regarding related Educational Activities: the first type Reuse, recycle, separate refers mostly to proposals on paper recycling, simple objects made from plastic containers and the identification of containers according to kinds of waste.

The second type of space cleanup corresponds with project ideas to clean public places such as the school playground, squares, parks and beaches.

In the third type of activities proposed, field trips, are grouped those responses related to visits to recycling plants and environmental reserves.

The fourth group, Information Workshops, represents proposals for invitations to experts to discuss issues related to waste pollution. Campaign of diffusion, identifies suggestions of elaboration of poster or decals that would be distributed in the next community.

Finally, the Other category includes ideas of activities methodologically little or nothing related to the problem.
Table 1. Frequencies and percentages of identified problems and related educational activities.

<table>
<thead>
<tr>
<th>Identified problems</th>
<th>Waste</th>
<th>Transport</th>
<th>Water consumption</th>
<th>Biodiversity</th>
<th>No answer and/or no relation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency / percentage of problems identified</td>
<td>F %</td>
<td>F %</td>
<td>F %</td>
<td>F %</td>
<td>F %</td>
<td>F %</td>
</tr>
<tr>
<td>145</td>
<td>80.11</td>
<td>15</td>
<td>8.29</td>
<td>11</td>
<td>6.08</td>
<td>9</td>
</tr>
<tr>
<td>Educational activities related to the identified problem</td>
<td>142</td>
<td>98</td>
<td>9</td>
<td>60</td>
<td>11</td>
<td>100</td>
</tr>
<tr>
<td>Educational activity not related to the identified problem</td>
<td>3</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Relative percentage of the total sample of activities related to the problem</td>
<td>78.5</td>
<td>4.5</td>
<td>6.1</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative percentage of the total sample of activities not related to the problem</td>
<td>2.1</td>
<td>3.9</td>
<td></td>
<td></td>
<td></td>
<td>0.4</td>
</tr>
</tbody>
</table>

The relationships established between problematic and proposed activities (Table 2) tend to repeat patterns of activities that result from their own learning experiences in previous studies. In this sense, it is clear that the problem of solid waste, with 80.11% of the references, has a relative percentage of 78.5% of proposals for related activities, the rest of proposed activities, 2.1%, have no relation to the problem.

The students that have identified Transport, 8.29%, only represent 4.5% of the total sample with their related activities, and the remaining 3.9% have not proposed related activities.

On the other hand, in the case of those who identified Water and who represent 6.1%, they have made related proposals, representing 6.1% of the total sample. With a similar frequency and relation, we observe the correlation between the problematic Biodiversity, which reaches 4.95% and related designed activities that get 4.7%.

Table 2. Frequency and percentages of the different educational activities related to Waste.

<table>
<thead>
<tr>
<th>TYPES OF ACTIVITIES RELATED TO THE WASTE PROBLEM</th>
<th>Reuse, recycle, separate</th>
<th>Cleaning of spaces</th>
<th>Field trips</th>
<th>Informative workshops</th>
<th>Dissemination campaign</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>F %</td>
<td>F %</td>
<td>F %</td>
<td>F %</td>
<td>F %</td>
<td>F %</td>
<td>F %</td>
<td>F %</td>
</tr>
<tr>
<td>68</td>
<td>47.89</td>
<td>24</td>
<td>15</td>
<td>10.56</td>
<td>11</td>
<td>7.75</td>
<td>6.34</td>
</tr>
</tbody>
</table>
Conclusions and methodological implications

The results of this research work can be applied in the subjects of other specialties of the Preservice Secondary Science Teacher Training Program, as well as in other subjects of the grades of teacher in Early Childhood and Primary Education. Specifically, the innovative, formative and evaluative tasks that arise within this project can be transferred to the subjects assigned to the Knowledge Area of Experimental Sciences Education in the Grade of Teacher in Early Childhood Education (Health, Hygiene and Infant Feeding and Sciences Education) and Teacher in Primary Education (Science Teaching and Experimental Science Teaching).

In the light of the analysis of the responses of the teachers in training, a series of orientations and recommendations are proposed on which to emphasize their training program. It is necessary to make explicit the objectives and competencies for each activity designed in the educational proposal that include the cognitive, attitudinal, affective and conative dimensions of environmental awareness.

To leave clearly expressed and grounded the environmental content, preferably as a result of a previous investigation of problems close to the student's environment; the recommended methodology is one that allows significant learning, not repetitive and topicality; that also allows to demonstrate the ways in which the students can make a rewarding self-assessment from the possibility of being able to act positively in their environment.

Regarding for the typology of environmental education activities: adapt and update the typical ones, such as paper recycling, separation of waste, cleaning of spaces, and generate innovative activities such as action research projects in context such as opinion and dissemination campaigns, actions related to activism, proselytism and others that generate habits of sensitivity, commitment and inherent behaviors.

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REFERENCES


CHALLENGES OF SCIENCE TEACHER EDUCATION IN LOW-INCOME NATIONS – THE CASE OF ETHIOPIA

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Science education in the low-income nation of Ethiopia have poor attainment and enrolment. The shockingly low attainment in the lower levels of education is troubling teacher education as well. In this study attempt was made to explore the challenges of physics teacher education in Ethiopia based on data collected from 16 Teacher Education Colleges, 432 pre-service physics teachers in their final year of study, and 31 college lecturers. From the qualitative and quantitative analysis of conceptual test results, interviews, and classroom videos the following major results have been found. At the end of one-year intervention with dialogic teaching, both the comparison and treatment pre-service teachers were found to score very low in selected TIMSS items from population 2 tests; pre-service teachers slightly but significantly favoured didactic over dialogical teaching and quite sharply favoured both of these over naïve inquiry teaching; Physics teacher education lecturers predominantly use the lecture method in their classrooms but intervention found to shift their style significantly to dialogical teaching; finally, it was found that pre-service teachers learning is highly influenced by weak English language proficiency, low motivation, and expectation of low social status for the teaching profession.

Keywords: dialogic, pre-service, conceptual, orientation

BACKGROUND

Low-income nations have poor educational attainment and enrolment compared to most middle- and high-income nations. Education in low-income nations is suffering from low enrolment and high dropout rates. Two decades ago, UNDP described this as a global learning crisis and aimed for “universal primary education” as one of its Millennium Goals. From 2000 to 2015 this effort paid off and enrolment in low-income nations increased from 83 to 91%. Despite this global picture, enrolment in primary education in Sub-Saharan Africa did not even reached the global threshold. In this group of countries, to which Ethiopia is a member, the fast-developing enrolment rate due to the global effort jumped from around 52% in 1990 to 80% in 2015 (UN, 2015). However, there are discomforting reports that low income nations are still falling behind from the target of enrolment rate of 100% and struggling with high drop-out rates (Global Partnership for Education, 2014).

A much more serious problem of the education system in low-income countries is low attainment. Even those who were enrolled in primary education at a relatively high number are leaving school without being able to read and write (Global Partnership for Education, 2014; Hill & Chalaux, 2011). Furthermore, participation in international learning assessments, such as PISA and TIMSS, revealed that there is as large as two standard deviations between scores of students from the low-income countries and high-income nations (Martin, Mullis,
Foy, & Hooper, 2016; OECD, 2012). Progress is also very low for children in low-income nations to fill the observed huge gap (Beatty and Prichett, 2012).

Attainment, however, maintained low and the Department for International Development (DFID) in the UK, together with the Economic and Social Science Research Council (ESRC), therefore launched a large-scale research programme, Raising Learning Outcome in Education Systems (RLO), to investigate ways of improving the overall quality of education in low-income nations. The current paper is based on a study in the RLO programme looking at STEM subjects and aims to analyse quality of physics teacher education for middle schools in Ethiopia. More specifically, the paper asks

- How does the level of conceptual knowledge among Ethiopian pre-service teachers compare to students in high-income nations?
- What are the pre-service teachers’ pedagogical orientations and conceptions of “good teaching”?
- What pedagogy dominates teaching in Colleges of Teacher Education (CTEs) and how does this pedagogy align with pre-service teachers’ orientation?
- What contextual factors influence quality of physics teacher education for middle schools in Ethiopia?

**LITERATURE REVIEW**

As Ethiopia did not participate in the international examination, the above data may not directly apply to our current case. Nevertheless, other studies comparing the Ethiopian case with other developing countries attest that the problem is even much worse than what has been observed above. The Young Lives Study (www.younglives.org.uk), a long-term international study of childhood poverty in Ethiopia, India, Peru and Vietnam, has been important to analyse education in Ethiopia. The study has followed 12,000 children over 15 years and gathered information from educational authorities, homes and schools. The study points out that mass education is a relatively new phenomenon in Ethiopia compared to the other three nations and that the fast-growing expansion of inclusion rate has had a negative effect on attainment (Beatty & Pritchett, 2012). For mathematics and reading literacy, Ethiopia is the lowest scoring among the four Young Lives nations and has the faster widening learning gap as the children grow up. The nation also has a big attainment gap between urban and rural areas. Joshi and Verspoor’s (2013) study of Ethiopian education, to be reported to the world bank, corroborated the finding in Young Lives study.

Two problems have been targeted in several Development Programmes launched by Ethiopia’s Ministry of Education: the low progress made by children over one year of education and the high failure rate of students in Grade 10. Many home factors influence these problems (Singh, 2014), but quality of teachers, teaching and curricula are also seen as important (Pritchett & Beatty, 2012; R. Singh & Sarkar, 2012). Ethiopia was not included in the ROSE project (Sjoberg & Schreiner, 2010), but students in other comparative African countries showed very positive attitudes towards school science. It is therefore a paradox that many researchers in Ethiopia report attitudes as one of the biggest problems for educational attainment, particularly in physics and mathematics (Weldeslassie, 2016). Attitude is also regarded as a problem for recruitment to teacher education (Woldehanna, Tassew, Mekonnen, & Jones, 2009).
In Ethiopia, there are more than 80 different languages and there is a policy to provide primary education with the different vernacular languages. Different regions use the mother tongue language in primary education to a different level. Teacher education colleges use a combination of the mother tongue and the English language. For example, the 9 CTEs in this study have a teacher education for the second cycle primary with the English language as a medium of instruction.

**METHODOLOGY**

The study had a sample of 432 pre-service teachers (Mean age 20.37 years) and 16 CTE lecturers from nine different CTEs spread geographically in three Ethiopian regions (Amhara, Addis Ababa and SNNP). Participant pre-service students were 336 (77.8%) male and 96 (22.2%) female. Furthermore, these participants were differing in entry profile to teacher education. Even though majority of them joined the CTEs after completing grade 10 still a significant minority, N=126 (29.2%) of them were from grade 12 completes. The present study focused on the senior year of a three-year teacher education programme and used a mixed methodology design, including a series of data gathering tools. A test containing released items from TIMSS measured physics conceptual understanding. This allowed item-by-item international comparison and development of a local scale for correlation to other variables in the data set. A validated pedagogical orientation questionnaire (Horizon, 2012) was translated into Amharic and used together with 16 focus group interviews of pre-service teachers to investigate conceptions of “good teaching”. Interviews also focused on motivation for working in education. Video observations of sixteen physics lessons and individual interviews with all CTE lecturers were used to investigate pedagogical practices in teacher education. Physics curricula and teaching material were studied in content analysis.

Interviews and video observations were transcribed and translated into English for thematic analysis in the software Nvivo. Video analysis focused on communicative approach (Mortimer & Scott, 2003), including amount of time teacher and students were talking and the quality of utterances made by teachers. Analysis of interviews focused on themes related to didactic (teacher-led) and dialogical (student-led) teaching, and contextual factors as well. Scales for conceptual understanding and pedagogical orientation were analysed in SPSS, using ANOVA and correlations, after Rasch scales had been developed in Winsteps.

**FINDINGS**

**Level of Physics Conceptual Knowledge Among Ethiopian Pre-Service Teachers**

For international comparison of physics conceptual knowledge among Ethiopian pre-service teachers the natural comparison would be items from TIMSS Population 3 (Final year of secondary school). However, trialling showed these items were too difficult. Items, therefore, were selected from Population 2 tests (Grade 8 students) and allocated into two groups as generalist and specialist items. A physics item was considered ‘specialist’ if the pre-service teachers just took a course related to the physics content to which it belongs. An example of this item by item comparison of students of grade 8 from the international data with the final year pre-service physics teachers scores is presented in Figure 1.
Figure 1. Percent of students who got correct on three TIMSS electricity items

It can easily be seen from Figure 1 that Ethiopian pre-service physics teachers, in their final year teacher education, could score somewhere between the highest and lowest TIMSS score for grade 8 students internationally. What could be seen from Figure 1 is only a fluctuation around the average score. Another example of the relatively lower score of the pre-service teachers is presented in Table 1.

Table 1. Percent of students who got correct on TIMSS sound wave items

<table>
<thead>
<tr>
<th>Item</th>
<th>TIMSS Lowest</th>
<th>TIMSS Highest</th>
<th>TIMSS Average</th>
<th>Ethiopian Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound Wave 1</td>
<td>15</td>
<td>68</td>
<td>65</td>
<td>43</td>
</tr>
<tr>
<td>Sound Wave 2</td>
<td>10</td>
<td>76</td>
<td>36</td>
<td>15</td>
</tr>
<tr>
<td>Sound Wave 3</td>
<td>11</td>
<td>71.5</td>
<td>32</td>
<td>17</td>
</tr>
</tbody>
</table>

Once again, we can see that in all of the three sound wave items Ethiopian pre-service teachers scored less than the TIMSS average and a little bit higher than the lowest. That is, final year Ethiopian pre-service physics teachers had a level of conceptual knowledge similar to Grade 8 students in the international tests. They scored substantially lower on all open-ended items requiring writing, but higher on some MC items. Furthermore, when the test was repeated towards the end of the academic year, progression was low with an average increment of 0.2 of a standard deviation.

Slightly better performance was observed among grade 12 entry pre-service teachers compared to those from grade 10. Table 2 presents the data for three Electricity items, as an example.

Table 2. Percent of Grade 10 (N=) and Grade 12 (N=) entry students who got correct on the three TIMSS Electricity items

<table>
<thead>
<tr>
<th>Item</th>
<th>TIMSS Lowest</th>
<th>TIMSS Highest</th>
<th>TIMSS Average</th>
<th>Ethiopian Average</th>
<th>Grade 10</th>
<th>Grade 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity 1</td>
<td>15</td>
<td>68</td>
<td>44</td>
<td>56.6</td>
<td>78.9</td>
<td>66.7</td>
</tr>
<tr>
<td>Electricity 2</td>
<td>8</td>
<td>71</td>
<td>43</td>
<td>57.8</td>
<td>66.7</td>
<td>33.3</td>
</tr>
<tr>
<td>Electricity 3</td>
<td>20</td>
<td>70</td>
<td>37</td>
<td>25.0</td>
<td>33.3</td>
<td>33.3</td>
</tr>
</tbody>
</table>

Student entering teacher education from Grade 12 scored significantly higher than students entering at Grade 10, and this difference increased over the academic year. This better performance implies that those with better entry profiles will better benefit from teacher education program than those with weaker profiles, as far as conceptual learning of physics is concerned. This is a conformation of results found elsewhere, for example studies by Sadler...
and co-workers (2013) for middle school students and Baumert and his associates (2010) revealed similar results for mathematics pre-service teachers.

**Pre-Service Teachers’ Pedagogical Orientation and Conception of “good teaching”**

Questionnaire for pedagogical orientation had three constructs: didactic (teacher-led), dialogical (student-led) and naïve inquiry led teaching. Of these, pre-service teachers slightly but significantly favoured didactic over dialogical teaching and quite sharply favoured both of these over naïve inquiry teaching. All scales, however, had low reliability and ceiling effects, suggesting many pre-service teachers struggled to see the difference between the constructs and exhibited random dispositions to the three orientations. In interviews, the pre-service teachers talked heartily about student involvement as good teaching and wanted physics teaching to be less abstract and more related to everyday contexts. What has been observed could possibly be a conflict between the intention of the teacher education program and what pre-service teachers experience as students. It seems that teachers’ knowledge originates from teachers’ own school learning experiences, teacher education and professional development programs, and teaching experiences (Friedrichsen et al., 2009). Obviously, for these pre-service teachers, the last one does not apply as they do not have teaching experience that affects their knowledge about the different teaching approaches. The general rhetoric around teachers and teacher education is about “student centred” teaching and in the teacher education program the pre-service teachers are lectured about the importance of student-involving instruction. Nevertheless, since their school years, including CTE classes, they are predominantly being taught with didactic approaches. Thus, the observed difference in students’ preference to didactic teaching over dialogic and enquiry oriented teaching in the questionnaires from their talks in the interviews is an indicator of this confusion.

**Pedagogy dominating teaching in teacher education**

Qualitative analysis of classroom videos, especially from teachers’ camera, in both the comparison and the intervention groups helped to identify the different pedagogical approaches the physics teacher educators employed. Comparison between treatment and comparison classes were made in early stage of the intervention as well as at the end of the year. The table (Table 3) presents the data from the post-intervention video records for the 31 lecturers.

Observations from classrooms generally demonstrated a strict didactic regime despite the attempt to transform the classes into dialogic approaches. We observe substantial differences between treatment and comparison groups. In the comparison group, teachers on average spent 72.77% of the time on lecturing. This is reduced to 21.97% in the treatment group. In contrast, teachers on average spend 4.96% on group work in the comparison group, while teachers in the treatment group spent 42.35% of the time on group work. Although students in some lessons did problem solving, students’ ideas and answers were rarely discussed in plenary in neither the comparison nor the treatment groups.
Table 3. Percent of lesson time spent on different teaching activities by CTE Physics Lecturers

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment (N=22)</th>
<th>Comparison (N=9)</th>
<th>Total (N=31)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Introducing</td>
<td>5.66</td>
<td>4.23</td>
<td>4.18</td>
</tr>
<tr>
<td>Teacher Lecturing</td>
<td>21.97</td>
<td>17.8</td>
<td>72.77</td>
</tr>
<tr>
<td>Group Work</td>
<td>42.35</td>
<td>26.34</td>
<td>4.96</td>
</tr>
<tr>
<td>Whole Class Dialogue</td>
<td>11.45</td>
<td>8.96</td>
<td>0.66</td>
</tr>
<tr>
<td>Individual Seatwork</td>
<td>2.17</td>
<td>4.09</td>
<td>6.64</td>
</tr>
<tr>
<td>Students Talk Individually</td>
<td>5.11</td>
<td>9.12</td>
<td>2.39</td>
</tr>
<tr>
<td>Teacher Revises</td>
<td>1.64</td>
<td>2.36</td>
<td>1.76</td>
</tr>
<tr>
<td>Teacher summarising</td>
<td>8.82</td>
<td>7.83</td>
<td>1.52</td>
</tr>
</tbody>
</table>

Dialogical teaching (teacher having a whole class (true) dialogue) which occurred in the treatment group occasionally (11.45% of class time), was almost none-existing in the comparison group. An important type of teaching for dialogic teaching, which is “meta-teaching” that involves whole class discussion and teacher summarizing the discussion are occurring less frequently in the comparison groups compared to the treatment group. A “mean” (50 minutes) lesson in the comparison group has 2-3 minutes introduction, 38 minutes lecturing, 6 minutes with students solving tasks individually or in groups, and 1-2 minutes summary by individual students and 1-2 minutes general summarising by the teacher. The similar lesson in the treatment group has 3-4 minutes on the introduction, 8-9 minutes on lecturing, 22 minutes on group work, 8-9 minutes on dialogical teaching and occasional individual presentations by students, and 5 minutes on general summarising by the teacher. In other words, the big difference is in lecturing versus group work, but also a more balanced use of time across more types of activities in the treatment group compared to the comparison group. This is the “mean” picture.

While a pedagogic shift has been observed from comparison group to the treatment group, a distinct variation also observed among the individual lecturers. Looking at the variation in lessons we find many differences, however, more so in the treatment group than the comparison group. The comparison group (ordinary teaching) has a strong dominance of lecturing in ALL lessons, with time allowed to individual problem solving (individual seatwork in Figure 2) being the only deviation. As the comparison group lecturers had little choice they all seem to depend on lecturing throughout. The bar chart in Figure 2 presents the case of two lecturers from the treatment CTEs from the video data towards the end of the year.

However, as can be seen from Figure 2, the treatment group lecturers seem to significantly differ from each other though they abandon lecturing and replace it with group learning in general. In the example displayed in Figure 2, lecturer 1 dominated his teaching by group work, lecturer 2 moderated group work with more of dialogic teaching components. The important elements of dialogic teaching, such as whole class discussion and teachers’ summaries are given appropriate considerations in the case of lecturer 2 in contrast to the other one.
Contextual factors influencing teacher education

In Ethiopia, the medium of instruction, especially starting from upper primary (Grade 7 and 8) and in teacher education, is formally the English language. Thus, the physics teacher education in the linear program is expected to be conducted in English. Nevertheless, in this study the English language emerged as a problem from interviews, conceptual tests and classroom observations. Both CTE lecturers and pre-service physics teachers were observed to have difficulties in expressing their ideas and engage in classroom discussions using the official language of instruction. Most of the lecturers were limited to stating textbook information in the English language instead of using it as a communicative means. In both small group and whole class discussions pre-service teachers mostly use the Amharic language with sporadic mentioning of physics technical terms and phrases in English. Thus, the research implied that the desire to use the English language in Physics teacher education without proficiency is a serious impediment system wide.

From pre-service teachers’ interviews (focus group interviews) what repeatedly immerged is that they neither their chose to join teacher education nor wanted to study physics. Even those who claimed to have some degree of motivation to become physics teacher qualify their motivation as a “profession for the time being”. This problem of motivation seriously affects their learning as well as desire to implement effective but demanding pedagogical approaches in their future teaching. Most of the time, pre-service teachers attribute their low motivation to the “too-low salaries for teachers” and the difficult nature of the subject matter of physics “to learn as well as to teach” it.

Furthermore, many of the pre-service teachers are also worried about the low status of teachers in society.
DISCUSSION

Findings in this study suggest that low level of physics attainment in compulsory education in Ethiopia (Little & Rolleston, 2014) carries on as a problem into teacher education. The nation is in need of strong academic candidates for engineering education and sends the weaker candidates to teacher education. The curricular content as implemented in the classroom was found to be very advanced compared to students’ level of conceptual knowledge revealed in the tests. Lecturers typically aimed their teaching at the highest achieving students. The existing physics curriculum is far too abstract for the majority of pre-service teachers and suited only for the best candidates recruited from Grade 12. The majority of them (77%) are recruited from Grade 10, and many with failed exams in physics. Due to a didactic teaching tradition, not suited for the academically weaker students, the gap between the two groups of students is growing through the teacher education years. Similar problems are known from other low-income nations (Pritchett & Beatty, 2012), and caused partly by the international push for increased enrolment. The Government in Ethiopia has chosen to let candidates into teacher education and further into teaching jobs in spite of failing exams at both levels and also strong evidences of low motivation to the teaching profession. The research suggests changes should be made to the physics curriculum and that pedagogy needs improvement. The current study illustrated that changing the pedagogy in teacher education is possible. However, low entry profile and contextual factors seem to militate against the effectiveness of the change in resulting in the desired learning outcomes. A longer-term solution should focus on the role of English as a teaching language and introduce standards for pre-service teachers going into teaching jobs.

ACKNOWLEDGEMENT

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REFERENCES


TEACHERS’ PERCEPTIONS ON THE OBSTACLES IN THE TEACHING OF SCIENCE THROUGH THE GOWIN V

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This investigation addresses reflective teaching in a learning community that brings together science teachers in initial training (STIT), mentor professors (MP) and a university professor (UP), who is the co-author of this work. The reflection centers on the practical teaching session of STITs when they propose a change in teaching practices at their school focusing on science inquiry and modeling, using the Gowin V diagram (GVD) as a support structure for scientific activity at school. The research question raised is: What are the perceptions of the STITs and MPs regarding the obstacles to the practical implementation of science teaching by inquiry and modeling using the GVDs? A content analysis is performed of the transcripts obtained from (a) semi-structured interviews by case study (STIT-MP); (b) individual interviews of the five STITs and their MPs; and (c) a focus group in which one STIT and MP participated, and another focus group in which only the STIT participated. The analytical framework is based on the model of pedagogical reasoning and action by Shulman and Schön. The results indicate the dimensions in which there is a consensus between the STIT and MP, and point to the development of two levels of reflection based on the consideration of obstacles to the use of the GVDs as an opportunity for educational change in science classrooms.

Keywords: Gowin V diagram, science teacher training, science inquiry and modelling.

INTRODUCTION

The investigation presented in this report addresses reflective teaching in a learning community that brings together the science teacher in initial training (STIT), a mentor professor (MP) and the university professor (UP). The reflection focuses on the practice of the teaching of STITs when they propose an educational change in science teaching at their school focusing on science inquiry and modeling, using the Gowin V diagram (GVD) as a support structure for scientific activity at school (Izquierdo et al, 1999 and Caamaño, 2011). We approach the professional knowledge acquired by the STIT and the MP in this experience from the connotation of reflective teaching given by Zeichner (2010), and we characterize it based on two frames of reference. On the one hand, we have adopted the reasoning model proposed by Shulman (1987) on reflection in relation to pedagogical activity, and on the other hand we have used the ideas of Schön (1992) on the importance of reflection "on actions." The question that has guided the research we present is: What are the perceptions of the STITs and MPs about the obstacles to the practical implementation of science teaching using inquiry and modeling with the GVD?

The model of pedagogical reasoning and action

In the characterization of professional knowledge, we have followed the model of reasoning proposed by Shulman (1986) in pedagogical actions through the understanding of the important concepts to be taught, obtained through the reflections made by the professors. Figure 1 shows
the pedagogical model of this research, which we understand as a cycle in which the teacher achieves an understanding of the content he teaches in such a way that it allows him to convert it into representations that would be for the students, so as to make it "teachable". It also includes the ideas of Schön (1992) about the importance of the reflection "on the action" in the training of teachers, by making it easier for each participant (PFI-PG and PU) to feel they are an important part of the process, with a discourse and experiences that educate the others (Moss, 2010) and that make it more likely for them to improve from the others (Canning, 2011).

Figure 1. The model of pedagogical reasoning and action of Shulman (1987) and Schön (1992)

This model suggests that in the preparation and teaching, the professors are inspired by sources of knowledge that we have identified as: knowledge of the content, didactic knowledge of the content, curricular knowledge, general didactic knowledge, knowledge of the goals and objectives, knowledge of the students, and knowledge of the contexts, frameworks, and educational management. Shulman (1987) points out that these sources for understanding make the process of reasoning and pedagogical action possible. The process of transformation that each teacher carries out is related to the different sources of knowledge, the most important of which is the didactic knowledge of the content. This owes to the fact that this method for knowing and understanding the subject is what distinguishes a professor from a specialist in the field. In this sense, the author indicates that the didactic knowledge on the subject (PCK) is built with and on the basis of the knowledge of the content, the general didactic knowledge, and the knowledge of the students.

Schneider and Plasman (2011) have studied for the didactic knowledge of content for two decades, and have identified five broad fields of PCK (1) orientation for teaching science, (2) how to think about science, (3) instructional strategies in teaching science, (4) the science curriculum, and (5) the evaluation of science students. All these areas of the PCK have components that characterize the field of knowledge.

Therefore, a description of the expected PCK of science professors is rather complex, and even more so for teachers undergoing their initial training, and as described by Borko and Putnam (1995), the teachers' knowledge has a significant impact on the decisions made by the professors. Therefore, "... to help teachers change their practice, we must help them expand and develop their systems of knowledge." (Borko and Putnam, 1995, p. 37).
The role of reflection in the construction of professional knowledge of the PFI.

A key aspect of the initial training must be the consideration that future teachers of science and teachers learn to teach not only from practice, but also from a rigorous analysis of that practice. This reflective approach clearly expresses the ideas of a questioning taking place "in" and "on" the action (Schön, 1983, 2002) and those of the professor as researcher (Stenhouse, 1987, Perrenoud 2010). According to Schön (1983, 1987), the point at which it becomes clear that reflection is necessary comes when a familiar routine produces an unexpected result, when an error resists being corrected, or when, for whatever reason, we begin to observe the results produced by the routine actions in a different way. This author emphasizes that professionals must learn to frame and rethink the problems they face, test various interpretations, and modify their results (Hatton and Smith, 1995, p. 3).

On the other hand, Zeichner (1993) points out that the reflection done on the basis of the practice is based on two essential principles. The first recognizes the professional status of educators and their central role in the teaching and learning process; the second establishes the capacity of the teachers to generate pedagogical knowledge. From this perspective, the teachers' knowledge is useful and allows them not only to develop practical knowledge but to investigate their practice and to produce theoretical knowledge, so this understanding goes beyond and is not limited merely to applying ideas created by other people.

The reflection, shared as part of a formative triad (PFI-PG and PU) allowed us to question the practice carried out in a space of broad reaching conversation, without hierarchical relations; in fact, it enabled the interaction and participation among everyone and the valuation of different viewpoints and experiences from different reference contexts (Walkintong, 2005). One essential aspect among the participants was to break away from the hierarchical view on the process of the practice (Zeichner, 2010; Russell & Martín, 2011), to feel like they are among their peers, and to pose convergent or divergent positions, to offer solutions, to ask questions, and to build new alternatives from the situations that have been established. Specifically, in the case of our study, the obstacles perceived by the participants while proposing a different class to the traditional one.

From our perspective, the training of a future teacher from this point of view suggests the integration of theory and practice, not so much in the traditional requirement that theory should illuminate practice, but rather that from a reflection "on the practice", a theory may then be built.

METHODOLOGY

This descriptive investigation corresponds to a multiple-case study (Stake, 1998). The subjects were five STITs, all of them women, studying their fourth year of a degree program in Pedagogy in Natural Sciences, at the University of Bio Bio in Chile, as well as five MPs from five different schools. The change in the initial training required the STITs to learn how to design a different class, characterized by integrating science teaching by modeling (Izquierdo 1995; Izquierdo et al, 1999; and Caamaño, 2011) with the use of the GVD as support strategy for science inquiry and modeling (Windschitl et al, 2008). The research was carried out during the six weeks of pedagogical practice of the STITs. Before it began, we met with the MP of the
establishment, and the STIT to organize the teaching unit and orient the classes. After that, the MP and UP observed the classes of the STITs, and once they finished, reflected on the obstacles facing their teaching for each case study. The instruments used for collecting the data included: (a) semi-structured interviews for case study (STIT-MP); (b) individual interviews with the five STITs and their MPs; and (c) the focus groups, one of which included the participation of the STITs and MPs, and the other focus group with only the STITs. The thoughts expressed by the STITs and MPs regarding the obstacles were analyzed by semantic networks, following the model of pedagogical reasoning and action of Shulman and Schön, which includes the following dimensions: (a) understanding of the concepts; (b) transformation of their design to the context; (c) method of teaching with the GVDs; and (d) evaluation.

DISCUSSION AND CONCLUSIONS

The results of the reflection on the obstacles faced by the STITs and MPs in teaching in the classroom using investigation and modeling with the GVD are presented based on the model of pedagogical reasoning and action of Shulman (1987) and Schön (1992) through semantic networks, as shown in Figure 1.

A. Understanding of concepts and objectives. All the STITs questioned their scientific competences. The STITs (1, 2, 5) recognize the gaps in their conceptual understanding by establishing their design and complexity by means of hierarchizing them (STITs 2, 3, 5). For their part, the MTs point out that the concepts need to be organized before teaching them, as shown in Table 1.

Table 1. Understanding of concepts and objectives of STIT and MT

<table>
<thead>
<tr>
<th></th>
<th>STIT1</th>
<th>STIT2</th>
<th>STIT3</th>
<th>STIT4</th>
<th>STIT5</th>
<th>MT1</th>
<th>MT2</th>
<th>MT3</th>
<th>MT4</th>
<th>MT5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual gaps and mistakes</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
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<td></td>
<td></td>
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<tr>
<td>Ranking concepts</td>
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<td></td>
<td></td>
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<tr>
<td>Complex to Organize</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Necessary to teach earlier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Scientific procedures</td>
<td></td>
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<td></td>
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<tr>
<td>Teaching explicitly</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Deficient in applying them</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

B. Transformation of their design to the context. Adapting and transforming the didactic proposal to the context. The STITs 1, 4, and 5 indicated their difficulties in creating questions ready for investigation (STITs 1, 2, 4). Both MTs and STITs indicate how complex it turned out to be for their students to work with a contextualized problem with the GDV by relating
the concepts, constructing their research-ready design, and incorporating scientific arguments in preparing their conclusion (Table 2).

Table 2. Transformation of their design to the context for STIT and MT.

<table>
<thead>
<tr>
<th></th>
<th>STIT1</th>
<th>STIT2</th>
<th>STIT3</th>
<th>STIT4</th>
<th>STIT5</th>
<th>MT1</th>
<th>MT2</th>
<th>MT3</th>
<th>MT4</th>
<th>MT5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create investigation-ready question</td>
<td>X</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Look for an appropriate problem</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>Problem, phenomenon – activity</td>
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<td></td>
<td>X</td>
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<tr>
<td>Problems in relation with concepts-scientific practice-conclusions</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

C. Forms of teaching. In the classroom, the difficulty of STITs 1, 4, and 5 in instilling discipline became clear. The work mechanism that was most effective for the STITs and MTs was their exposure to the professor following the group collaborative work, due to the necessity to improve the management of the classroom climate by the STIT. All STITs agree that this change of focus favors developing scientific research skills in their high school students; only STIT 1 and MT (2, 4.5) refer to it in developing the scientific method (Table 3).

Table 3. Forms of teaching with the didactic proposal for investigation and modeling with GVD.

<table>
<thead>
<tr>
<th></th>
<th>STIT1</th>
<th>STIT2</th>
<th>STIT3</th>
<th>STIT4</th>
<th>STIT5</th>
<th>MT1</th>
<th>MT2</th>
<th>MT3</th>
<th>MT4</th>
<th>MT5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty in managing the classroom</td>
<td>X</td>
<td></td>
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<tr>
<td>Work method in the classroom</td>
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<tr>
<td>Only presentation by professor</td>
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<tr>
<td>Presentation by professor and collaborative work in groups</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Only collaborative work in groups</td>
<td>X</td>
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<tr>
<td>Purpose of strategy for change</td>
<td></td>
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<td></td>
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<tr>
<td>Developing scientific research skills</td>
<td></td>
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<tr>
<td>Applying the scientific method</td>
<td>X</td>
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</tbody>
</table>

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D. Evaluation of teaching. For the STITs and MTs, this dimension involved confronting their own beliefs about their didactic model "of teaching the same way I was taught" (the traditional model) against the alternative model of investigating and modeling using the GVD. In the interaction between STITs and MTs, it became clear that there were low expectations on their students' learning abilities (STITs 1, 2), and how the fear and insecurity in the case of STITs 1, 4, and 5 influenced their practical development with this innovation (Table 4).

Table 4. Evaluation while teaching with the didactic proposal by investigation and modelling with GVD.

<table>
<thead>
<tr>
<th>Beliefs</th>
<th>STIT1</th>
<th>STIT2</th>
<th>STIT3</th>
<th>STIT4</th>
<th>STIT5</th>
<th>MT1</th>
<th>MT2</th>
<th>MT3</th>
<th>MT4</th>
<th>MT5</th>
</tr>
</thead>
<tbody>
<tr>
<td>I teach the way I was taught</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>I continue creating an ideal course</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>Expectations (self-efficiency)</td>
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<tr>
<td>Low, students unmotivated</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>High, students motivated</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Emotions</td>
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<td></td>
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</tr>
<tr>
<td>Insecurity-Fear</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confidence performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DISCUSSION AND CONCLUSIONS

The obstacles for which the greatest consensus between the STITs and MPs has been reached were, firstly, those related to understanding the concepts and objectives of the GVD. And secondly, they also coincide in their identifying of the complexity their students face in relating the concepts, constructing their researchable design and incorporating scientific arguments in its conclusion.

The STITs and MPs show discrepancies in relation to the obstacles to the acquisition of scientific skills and the scientific method. In the STIT-MP interaction, different levels of reflection were shown on the basis of the identification of obstacles. While STIT1 only acknowledges the obstacles and repeatedly notes the security given by the traditional model, "With the traditional class, you are clear on the concepts your professor gives you to guide you, and how they will be given to you at any time during the class, it’s easier to schedule it.” (Focus grup STIT [7:72] [51]).

STITs 2, 3, 4 and 5 point out that the obstacles served as an opportunity for them to learn to change their way of teaching:

"The reality of the classroom helped me grow, in the sense of being able to stand in front of a classroom to teach a different kind of class, using GVD. Now I believe that the changes in my
offering to the class depends on myself, and not on limiting myself to the traditional class with the textbook.” (STIT 4- M T [36: 40] [70]).

In the reflexive triadic space, the PFIs had the opportunity to question their lack of creativity in conceptualizing a problem or phenomenon in keeping with the subject matter of the class, together with their MTs, which was reflected by STIT 3: What are the activities that would allow my students to learn better? Or STIT 4 in: How am I going to design my class? It also involved a critical and flexible attitude for them in assuming their own limitations and incorporating improvements into their work (Zeichner, 1993). For their part, the MTs valued the leadership of the STITs as indispensable in achieving learning, indicating that “it’s impossible to learn in a chaotic situation”, and in the classroom, it is the teacher who is responsible for providing a climate conducive to learning.

The result of the shared reflection between the STIT, MP, and UP generated professional knowledge that involved a collaborative exercise to improve the practical teaching session of the STIT based on the identification of obstacles. We believe that the initial training from this approach differs from the traditional focus, in which theory enlightens practice, but is enriched when theory is constructed on the “reflection on practice” by linking the initial training of the STITs with practical training at schools and from research.

ACKNOWLEDGEMENT

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RESEARCH ON TEACHING AND LEARNING IN BIOLOGY, CHEMISTRY AND PHYSICS IN ESERA 2013 CONFERENCE

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This paper provides an overview of the topics in educational research that were published in the ESERA 2013 conference proceedings. The aim of the research was to identify what aspects of the teacher-student-content interaction were investigated frequently and what have been studied rarely. We used the categorization system developed by Kinnunen, Lampiselkä, Malmi and Meisalo (2016) and altogether 184 articles were analyzed. The analysis focused on secondary and tertiary level biology, chemistry, physics, and science education. The results showed that most of the studies focus on either the teacher’s pedagogical actions or on the student-content relationship. All other aspects were studied considerably less. For example, the teachers’ thoughts about the students’ perceptions and attitudes towards the goals and the content, and the teachers’ conceptions of the students’ actions towards achieving the goals were studied only rarely. Discussion about the scope and the coverage of the research in science education in Europe is needed.

Keywords: science education, didactic triangle, meta-study

BACKGROUND

Holistic understanding in the field of the educational research is important for anyone who is mentoring and tutoring pre- and post-graduation students. Such knowledge calls for carrying out many years of systematic research on the different fields of education. This is not an easy task, and typically the researchers specialize in a narrow area of expertise in order to gain deep insight in some special area. However, the research community as a whole could achieve versatile and holistic understanding on the field, even though individual researchers may concentrate on narrower areas. While this may seem self-evident, we wish to raise the question, whether we, as a research community, have indeed studied the instructional process from a wide enough range of viewpoints.

Several researchers have done a considerable amount of work in order to build a big picture of the research in science and technology education. For example, Tsai and Wen (2005), Lee et al. (2009), and Tsai et al. (2011) analyzed almost 2000 papers published 1998–2007 in the most popular journals of the science education research. They searched for trends in research topics from preschool to the university graduate level. They analyzed the origin of the authors, and the nature of the contribution, that is, whether the papers included empirical work, theoretical work, a review or presented a position. They found out that the number of papers in both learning-conceptions and learning-contexts categories had increased during the years. Lin et al. (2012) found that more than 70% of the papers had a focus on learning contexts, and the number of such papers had significantly increased during the somewhat same years. Chang et al. (2009), in turn, found out that conceptual change and concept mapping are one of the most researched areas in the field. Other much-researched topics were professional development, and the nature of science and socio-scientific issues. Some other aspects include, for instance,
research type and design, authors' country, and research foci (Lin, Lin & Tsai, 2014; Wu et al., 2013; Tan, Chai, Tsai & Lim, 2012). Another recent approach to identify emerging research themes and core publications, as well as to get an overall picture of the research field, is citations analysis (see, e.g. Tang & Tsai, 2016; Tand et al. 2016; Tang et al., 2014). However, all the studies mentioned above have used a data driven approach, that is, the classifying categories have emerged from existing data. Such a method shows what research is being published, but can reveal only those aspects found in the data. Kinnunen’s (2016) and others’ approach allows us to reveal such aspects of research, which the theoretical framework suggests, but which have not been researched and thus provides guidance for future research.

The categorization system has its origin in the didactic triangle as presented by Kansanen and Meri (1999) (Figure 1). Kinnunen (2009) extended it considerably when presenting her new categorization system, which has been later on applied with some adjustments in several studies by Kinnunen et al. (2010; 2013a; 2013b; 2014; 2016). The triangle presents the relations of three main aspects in the instructional process, the teacher, the student, and the content to be learned. The vertical arrow describes the teacher impact on the student - content relationship, typically regarded as the teaching. However, in this context it covers both the teacher’s pedagogical actions, his/her views of students’ learning and their actions to achieve the learning goals, as well as teacher’s reflection to his/her didactical actions. The diagonal arrow, in turn, describes the student's experience of the pedagogical activities and feedback on them. These aspects and their various relations form the basis for identifying categories for research foci.

Figure 1. Didactical triangle.

The foundational view of the didactic triangle as teacher-student-content relationship can be extended to a broader view to take into account the different educational and societal dimensions (Table 1). Similar relationships exist across teaching organizations, students studying in degree programs and the contents of several courses or a whole curriculum. The pedagogical actions of the organization influence the students’ learning processes during their degree studies, and students are frequently asked feedback on these courses. Furthermore, similar relations exist in the society in an even wider scale, between the educational organizations of the whole society, citizens and the general goals of education. Finally, teaching and learning phenomena can also be discussed in an international context (international level), as some pedagogical actions, such as PISA evaluation studies, are operated as international activities. We can present multiple scope of the didactic triangle, as follows in the Table 1.
Table 1. Extension of the didactic triangle from the course scope to the teaching organisation, society, and international scopes.

<table>
<thead>
<tr>
<th>Scope</th>
<th>Course</th>
<th>Organization</th>
<th>Society</th>
<th>International</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>Community of student</td>
<td>Citizens</td>
<td>Citizens of nations</td>
<td></td>
</tr>
<tr>
<td>Teacher</td>
<td>Organization</td>
<td>Society</td>
<td>Nations</td>
<td></td>
</tr>
<tr>
<td>Course content</td>
<td>Degree program/curriculum</td>
<td>National curriculum</td>
<td>International goals</td>
<td></td>
</tr>
</tbody>
</table>

In this study, we analyze science education research papers published in ESERA 2013 conference. We see the ESERA-conference as one of the most important conferences in the field of research of science education and therefore the conference proceedings represent one of the most important data pools in this area.

Our main research question is: On which aspects of the teaching and learning process have biology, chemistry, and physics education researchers focused in ESERA 2013 conference?

**METHOD**

Our typology identifies research in eight main categories, and several subcategories within them (Table 2). Here we do not go in depth concerning the development of the categories since it has been documented in detail in our previous work (Kinnunen et al., 2016). Three categories derive from the nodes of the triangle and five other categories derive from the interaction pathways (Figure 2). Two interaction pathways were divided into subcategories to better separate different forms how the relations may manifest themselves; the student-content relationship (Category 5) and teacher’s impact on it (Category 7). All of the categories are applicable in different levels.

![Figure 2. Coding of the areas of interest (1 - 3) and the interaction pathways (4 - 8) in the didactical triangle.](image)

Most papers included content which could be categorized in several categories, for example, a description of a novel teaching intervention (7.3), pretest results (5.1) and posttest results (5.3), as well as students’ feedback on the intervention (8). We decided to report only the three most significant categories in which the paper could be included. Thus we, for example, did not
include category 8, if the student feedback was included in one paragraph or a few sentences only.

Additional dimensions include the scope of data collection in the paper, if any (course / organization / national / international) and educational level (from pre-school to university), as well as data analysis methods. The guidelines that we have applied concerning the scope dimension include the following: 1) course scope denotes data collection in a single course, which may have parallel versions, 2) organization scope denotes the same/similar course in several institutes, or several courses/whole program in one institute, 3) national scope is used in cases where the data covers significant share of national level education, like several courses in several institutes, and 4) international scope is used in cases when data is collected from at least two countries and the results include some comparison between countries. We acknowledge that the borderlines between these categories cannot be strictly defined, and in several cases the decision was made by consensus after joint discussion.

Finally, we listed also for each paper, the country of origin of the authors, as well as, whether the papers used quantitative and/or qualitative data analysis methods or was merely descriptive in nature. This information was collected to allow us identify any finer nuances among the main categories.

We chose to analyze the papers published in the ESERA 2013 conference proceeding which was the newest publication on the time the analysis started. The data pool comprise 327 papers of which 184 papers were approved for analysis and 143 papers were excluded. The research group focused on the biology, chemistry and physics education and on the upper secondary and the tertiary level education. These disciplines and the educational levels had best match with the expertise and the educational background of the research team. All other papers were excluded from the data pool.

The analysis started by each author of this paper individually reading the articles and identifying all research foci, scope and levels based on the categorization system. To improve the quality of the analysis, the group selected one tenth of the reviewed article randomly and re-reviewed the categorizations. It was agreed beforehand that majority of the reviewers (three fourths) must categorize the paper similarly and only small variance was allowed to exist. Some variance might exist in manuscripts that comprised more than one foci. The re-review showed that individually done categorization produced too much variance and the entire data pool had to be re-analyzed. The analysis method had to be improved and re-analysis was done in pairs. Two researchers read the manuscript independently and then they had a pair discussion about the categorization. Final categorization was based on the pair discussion. Most problematic cases were introduced to the whole research group. The research group discussed the paper profoundly and the final categorization was based on the co-decision. Consensus was also used in a few cases where the paper had a very descriptive nature and we could not conclude clearly what categories would be relevant (in these cases there were not any research questions mentioned, nor clear reported data to help us in decision making). In these cases the paper was deemed out of scope.
Table 2: List of categories and their definitions. The number of the categories correspond to the numbers of the nodes/arrows in the Figure 2. Note that each category operates at four levels: course, teaching organisation, society, and international levels

<table>
<thead>
<tr>
<th>Category name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Goals and contents</td>
<td>The goals and/or contents of a course, study module, goals of a degree program.</td>
</tr>
<tr>
<td>2. Student</td>
<td>The student’s characteristics (e.g. gender, level of education)</td>
</tr>
<tr>
<td>3. Teacher</td>
<td>The teacher’s characteristics.</td>
</tr>
<tr>
<td>4. Relationship between the student and the teacher</td>
<td>How the student perceive the teacher (e.g., studies on how competent students think the teacher is) or the teacher perceive the student.</td>
</tr>
<tr>
<td>5.1 Student’s understanding of and attitude about goals and contents</td>
<td>How student understands a central concept at the course or how interesting student finds the topic.</td>
</tr>
<tr>
<td>5.2 The actions (e.g. studying) the student do to achieve the goals</td>
<td>Student’s actions include all actions/lack of actions that are in relation to learning and achieving the goals.</td>
</tr>
<tr>
<td>5.3 The results of the student’s actions</td>
<td>The outcome of the studying process. E.g., studies that discuss the learning outcomes after using a new teaching method would be placed into this category.</td>
</tr>
<tr>
<td>6. Relation between the goals/contents and the teacher</td>
<td>How teachers understand, perceive or value different aspects of the goals and contents.</td>
</tr>
<tr>
<td>7.1 Teacher’s conceptions of student’s understanding of/attitude to goals/contents.</td>
<td>How teachers think about student’s perceptions and attitudes towards goals and content. E.g., studies on what kind of knowledge teachers have on student’s understanding of some central concept/process.</td>
</tr>
<tr>
<td>7.2 Teacher’s conceptions of students’ actions towards achieving goals</td>
<td>Teacher’s perceptions of the student’s actions (e.g. studying).</td>
</tr>
<tr>
<td>7.3 Teacher’s didactic activities</td>
<td>The teachers’ didactic actions (e.g. lecturing, providing a learning environment, assessment methods)</td>
</tr>
<tr>
<td>7.4 Teacher’s reflections on his/her own didactic actions</td>
<td>E.g., to what degree teacher thinks the new teaching method was successful.</td>
</tr>
<tr>
<td>8. Relation between student and teacher’s didactic actions to enhance learning</td>
<td>How the students feel about the teacher’s didactic actions (e.g. course feedback)</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

The data pool comprise 174 papers published in the ESERA 2013 conference proceeding. All papers were classified based on the Kinnunen’s and others (2016) categorizing system. Distribution of papers in different categories are shown in the Table 3. Most popular aspects were the student-content/goals relationship (Category 5, 51 %) and teacher’s impact on that relationship (Category 7, 27 %). Some interest was paid on the content/goals of the education (Category 1), the teacher-content/goals relationship (Category 6), and the students’ feedback on the teacher’s teaching (Category 8). All the other aspects were much less studied. In this
study we will concentrate on the most frequently studied aspects whereas findings concerning the other aspects, such as, how the distribution of the papers differ between ESERA 2013 proceedings and NorDiNa journal forum, or Europe and the other countries, or in different disciplines, or many other aspects will be reported elsewhere.

Table 3: Distribution of foci in different categories in ESERA 2013 conference. Note that most papers included more than one foci.

<table>
<thead>
<tr>
<th>Category</th>
<th>Nfoci</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>5%</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>3%</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>2%</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>5.1</td>
<td>77</td>
<td>23%</td>
</tr>
<tr>
<td>5.2</td>
<td>22</td>
<td>7%</td>
</tr>
<tr>
<td>5.3</td>
<td>72</td>
<td>22%</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>6%</td>
</tr>
<tr>
<td>7.1</td>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>7.2</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>7.3</td>
<td>84</td>
<td>25%</td>
</tr>
<tr>
<td>7.4</td>
<td>6</td>
<td>2%</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>6%</td>
</tr>
</tbody>
</table>

Category 5

When we took a closer look to the figures in Category 5, we found out that majority of the studies were concentrating on either students’ knowledge and attitudes (5.1/28%) or students’ improvement in these areas (5.3/24%), but notably less studies concentrated on the students’ study methods (5.2/11%) (Table 4). Most popular combination of foci were investigating both the students’ knowledge or attitudes and their improvement in these aspects (5.1 & 5.3/30%). All other viewpoints were notably scarce.

Table 4: Distribution of research interest in different categories in the Category 5. (Note: Percentages are rounded figures)

<table>
<thead>
<tr>
<th>Category</th>
<th>Npaper</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 The student’s understanding of and attitude about goals and contents</td>
<td>35</td>
<td>28%</td>
</tr>
<tr>
<td>5.2 The student’s actions to achieve the goals (e.g. studying)</td>
<td>13</td>
<td>11%</td>
</tr>
<tr>
<td>5.3 The results of the student’s actions</td>
<td>29</td>
<td>24%</td>
</tr>
<tr>
<td>Papers focusing on 5.1 and 5.2</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>Papers focusing on 5.1 and 5.3</td>
<td>37</td>
<td>30%</td>
</tr>
<tr>
<td>Papers focusing on 5.2 and 5.3</td>
<td>4</td>
<td>3%</td>
</tr>
<tr>
<td>Papers focusing on 5.1, 5.2, and 5.3</td>
<td>2</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>123</td>
<td></td>
</tr>
</tbody>
</table>

Few tentative explanations could be given to the findings. From the school education point of view, the Category 5 lists all the studies that deal with the students’ studying in its manifold manners. Learning the contents and the change of the attitudes belong to the foundational goals of the education in all levels. Therefore, the generality of the Category 5 is somewhat self-evident. From the research point of view the situation is the same. Analysing the learning preconditions and investigating the students’ studying habits and finding out what they have learned comprise the foundational ground for the teachers’ teaching plans, the curriculum development and more general educational changes.
However, the distribution of the studies in different subcategories in the Category 5 was uneven and we wish to make few notions and remarks based on the finding. In an ideal situation the studies would distribute evenly in different subcategories. We could say that we have studied well the entire learning process and we have a good comprehension about it: the prerequisites of the learning, the students’ studying habits and the learning outcomes. Unfortunately, our findings show that this is not the case. The distribution of the studies in different subcategories is uneven and clearly we pay much more interest on the preconditions and the outcomes than on the studying methods.

One tentative explanation for this could be the easiness. The studies about the preconditions and the outcomes of the studying process are somewhat easier to carry out than investigations of the studying methods. The preconditions and the outcomes may be investigated by questionnaires, tests, web-forms and quizzes whereas the investigations concerning the studying methods typically require some form of observations and/or interviews. They might require that the researcher spends considerable time in the classroom collecting the field data or analyses other observational data, such as audio or video recordings. The classroom observations take much time both to collect and to analyse the data than the simpler “paper-and-pencil” tests, which might show it as an unattractive, time-consuming and demanding approach.

Another tentative explanation could be the nature of the data. Unfortunately, the teachers, the school heads, the parents, and the policy makers are often more interested in the quantitative aspects than the qualitative aspects. They follow intensively what grades are needed to enrol to the school, how the students’ course grades change during the school year and how many of them continue their studies to the next educational level. Much less interest is paid on the students’ well-being and their actions in lessons and in everyday life. These so called soft values are taken into consideration merely on populist speeches and writings, but weigh much less in the school budget debates. It is fair to say that the educational policy and the educational research are in dualistic relationship; they both depend on the other, also benefits from each other. The policy makers need quantitative data to support the decision making process and the researchers produce it. The researchers need resources for their research that is perhaps more easy to get if the outcomes of the research are usable from the financier point of view. Consequently, research on preconditions of the learning (5.1) and the learning outcomes (5.3) are measure more frequently than the student’s studying (5.2)

We should also take into consideration the areas of interest of the academic audience and not to blame only the needs and interests of the policy makers. It is plausible that many of the studies focusing on the classroom actions are descriptive in their nature and for that reason they seem uninteresting from the academic audience point of view. A study reporting merely the students’ study habits without evidence on their learning progress might be too tedious or even considered insignificant.

However, there is also the third option for the small number of studies in the Category 5.2 that somehow we justify the students’ study methods by the claim that good learning results speak for themselves. If the students’ performance tests show that they are progressing in learning well and there are no bad news heard from the school, is there really a need for investigating
the teaching and learning habits at all? They must be good, shouldn’t they? We wish to note that this kind of thinking pattern is a threat to all education and we should never justify our actions just by easily observable and collectable data. On the contrary, we should know much more about the students’ study methods and increase the number of research focusing on this issue. The better we comprehend how the good learning results are gained the better we can avoid the pitfalls on this path.

Finally, we should take into consideration the possibility that most of the studies of the Category 5.2 are published somewhere else, for example, in the forum of the ethnographic or the social science studies.

**Category 7**

Altogether 27% of all research papers focused on the teacher's impact on the student-content/goals relationship (Category 7). This made it the second most frequently studied aspect in the didactical triangle. The majority of the studies were concentrating on the teacher’s pedagogical actions (7.3/92%) and all other viewpoints were notably scarce. Only very few studies were focused on how teachers see the student’s understanding or attitude to the goals or contents (7.1/1%) and none of the studies focused on teacher’s view on the student’s actions achieving the goals (7.2/0%). Also the studies focusing on teacher’s reflections on his or her own teaching were rare (7.4/3%) as well as studies focusing on more than one point of view (7.3 & 7.4/3%). See the Table 5.

**Table 5: Distribution of research interest in different categories in the Category 7. (Note: Percentages are rounded figures)**

<table>
<thead>
<tr>
<th>Category</th>
<th>N_paper</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 The conceptions of teacher(s) of students’ understanding/attitude to goals/contents.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>7.2 The conceptions of teacher(s) of students’ actions towards achieving goals</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>7.3 Teacher’s didactic activities</td>
<td>81</td>
<td>92%</td>
</tr>
<tr>
<td>7.4 Teacher’s reflections on his/her own didactic actions</td>
<td>3</td>
<td>3%</td>
</tr>
<tr>
<td>Papers focusing on 7.3 and 7.4</td>
<td>3</td>
<td>3%</td>
</tr>
</tbody>
</table>

We begin the analysis of the Category 7 from the school education point of view. This category comprises all the studies that deal with the teacher’s teaching in its manifold manners. The research on the teacher’s didactical actions and the continuous refining of our conception of the teaching - studying dynamics comprise one of the cornerstones of all educational actions. Research on the teacher’s teaching constitutes the foundational basis of the educational development and therefore the generality of the Category 7 was not particularly surprising. However, the distribution of the papers in the different subcategories was even more uneven than in the Category 5 and the striking majority of the studies were placed on one subcategory that deals with the teacher’s didactical actions (7.3). True, the teacher’s didactical actions are in the heart of instructional processes and partly explains its’ frequency among the study foci.
Another tentative explanation to the uneven distribution of the papers is the category 7 could be the nature of the publication forum. The primary aim of the ESERA conference is to serve as a publishing channel for the latest scientific findings in the area, but by the same token it serves as a springboard for young researchers, as well as a discussion forum for the experienced researchers. It is not particularly uncommon to submit to the conference proceedings a well prepared working paper, a descriptive paper without study design, or manuscripts about the first hand research findings of the ongoing research. In other words, the threshold level for the acceptance of a manuscript in the conference proceedings is somewhat lower than in the academic journal and therefore descriptive papers may be a bit more common. For example, we compared the categories 5 and 7 and found out that actually the descriptive papers were more common in the Category 7 than 5. Nearly one third of the papers in the Category 7 were classified as descriptive (27/88 or 31%) whereas only little above one fifth of the papers in the Category 5 (27/123 or 22 %). Another notable aspect was that in the Category 7 all these papers were placed in the one subcategory 7.3 where as in the Category 5 the papers were distributed to all three subcategories or to the combination of these subcategories. A plausible explanation for this is that the description of the pedagogical activity (often augmented with pedagogical design arguments) was used only to explain the intervention and the main focus of data collection and analysis lied in Category 5. Actually, in only a few papers the teacher’s actions were the target of data collection, for example, in the form of observations or interviews.

From the research point of view, there is the possibility that our instrument lacks at least some resolving power in this particular area. We acknowledge that, perhaps, the analysis instrument has not yet reached of its complete form and still needs refinement and improvement. For example, we did not separate pedagogical actions from assessment practices, which could have been categorized as its own subcategory of the Category 7. Therefore, we understand that the accuracy of the instrument could be better and it may produce obscure results in some occasions. Even though resolution of the instrument could be improved, it does not explain why similar finding was found in the NorDiNa journal data pool, too (see Kinnunen et al, 2016). Therefore, at this point of the research we have some challenges to define if the instrument lacks resolving power in this particular area or is it an accurate observation and a true finding that we tend to focus our research very much in this small yet important area of interest.

On the other hand, the small number of the studies in any other subcategory was duly noted. Only a few papers focused on how the teachers perceive the students’ knowledge or attitudes (7.1/1%), or on the students’ actions in different kind of learning situations (7.2/0%), or on the reflection of their own teaching (7.4/3%). It seems that we pay much more interest on the teacher’s teaching actions than on the teachers themselves. Many academics and scholars underline the importance of the reflective thinking in order to improve his or her own teaching, but our finding shows the opposite. The teacher’s thinking, their views on the students’ thinking or their own reflections are studied very infrequently. As argued before, we acknowledge the possibility of limited resolving power of our instrument in this particular area of interest. However, we have investigated the other areas of interest, too, such as the teacher - the content relationship (Category 6) and the teachers themselves (Category 3), which corroborate the finding in the Category 7. In both latter mentioned cases, the frequency of the studies are not
even close to the popularity of the Categories 5 and 7. More elaborated analysis of this area will be presented in the follow up studies.

To sum up, we wish to justify the question that have we as a research community been too much occupied with ensuring that what is taught is right and true and should not we be more concerned about the finding that we know too little about how the teachers perceive the students as learners, or the teachers themselves? It is well documented that the teacher’s awareness and beliefs concerning the purpose of the school work, the rules governing learning, and the possibilities the learning environment offers, are crucial for educational changes. We hope that these studies are reported elsewhere, in some other academic forums that concentrate more specifically on research in these aspects. The other publishing forums could be those that have a more broad pedagogical scope, such as, ECER conference (European Conference on Educational Research) or EARLI conference (European Association for Research and Instruction).

CONCLUSIONS

The educational research in science education across Europe and beyond seems to focus on either student’s knowledge and skills or teacher’s teaching, but many other points of view of the teaching, learning, and the studying process are poorly investigated. Especially alarming is the lack of studies focusing on students’ study methods, student’s feedback to teachers’ teaching actions and teacher’s reflections of their own teaching actions. We truly hope that these other viewpoints are not really missing but are published in other publication forums and therefore do not appear in our data pool. Nevertheless, more research in this field is necessary.

Implications of this study range from classroom instruction to educational research and beyond. Research has direct and indirect influence to society, especially to national curriculum development actions, educational practices and more broadly to the education as a whole. If the educational research focuses on few aspects only, it is plausible that the researchers, the research group leaders, the policy makers, and many other relevant stakeholders do not get all the relevant information that are needed for educational change and at least in some extent may jeopardise the educational renovations. For example, our data pool shows that categories 5 and 7 are much more studied than any other aspect in the didactic triangle. Similar findings were noted in Kinnunen’s and others study on 2016 that investigated the science education research published in NorDiNa journal and therefore the findings of our current study does not seem just a single finding, an anomaly, but some sort of trend that is important do investigate more.

From the ESERA conference point of view it was interesting to find out what kind of research has been done, how it is done, what kind of findings has been reported and compare the trends with the countries outside the Europe. The ESERA conference proceedings covers educational research from the pre-primary level to the university level, many disciplines and many nations. The conference is namely European, but participants represent many nations and continents outside Europe. In our data pool, about three fourths (73%) of the papers were classified as European and the remaining one fourth comprise all other nationalities (27%). The data pool is rather small and therefore generalizations are highly tentative. However, the distribution of
studies in different categories in the didactical triangle is very much similar between Europe and other nations. We will present more detailed findings on this issue in the follow-up studies.

From the methodological point of view, the data-analysis method designed by Kinnunen and others (2016) and applied in this study produce more reliable results if the content analysis of the papers is based on a group work rather than each researcher reading the papers individually. As a thumb rule, the more researchers read the same paper, the more reliable the results of the analysis will be. We found out that individually done categorization produces too much variance, but work-in-pairs clearly improves the quality of the analysis. Work-in-groups would produce even more reliable results, but based on our experience in the previous study (Kinnunen et al., 2016), the more people read the paper, the slower the analysis becomes. Therefore we recommend the work-in-pairs or the work in small groups (3 - 4 persons) for those who plan to apply our methodology in their own study.

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COMPETENCE-BASED TEACHER EDUCATION:
DEVELOPING A MODEL FOR INTERDISCIPLINARY
TEACHING-LEARNING CONCEPTS

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This study analyses competence-based teacher education, which addresses the current developments in the German education system. The changing conditions call for teaching concepts that integrate content knowledge (CK), pedagogical content knowledge (PCK), pedagogical knowledge (PK) and teaching experience in the natural sciences. Based on the examination of established models and theories, our research group created a Munich Model which identifies and structures potential influence factors and their interrelations underlying the German education system. The model focuses on innovative teaching-learning concepts which suggest a cross-disciplinary integration that can be applied to biology, chemistry, physics and mathematics. Strengthening the interdisciplinary perspective, the model provides teaching methods of experimenting, modelling and verbalizing that are significant for all natural sciences. According to the design-based research approach, first applications of the model in biology, chemistry and physics pursue further theoretical development and empirical evidence. This competence- and evidence-based understanding offers valuable insight not only to teacher education but also to higher education in natural science.

Keywords: conceptual models, higher education, initial teacher education (pre service)

CURRENT DEVELOPMENTS IN THE GERMAN HIGHER EDUCATION SYSTEM

Strengthening the quality of teacher education in the field of natural sciences continues to be an important aim for German universities. Specifically fostering the students’ professional capabilities is critical to enhance their success as future teachers (Bauer & Prenzel, 2012; Grossman, 2011). The responsibility for the education system in Germany is determined by the federal structure of government, meaning educational conditions and teacher education differ between the 16 federal states. Basically, teacher training is divided into two stages, a course of higher education at university and practical pedagogical training at school and teacher training institutes (preparatory service). In the first period at university the training is composed of (i) a scientific component; (ii) an educational science component; (iii) teaching practice. This article focuses on this first period for teaching careers at (1) Gymnasium (upper secondary academic track) and (2) in vocational subjects at upper secondary level or at vocational schools. Both types can be studied at the Technical University of Munich in Bavaria. In the former case the scientific component involves at least two equal subjects (e.g. Chemistry and Mathematics) and the subject-related didactics. In the latter case, students have to choose a vocational subject area (including at least one year working experience) and a second teaching subject. The current changes in the German education system regarding the implementation of national education standards and the resulting new curriculum call for a further development of the universities’ teacher education that stresses competences to integrate, adapt and apply
knowledge. While European countries, such as Finland established a competence-oriented teacher education Germany still shows a discipline-focused university curriculum (European Comission, 2011; Jorde & Dillon, 2012).

To support an innovative development of teacher education, the Federal Ministry for Education and Research launched the “Quality Offensive” (Qualitätsoffensive) as a competitive policy initiative and funded 59 German universities, which highlights the relevance attributed to this aim. As a part of this initiative, our research group at Technical University of Munich therefore aims to create teaching concepts that integrate content knowledge (CK), pedagogical content knowledge (PCK), pedagogical knowledge (PK) and teaching experience in the natural sciences.

THEORETICAL BACKGROUND

To identify potential influence factors on the development of a multi-disciplinary knowledge, one must be aware of the basic structures underlying the education’s processes (Shulman, 1987; Abell, 2007). Theoretical models discuss the process of teacher education, its influence on the development of teachers’ competencies and the resulting effects on the successful learning of pupils (Terhart, 2012). Furthermore, learning opportunities models analyse the relations of factors provided by teachers and factors used by students (Helmke, 2015) and the COACTIVE study, which structures determinants and consequences of professional competencies of teachers (Kunter et al., 2011). The models were evaluated in terms of common elements and their interrelations in order to identify a conceptual pattern (Parchmann, 2010). By establishing a strong theoretical basis, the models offer valuable insight which was subsequently adapted to this study’s specific research interest.

THE MUNICH MODEL

Based on this theoretical analysis, our research group created a Munich Model (Figure 1) in order to evaluate relevant elements and processes of natural science teacher education at the Technical University of Munich. The model consists of five elements, namely university lecturer, teaching and learning concepts, teaching activity, learning activity and students, which are embedded in a context. While the elements university lecturers, students and learning activity closely refer to influence factors discussed in the established models, both elements teaching and learning concepts and teaching activity specifically apply to the natural science teacher education. The very centre shows the teaching and learning concept, which is specified by a cross-disciplinary integration of PCK, CK, PK and teaching experience based on thematic adjustment deriving from the disciplines, structural adjustment of the temporal order and interpersonal collaboration of relevant actors. The closely connected element teaching activity highlights the common methods of the natural sciences biology, chemistry, physics and mathematics, defined as experimenting, modelling and verbalizing. Both teaching and learning concept and teaching activity reveal the education’s further development that needs to be applied at university level to be transferred to school level eventually. To support the process between teaching and learning the model takes reciprocal interaction between the teaching and learning activity as well as feedback between university lecturers and students into account.
highlighting the importance of implicit and explicit communication underlying successful educational concepts.

Figure 1. Munich Model: Analysing Elements and Processes of Teacher Education in the Natural Sciences.

FIRST APPLICATIONS OF THE MUNICH MODEL

Our research group developed exemplary concepts for the students of teacher education in the field of natural sciences at the Technical University of Munich. In biology CK, PCK and PK is linked with the help of the model organism honeybee. In chemistry successively acquired knowledge is integrated in final seminars such as “Advanced Aspects of Chemistry”. In physics the awareness of professional competences in increased with respect to school experimentations by providing additional teaching materials, such as simulations and videos. The Munich Model will continue to serve as a basis for evaluation in terms of the design-based research approach (Collins, Joseph & Bielaczyc, 2004). The practical application of the model thus examines the theoretically identified elements and strengthens its empirical evidence. This competence- and evidence-based understanding offers valuable insight not only to teacher education also to higher education in natural science research. Connecting the different disciplines is regarded as necessary to bridge the gap from theoretical, easy structured exercise to complex professional problems with a practical application of knowledge.

Chemistry: Focus on Structural Adjustment

In the field of chemistry, the focus lies on the structural adjustment of the subject combinations biology and chemistry (B/C) and mathematics and chemistry (M/C) which are available in teacher education for Gymnasium. In order to standardize the subject combinations’
requirements and contents as well as their competence-orientation, innovative teaching and learning concepts were developed and implemented during different stages of the study program. In the following, three examples of these concepts are presented:

**Basic Laboratory Course in Inorganic Chemistry:** Prior to the structural adjustment, the subject combinations (B/C and M/C) differentiated in terms of their content and scope. Yet the students were expected to accomplish the same competences at the end of their study program. The structural adjustment therefore aims to standardize the conditions, to strengthen the aspects of PCK as well as to deepen the teaching practice. These didactical aspects involve the competence to experiment, the appropriate technical capacities, the accurate handling of chemicals and laboratory facilities as well as the safety arrangements and disposal process. Furthermore, the experiments are discussed regarding their theoretic content and practical applications (such as a qualitative substances’ analysis). Also, the accurate experiment protocol is an important aspect. An additional seminar focuses on the teaching practice and how the experiments could be realized. In advance to the course, a teaching video on the online platform Moodle offers instructions on how to set up the laboratory facilities and visualizes basic working techniques.

**Supplement Course to Chemistry of Non-metals:** A further seminar specifically addressing students in teacher education complements the corresponding lecture and provides insight to scientific content. The lecture is designed for both students in teacher education as well as chemistry students and therefore demanding in terms of scientific knowledge. The supplement seminar thus strengthens the scientific basics such as chemical equation and complex Lewis- and structural formula and their comparisons. Taking into account that chemistry students participate on such seminars in their regular study program, it is critical to develop such seminars for students in teacher education as well. Furthermore, the specific focus on students in teacher education allows the discussion about school context, applications and limits of different models as well as challenging theories.

**Advanced aspects of inorganic Chemistry:** The course is an optional module for the Master program for both subject combinations (B/C and M/C). In this course cross-disciplinary concepts deriving from the basic chemistry, the inorganic chemistry as well as the physical chemistry are being discussed in the context of the First State Examination (*Erstes Staatsexamen*). This session aims to address concepts of chemical processes, their range of applications as well as their evaluation and precise oral (and written) presentations. In their presentations, students have to link their scientific knowledge with given examples, choose appropriate media and accurate scientific language. This approach to complex scientific research questions also highlights the didactical reduction and reconstruction. The developed courses and seminars are implemented to the university’s study regulations as optional sessions and recorded to the students’ academic qualification.

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1 After the first period of teacher education for Gymnasium students in Bavaria still have to pass a central organized First State Examination.
Physics: Focus on Content Adaption through School Physical Understanding

Many lecturers report that students hardly rely on their content knowledge from their physics courses (especially theoretical physics) for the preparation and planning of lessons (school internships or as part of seminars). At best, students reproduce what they still know from school. One possible reason for this might be the enormous gap between physics at university level and on a school level. Overcoming the first transition is rather the responsibility of the usual physics courses than of didactics courses. Subsequently the main task of didactics is to connect the theoretical physics of the university with school physics to assist the second transition. However, with only few compulsory courses in didactics and the huge spectrum of subject contents, physic didactics can hardly achieve this aim. Furthermore, many themes lack teaching material, which links physics on a university and school level. The aim of the work in the field of physics is to provide a low-threshold offer of courses and course supplements, which complement the theoretical physics course, enrich the follow-up regarding school physics and serve for the later lesson planning. In order to achieve this goal, the courses “School Physical Extension Course of Electrodynamics” and “School Physical Extension Course of Quantum Mechanics” provide suitable content on an e-learning platform using digital teaching and learning formats. Students benefit from further support in these topics, as they appear in the Gymnasium, and because university-students have serious difficulties in the according courses in theoretical physics. Starting in the 5th or 6th semester in the bachelor program, students can take part in the courses parallel to the corresponding courses in theoretical physics.

School Physical Extension Course of Electrodynamics: The structure of this course is in close relation to a course of theoretical physics of electrodynamics. The focus lies on the connection to the Gymnasium, with some remarks to the lower secondary level. Each unit centers a simple school experiment and its theoretical description. Units contain two main sections. Firstly, the concepts and representations of theoretical physics are examined from a didactic point of view. Secondly, the major part of a unit is the interconnection of theoretical physics and the contents of the physic didactics as well as textbooks. The way of an elementarization and didactic reconstruction, and its success, is examined in detail. Additionally, the main content of the university content knowledge is practiced. Part of the electrodynamics of the upper secondary level for example are aspects of special relativity. This field represents a very difficult subject, even for many physicists. However, a (prospective) teacher needs a deep and profound understanding of this material in order to be able to elementarize, teach and adequately reply to student issues in the classroom. A theoretical physics course at the university usually only touches this subject lightly.

School Physical Extension Course of Quantum Mechanics: This course is only loosely based on a corresponding course in theoretical physics. Merely the foundations of quantum mechanics, sometimes also called postulates of quantum mechanics, and the presentation of the theory with the Dirac-notation, are discussed similarly. Courses in theoretical physics continue and focus mainly on working with basic examples such as particle in a box, harmonic potential or the Coulomb potential. Illustrative questions, e.g. the measurement problem or Bell’s inequalities, are rarely further discussed. The e-learning course picks up such topics and discusses them extensively as they are often presented in school books and thus prompt
questions by pupils. At school these scientific topics are reflected by four (in Germany well known) teaching concepts for quantum mechanics: 1st: Berlin Concept (Fischler & Lichtfeldt, 1992), 2nd: Bremen Concept (Niedderer, 1992), 3rd: Munich Concept (Müller & Wiesner, 2000), 4th: The Karlsruhe Physics Course (Herrmann, 2000). Beside scientific correctness of the respective elementarization, also the models and modeling in physics and physics didactics and their visualization is focused. In physics didactics, the Bohr atomic model is critically discussed. In all teaching concepts, however, there are different alternative models for the calculation of atomic energy levels. As part of the e-learning course, the in accuracy varying models are analyzed to the extent that a new model was created which reproduces the well-known formula of the hydrogen atom.

Once these e-learning courses have been developed, they can be continued with little effort. Furthermore, they have a modular structure, thus individual elements can be used in other courses of physic didactics and could therefore contribute to a comprehensive digitalization concept. By critically examining the existing materials for linking university and school physics, existing shortcomings of both school and university textbooks can be addressed, improved and extended. The results go beyond the mere teaching of existing content, but constitutes original material for future publication in journals.

Mathematics: Focus on Thematic Adjustment in the Vocational Education Studies

Developing innovative teaching-learning concepts for students in mathematics vocational education, the main aspect to take into account, is their heterogeneity. There are various reasons for the students’ heterogeneity including the different professional qualifications, the selected specialization of their studies or the lack of specified times for the curriculum. However, students in different stages of their study program, with different prior knowledge attend the same lectures.

Analysis 1 for Vocational Education: To get an understanding of the students’ different qualifications a basic test regarding school mathematics was developed. Based on the findings a preparatory course specifically for students of mathematics in the vocational education will be established. The preparatory course addresses the different levels of knowledge, challenges and requirements of the students in more detail. Furthermore, the preparatory course highlights the importance of content knowledge for future teachers, straight from the beginning of the study program. This should strengthen the students’ motivation and interest for mathematics. In addition, the didactical as well as pedagogical aspects are accentuated, by training how to identify pupils’ difficulties, give feedback and ways to structure a lesson.

Linear Algebra 1 for Vocational Education: Bachelor modules for vocational education in mathematics consist of a lecture, an exercise and a supplement course. Specifically, the supplement course offers the chance to develop new teaching and learning concepts linking pedagogical content knowledge and mathematics. During the supplement course the students select a mathematical proof and present their approach to their fellow students. Prior to this course, a presentation discusses appropriate ways to address mathematical proofs, potential difficulties and aspects of PCK. To highlight the relation between the students’ future professional practice and the theoretical material of the university lecture, final school
examinations (integral/differential calculus) were chosen as topics. In their presentation, students incorporate aspects of teaching methodology. Furthermore, the module offers the use of digital media. By means of an iPad and the teaching-learning App “Explain Everything”, the students independently created a teaching video, which is discussed in the supplement course. The use of digital media offers the chance to get to know a new working method, which engages the students in an interactive way. Thus, not only the scientific knowledge is trained but also the use of digital teaching methods.

To allow the sustainable implementation, the regular staff will continue the new teaching-and-learning concepts. Assistance for the implementation is given by providing the guideline presentation for students and an additional how-to manual for iPads and the used Apps. After repeated concept testing, the method is to be continued on a permanent basis and included to the curriculum.

Biology: Integrated Teaching-Learning Concept based on a Model Organism

The biology curriculum shows, that different research fields such as botany, microbiology, molecular biology, ecology, physiology, behavioural biology or zoology are taught isolated from each other and therefore lack systemic understanding. The following teaching learning concept thus aims to link the fields based on the model organism of the honey bee. The concept consists of the lecture Beekeeping (Apiculture), a following didactic seminar and subsequent teaching practice.

Lecture Beekeeping: The scientific lecture “Beekeeping” presents theoretical and practical scientific knowledge and is open for students from different study programs (teacher education and natural sciences). It focuses on the species’ variety, the connection of organisms with their environment as well as the threats caused by anthropogenous and natural influences. Horizontal connection to further areas, such as botany, is shown by the pollination performance of bees. The lecture is complemented by a microscopic labwork course for university level addressing the functional anatomy of bees, the identification and treatment of diseases among bees as well as the evaluation of biodiversity. The model organism of the honey bee provides a wide range of applications throughout the curriculum. This lecture is open for students from different study programs.

Didactic Seminar: The scientific lecture is complemented by a biology didactic seminar “Innovations in teaching Natural Sciences – The Model Organism Honey Bee”, addressing specifically students in teacher education for Gymnasium and vocational education. In this seminar, selected topics of the lecture are presented in a didactical way. The seminar focuses on methods of natural science epistemology, such as the process of thinking and working, as a core competence for future biology teachers. The seminar also involves molecular biological analysis at the out-of-school learning environment “Schülerforschungszentrum Berchtesgadener Land” to introduce current research methods such as DNA-extraction, PCR, restriction digests of DNA and the gel electrophoresis, which are usually not used at schools. The technical facilities, the methodical processes as well as the settings are discussed in terms of scientific, didactical and practical aspects. A further experiment for advanced pupils is the classic conditioning of honey bees regarding scents. The experiment focuses the different
phases of scientific insight as well as the possibilities and limits of the respective research methods (light microscopy vs. molecular biology). The students prepare the practical application in a didactical way and identify the scientific epistemology and research questions.

School practice: The subsequent teaching practice takes place at either a collaborating Gymnasium or at some authentic contexts outside the classroom such as laboratories or the Schülerforschungszentrum Berchtesgadener Land. Furthermore, the developed concepts may also be realized as a seminar addressing advanced pupils at the Technical University of Munich. The didactical aspect offers the link of theory and practice in the biology study program. During the development of their projects, the students are supported by a professional teacher as well as a didactic lecturer. Thus, they can benefit from the expertise of a teacher while planning the practical application with pupils at the Gymnasium. Also after the students submitted the experiments’ plan and application, the teacher reflects and discusses the work to suggest challenges and improvements. Furthermore, the teacher reviews the lessons taught by the students and discusses further option of teaching practice to strengthen the training for school practice.

The presented concept linking biology science (CK), didactical science (PCK) and school practice based on the model organism honey bee, has been established successfully and is appreciated by the students. The concept can be applied to different research fields and model organisms and thus serves as an example for competence-orientated teaching-learning processes.

**Professionalization Concept**

Strengthening the sustainable implementation of competence-oriented teaching, a professionalization program offers training and coaching. The program addresses lecturers in the field of teacher education, who differ regarding their scientific knowledge, their cross-disciplined understanding as well as their individual pedagogical competence.

**Professionalization Trainings:** To date, eleven trainings created a setting to discuss the different aspects of competence-orientation (e.g. metacognitive strategies or teaching method for concepts such as cooperative learning or inquire-based learning). A further focus lies on digital learning (e.g. digital learning at schools or in higher education). The trainings are separated into subject-specific sessions (e.g. digital learning in the teacher education for chemistry and physics) and cross-discipline sessions addressing lecturers from different fields (e.g. giving and receiving feedback). The content of one training series is repeated in the subsequent training series, to enhance successful learning. The trainings are designed discursively to support the exchange between the participants. To meet the individual needs of the participants, the group consists of six to ten lecturers and takes three hours.

**Professionalization Coaching:** To strengthen an individual approach and offer specific support, a professionalization coaching offers direct support in seminars, lectures or tutorials in teacher education. Depending on the design of the session and also the number of participants (lectures, students), different tools can be applied to the coaching process: observing and evaluation tools of the session, video recordings of the lecturer or interviews with the students. The results are discussed responsively with the lecturer. The way and the scope of the coaching
is up to the lecturer. The coaching should at least cover two sessions but can be extended to the whole semester (6 months).

The elements of the Professionalization Trainings and the Professionalization Coaching complement each other: the training sessions, group discussions and questionnaires analyse the challenges and needs of the participants, which subsequently can be addressed on the coaching sessions. Coaching methods, that are most successful reciprocally discussed in the training sessions. This interplay creates a sustainability, which is strengthened by teaching videos that are created so far. The sustainable documentation of teaching videos will be developed further to contribute valuable insight to the trainings and coaching sessions. Sustainable learning success will be achieved by continuous repetition and ongoing support.

**DISCUSSION**

The innovative teaching-learning concepts strengthen the competence orientation by linking and connecting science (CK), didactics (PCK), pedagogy (PK) and school practice. The previous examples show that this aim can be achieved in different ways: structural adjustment, content-related alignment, digital complementary documents, and online courses to adapt cross-disciplinary competences. It is critical that lectures highlight the interrelations between disciplines so that the students become aware of their meaning.

The Munich Model shows that there are influence factors which are constituted by university specific conditions. These factors include the established standards of German teacher education, the teaching examination regulations and the university’s specific study regulations as well as different university locations. For the successful development and implementation of innovations, it is yet important to take those factors into account, as they shape the context.

Strengthening competence orientation to teacher training, explicit references highlight the interrelations between corresponding themes deriving from science and didactics. Identifying the link between the lectures, redundant repetitions can be revealed and avoided. As shown in the examples, competence orientation may not only be achieved content-wise but also in terms of teaching-learning activities: working methods, scientific language, use of media. Especially the natural sciences chemistry, physics and biology focus on the process of epistemology and its implementation by means of practical experiments. Especially the working method modelling offers different options of digital or analogue visualization, which can be compared and discussed in terms of their benefits and limits. The use of digital media promotes the communication competences and prepares the students for teaching at school. The app “Explain everything” for example offers processes of verbalisation and the training of appropriate scientific language. Participating on scientific lectures and intensive courses strengthens the in-depth knowledge and facilitates the approach to the respective field of science. In mathematics, this aspect is realized by supporting students individually and drawing on appropriate media to enhance verbalisation processes. A further important aspect regarding competence orientation is the close collaboration with partner schools of the university. This exchange offers the possibility to implement an innovative concept to school practice. A further success factor is the option to present different aspects of the scientific field on the basis of one model organism as shown in biology and the teaching learning concept of the honey bee.
Moreover, the professionalization concept establishes the dialogue and collaboration with different faculties in order to enhance didactical, pedagogical and practical processes as well as digital teaching and learning.

The continuous exchange with different actors allows a cross-disciplinary basis for communication. The aim is to create a common language, in order to build teaching-learning concepts that can be integrated across faculty borders. Including all actors involved actively, and taking their ideas and decisions into account prevents a refusing attitude towards innovative developments (Gräsel & Parchmann, 2004), and thus strengthens the sustainable implementation of innovative teaching-learning concepts.

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IDENTIFICATION OF LEARNING OPPORTUNITIES FOR THE PROMOTION OF DIAGNOSTIC ABILITIES IN PRIMARY TEACHER EDUCATION DURING LONG-TERM INTERNSHIPS

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Diagnostic abilities are seen as a crucial aspect of professional knowledge. Study results point out that these abilities should be already promoted during teacher education at university. Furthermore, recent research shows that formal learning opportunities in the first phase of teacher education are important for the development of professional knowledge. Because of the relationship between theory and practice, internships play an important role in this phase of education. However, there is a lack of knowledge regarding future teachers’ learning opportunities in practical situations. The present study attempts to identify possible learning opportunities concerning the promotion of diagnostic abilities during long-term internships in primary teacher education for a special German subject ‘Sachunterricht’. ‘Sachunterricht’ combines several disciplines of social and natural sciences at primary school. In this study, experts from school and teacher trainings centres will be interviewed to gain insight into their expectations concerning the relevance and viability of potential learning opportunities. The results are analysed using qualitative content analysis. Additionally, a questionnaire is developed and given to a larger group of teacher mentors from school and teacher trainers of teacher training centres. The goal of the questionnaire is to figure out, to what extent teacher trainers agree with the interviewees.

Keywords: internship, primary teacher education, diagnostic abilities

INTRODUCTION

Long-term internships implemented in teacher education at university are, as a rule, subjectively rated positive. As an example, master’s degree teacher students from University of Duisburg-Essen considered the experiences they made throughout the ‘Praxissemester’ - a special long-term internship in the first phase of the teacher education in the federal state of North Rhine-Westphalia- as an important preparation for the second phase of teacher education in Germany. The direct exchange with students and teachers provides them a realistic insight into ‘how school is run’ and ‘what is important at school’. From the educational policy perspective, high expectations are associated with this long-term internship: The framework for the contents and structure (MSW, 2010) embraces a broad range of intended learning and development goals. Due to the high relevance of diagnostic abilities of teachers for the initiation of sustainable learning processes in class (Helmke & Schrader, 1989 quoted in Helmke, 2012; Brunner et al., 2012), competences for diagnostic abilities are formulated and can be found in this framework. These competences cover a wide range of diagnostic activities, as they are described for example by Ingenkamp & Lissmann (2008): from the diagnosis of the students’ current abilities and interests to the development of assessments of the students’ learning progress (MSW, 2010).
For the acquisition of diagnostic abilities during the internship, appropriate learning opportunities are required. It has not been clarified yet, which of the diagnostic abilities postulated by the curriculum are already considered in teacher education at school and which learning opportunities are given or can be implemented under the conditions of the subject ‘Sachunterricht’ (Hascher, 2012, König, Tachtsoglou, Darge & Lünemann, 2014).

**AIM OF THE STUDY**

The study’s purpose is to identify and operationalize learning opportunities in the subject ‘Sachunterricht’, which promote the diagnostic abilities given by the competences and standards stated by the framework for the contents and structure of the long-term internship.

**THEORETICAL BACKGROUND**

**Learning Opportunities as a Basis for Students’ Learning Processes**

Following the model of the COACTIV research program (Kunter, Kleickmann, Klusmann & Richter, 2011; p. 67) explicitly provided learning opportunities in teacher education at university are seen as a prerequisite for the development of future teachers' professional competence (Figure 1).

![Figure 1. Model of the determinants and consequences of teachers’ professional competence from the COACTIV research program (Kunter et al., 2011, p. 67).](image)

Results with moderate effect sizes from the follow-up study COACTIV-R (Kleickmann & Anders, 2011) confirm that the development of professional competence is influenced by differences in the explicitly provided formal learning opportunities. Considering the diagnostic abilities as part of the professional competence of teachers (Brunner et al., 2011), it can be expected, that they can be promoted by learning opportunities in various learning settings at university. Results of recent research focusing on teacher judgment accuracy, show the compelling need to promote diagnostic abilities throughout teacher education at university and the further education level (Südkamp, Kaiser & Möller, 2012). Therefore the special long-term internship in the first phase of German teacher education seems to be an appropriate opportunity to foster these abilities in a practical context.

In internships the connection between theory and school practice is of major significance. Thus, learning processes of the students are stimulated and organized by addressing theories and concepts in various university courses (Arnold, Hascher, Messner, Niggli, Patry & Rahm, 2011). But how could learning opportunities at the learning place school be designed? In
practice, the academic reflective knowledge (Radtke & Webers, 1998) has to be used depending on action situations in the lessons of the subject ‘Sachunterricht’. Following Arnold et al. (2011) learning opportunities in teacher education at school can be seen as action situations arising from practical actions, which give the students the opportunity for focused experiences (Arnold et al., 2011, p.224). Thus, related to the present project learning opportunities in the long-term internship are defined as explicitly provided action situations for students, in which the teacher students can carry out diagnostic activities in the subject ‘Sachunterricht’ and in which they can discuss diagnostic issues based on theory.

The action situations are provided or enabled by the teacher mentors from school and the teacher trainers from teacher training centres.

Table 1 shows the implementation of these action situations in the teaching-learning settings according to the framework for the ‘Praxissemester’ (MSW, 2010):

**Table 1: Teaching-Learning Settings in the ‘Praxissemester’ at school.**

<table>
<thead>
<tr>
<th>Offers by teacher mentors at school</th>
<th>Offers by the teacher trainers</th>
</tr>
</thead>
<tbody>
<tr>
<td>classroom observations</td>
<td>introductory course</td>
</tr>
<tr>
<td>lesson planning and teaching</td>
<td>reflection of lesson planning and teaching</td>
</tr>
<tr>
<td>small specific student research projects</td>
<td></td>
</tr>
</tbody>
</table>

In these teaching-learning settings action situations need to be established, in which students’ diagnostic activities are initiated considering various approaches (cf. König et al., 2014):

- Classroom observations, in which the teacher students have the opportunity to observe teacher mentors and other teacher students performing diagnostic activities,
- Lesson planning and teaching, in which teacher students plan diagnostic activities based on theory and reflect their realization supported by the teacher mentors and teacher trainers,
- In small specific student research projects the teacher students have the opportunity to focus on diagnostic issues (for example: to evaluate student misconceptions),
- In introductory courses at the teacher training centres, teacher students’ practical experiences in the field of assessment can be discussed and analysed based on theory.

Considering the theory-practice problem the identification of potential learning opportunities are of high relevance for school practice and teacher educational research.

The identification of potential learning opportunities allows linking learning experiences at university with learning experiences in school practice deliberately. If this connection is missing, following Arnold et al. (2011, p. 227), teacher students would learn in ‘separated

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worlds’. This could lead to the situation, that the usefulness of theory for school practice is in question (Weyland, 2012, p. 61).

Potential learning opportunities are identified by using the expertise of teacher mentors from school and teacher trainers from the teacher training centres for the subject ‘Sachunterricht’, who have experiences supporting students during the ‘Praxissemester’.

**RESEARCH QUESTIONS**

The study is expected to provide answers to the following research questions:

**RQ1:** From the view of teacher mentors from schools and teacher trainers from teaching training centers: Which action situations concerning the promotion of diagnostic abilities are seen as relevant and viable by the teacher mentors and teacher trainers?

**RQ2:** Which parameters lead to these perceptions?

**RQ3:** Which of the identified action situations are actually implemented in this teacher training situation?

**RESEARCH DESIGN AND METHODS**

Figure 2 gives an overview of the design of the study.

![Research Design and Methods Diagram]

For answering research questions one and two interviews with teacher mentors and teacher trainers are conducted. The interview guide follows the main principles of Helfferich (2009). Therefore, the interview is separated into different phases. This allows focusing on different dimensions, which are necessary for answering research questions one and two. Table 2 gives an overview of the different phases of the interview.

Hereafter, the interviews are analysed using qualitative content analysis to identify possible learning opportunities. The results of the interviews are presented to the experts for communicative validation (Steinke, 2013). Based on the results a questionnaire is developed, to check, if other teacher mentors and teacher trainers agree the assessments of the
interviewees. During the internship, teacher students, teacher mentors and teacher trainers will be asked which learning opportunities have been provided and used. Therefore, a second questionnaire will be developed and used. Thus, the third research question will be answered.

Table 2: Interview structure.

<table>
<thead>
<tr>
<th>Phases</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td><em>Expectations towards the ‘Praxissemester’: subjectiv theories concerning the contribution of the ‘Praxissemester’ for teachers’ professionalization should be identified → Which learning needs of the student teachers are noticed by the teacher trainers? Do diagnostic issues play an important role? Which learning situations are relevant from the view of the teacher trainers? Are diagnostic issues relevant from the view of the teacher trainers? How should the learning situations be designed for promoting meaningful learning? (RQ1)</em></td>
</tr>
<tr>
<td>Phase II</td>
<td><em>Actual state: Which diagnostic abilities are already promoted during the ‘Praxissemester’? → indicating viability of learning opportunities (RQ 1)</em></td>
</tr>
<tr>
<td></td>
<td>Identification of difficulties regarding the investigation of diagnostic issues; reasons for the missing implementation → relevance and viability (RQ1)*</td>
</tr>
<tr>
<td>Phase III</td>
<td><em>The second phase of German teacher education: Identification of difficulties regarding the investigation of diagnostic issues: What is possible during the second phase of teacher education? Why is it possible? (RQ1)</em></td>
</tr>
<tr>
<td></td>
<td><em>Which abilities should be acquired by the teacher students at university? (RQ 1)</em></td>
</tr>
<tr>
<td>Phase IV</td>
<td><em>Comparing the competences and standards to be acquired in the ‘Praxissemester’ and the identified action situations / difficulties: Could all competences and standards have been considered / have all competences been considered in action situations? (RQ 1&amp;2)</em></td>
</tr>
<tr>
<td>Phase V</td>
<td><em>Closing</em></td>
</tr>
</tbody>
</table>

**FIRST RESULTS - THE INTERVIEW AS A METHOD TO IDENTIFY POTENTIAL LEARNING OPPORTUNITIES**

For the generation of learning opportunities/action situations and for answering research questions one and two, guided interviews with teacher mentors (TM) and teacher trainers (TT) have been conducted and audiographed (TT: $N = 6$; TM: $N = 3$ participants).

The first four interviews have been carried out between June, 2017 and July, 2017. In accordance with Kuckartz (2014, p. 78), after the transcription an *initiated text work* has been conducted: The transcripts have been analysed considering the research questions by marking relevant or noticeable text segments.

In the following, first remarkable statements from the interviews are presented.

*Relevance of lesson planning and teaching for acquiring diagnostic abilities (Phase I-RQ1)*:

All participants appreciate the long-term internship as a valuable opportunity for the students to learn how to plan lessons for ‘Sachunterricht’ aligned with the learning preconditions of the students in authentic application situations. Thus, they generally support the relevance of diagnostic abilities and the viability of their promotion during the internship.
But at present, debriefing sessions are not explicitly used to promote diagnostic abilities. This can be drawn from the answers to a further interview question from Phase II. This question aims at identifying action situations, which are already used for the promotion of diagnostic abilities in the context of reflection of lesson planning and teaching in debriefing sessions (actual state analysis).

Referring to this, the interviewees said, that the debriefings are not yet explicitly used for diagnostic issues.

**Reasons for the missing implementation of action situations promoting diagnostic abilities in debriefing sessions (Phase II-RQ1 &2):**

All teacher trainers stated the cause of this missing implementation in the personal advisory needs of the teacher training students. It seems, as if subject didactic issues are hardly relevant for the students. Even though the students have already the possibility to reflect their teacher personality during further internships of the Bachelor’s programme, it seems as if it is still one of the most important aspect in the ‘Praxissemester’.

One teacher trainer assumes a progression of relevant issues during the debriefings in the different phases of teacher education as described in Figure 3:

**Figure 3. Progression of relevant issues during the debriefings, as it is assumed by one of the interviewed teacher trainers.**

Moreover, the teacher trainers consider the lesson content as a necessary aspect of the debriefing sessions. Three teacher trainers report difficulties of the students to analyse the lesson content adequately. Especially referring to supposedly ‘easier’ contents, the students seem to reflect their own knowledge in the run-up to the planned lesson not sufficiently (interviews 1, 2).

From the view of the interviewees, the lack of explicitly provided action situations in the debriefing sessions can be partially explained by the low amount of debriefing sessions and missing binding agreements on main topics (e.g. focus on a subject didactic issue – interview 4).

The first analysis gives a first hint of which aspects could complicate the implementation of diagnostic action situations in practice.

**OUTLOOK - FURTHER INTERVIEW AND DETAILED ANALYSES**

In a next step, further interviews with teacher trainers ($N = 2$) and teacher mentors ($N = 3$) will be conducted. The learning opportunities identified will be presented to the interviewees for
communicative validation. After the compilation of the results, the learning opportunities not considered by the interview participants will be in the focus of a further discussion between the interviewees. On basis of the results of this discussion, a questionnaire will be developed in order to check if further teacher trainers (N = 25) and teacher mentors (N = 100-150) agree with the assessments of focus groups. To answer the third research question, a questionnaire will be used to ask teacher trainers (N ≈ 3), teacher mentors (N ≈ 50) and teacher students (N ≈ 50) during the internship which learning opportunities could have been used.

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Retrieved from: https://www.schulministerium.nrw.de/docs/LehrkraftNRW/Lehramtsstudium/Praxiselemente/Praxissemester/FAQ-Lehramtsstudium-Praxissemester/FAQ8-Lehramtsstudium-Praxissemester/Endfassung_Rahmenkonzept_Praxissemester_14042010.pdf [last access: 30/01/2018] [Framework for the ‘Praxissemester’]


INTERDISCIPLINARY PROJECTS: INTEGRATING NEW PERSPECTIVES IN TEACHER TECHNOLOGY EDUCATION

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The University of Applied Sciences of Northwestern Switzerland (FHNW) has developed a program called EduNaT (Education in Natural Science and Technology) to promote the interest for natural science and technology education by interdisciplinary projects between the different schools within the University of Applied Sciences. The collaborations between the six disciplines benefit from various perspectives on chances and challenges, issues and need for action in the field. At the same time, experts from teacher education, engineering, geomatics, life sciences, technology, psychology, arts and design bring together their specific knowledge and new ideas, what fosters the relation of theory with practice and innovative methods. Within the program EduNaT, 18 different projects have been developed. They not only focus on the development of the pre- and in-service teacher technology education and technology didactics in Switzerland. Some projects also address gender equitable approaches for natural science and technology for all ages or work on making STEM subjects more attractive and available for the society. After an introduction about the program EduNaT, the presentation shows three projects, their interdisciplinary work and the experiences with it. One can learn about new instructional methods in pre-service teacher education and the relation of theory with practice in it, and about the development of professional knowledge of teachers by integrating results of interdisciplinary research projects in their studies.

Keywords: Technology education, professional knowledge of teachers, relation of theory with practice

STRATEGIC INITIATIVE EDUNAT

In Switzerland and many other industrialized countries there are different challenges regarding the scientific and technology education. There is a big deficiency in specialized personnel in scientific and technology subjects as science, technology, engineering and mathematics also known as STEM subjects. Additionally, the number of women who study or work in scientific or technology-oriented fields is very low. Furthermore, the majority of teenagers consider most of STEM subjects as difficult and complex. Due to these and other reasons, in the last years schools, universities and the state focus more on scientific and technology education.

To overcome these deficiencies and to support the focus on improving STEM education, the University of Applied Sciences of Northwestern Switzerland (FHNW) has developed a program called EduNaT (Education in natural sciences and Technology). The major goal of the program is to promote the interest for natural sciences and technology and to strengthen the education in this field. Another aim of the program is to work interdisciplinary between the different schools within the University of Applied Sciences Northwestern Switzerland. The following six different Universities of Applied Sciences are participating in the program: School of Applied Psychology, School of Architecture, Civil Engineering and Geomatics, Academy of Art and Design, School of Life Sciences, School of Engineering and School of
Teacher Education, which is the leading direction of the program.

**Interdisciplinary work**

To work interdisciplinary means that people from at least two different disciplines are working together pursuing the same goal. When working interdisciplinarily the different specialists can benefit from each other and broaden their minds. Also, the maximum result can be achieved as the specialized knowledges of the scientists and researchers can be combined. There are some characteristics which were defined as good and effective interdisciplinary work:

1. **Common object of research as well as common questions and goals:** It is important to define the research questions and the aim of the collaboration at the beginning. One goal should be to combine the different research fields of the participants.

2. **To agree on the method:** The participants agree on the methods they want to work with and how the integration of the different sub-projects should work.

3. **Integration:** The integration of the sub-projects should not be fulfilled at the end only. Already from the beginning a clear definition on how the different sub-projects suit to each other and how they can be integrated in the entire project is needed.

4. **Research director and team building:** A good interdisciplinary work depends on competent research directors and coordination as well as good teamwork. It would be advantageous if the research director already were experienced in interdisciplinary work.

5. **Common language and communication:** A good communication is very important. Main terms have to be defined from the beginning.

6. **Preparation and processing of the results:** Since there are different scientist form different fields working on a common project, the different results should be described and presented understandable and clear for everybody.

**Aim of the program EduNaT**

Within the program EduNaT 18 different projects have been developed. All 18 projects share the following five main objectives. All objectives concern the content of the different projects:

1. Improve the technology education and technology didactics in Switzerland
2. Develop and improve the knowledge and skills of teachers of every level of education in natural sciences and technology and increase the teachers' confidence
3. Analyze the (interdisciplinary) teaching in the scientific and technology field at the FHNW
4. Implement gender equitable approaches for natural sciences and technology for all ages especially teenagers before their choice of study and profession as well as students
5. Make STEM subjects more attractive and available for the society

On the structural and strategy level there are the following two objectives:

- Connect the six school within the University of Applied Sciences Northwestern Switzerland and their employees by common projects in teaching, research, development and further trainings.
• Establish the FHNW as the leading Swiss institution in the field of scientific and technology education and in long-term in the education of STEM subjects.

Structure of the program EduNaT

All involved schools at the University of Applied Sciences were represented in the program control, which met three to four times a year. In the meetings the regulation and control structures have been worked out, the current situation of the program has been discussed, measures have been taken as well as the communication between the schools at the University of Applied Sciences has been ensured. An advisory board of seven people, which met three times as well as a brain trust of four people, which met four times, counselled and accompanied EduNaT.

The draft paper of EduNaT was passed from the program control October 27, 2014. Besides goals, milestones and program organization it already contained a collection of ideas for 21 concrete projects. Out of these, 18 full project applications were submitted in two rounds (April and June 2015). In this process, two experts examined and evaluated every project with the help of given criteria. These reports were an important foundation for the classification of the projects by the program control.

Outcome of the program EduNaT regarding interdisciplinary work

Altogether, the projects achieved the expected goals and effects. With 18 projects and about 70 collaborators, EduNaT contributes to a wide and interdisciplinary network within the FHNW with a meaningful exchange and with impulses for the natural sciences and technology education, also after the program is finished.

The majority of the project reports mention positive effects relating to the competence growth, the integration of different perspectives and the increase of the network. In the cooperation between the Universities of Applied Sciences appreciation, openness and enrichment has been experienced. Nevertheless, the additional effort in time and administration, the bridging of cultural and structural differences and some difficulties in orientation should not be underestimated. In addition, not all involved parties have benefited equally form the projects. For example it is difficult to publish papers with focus in education in scientific communities addressed by the School of Architecture, Civil Engineering and Geomatics, School of Life Sciences and School of Engineering. Looking back it is also to discuss how interdisciplinary the projects really were. The planning of the employees in the single projects could have been done more carefully and fairly long-term. As well as the contribution of every faculty should have been described more clearly. There should have been more attention at the selection criteria of the projects and if there was no real interdisciplinarity it should have been corrected. The program board of control considers an early, intensive and voluntary cooperation as a prerequisite of success.

Nevertheless, the program control noticed the interdisciplinarity as a positive challenge to overcome the described difficulties and to decrease them. It also crystallized that the natural sciences and technology education is a field, which has to be approached interdisciplinarily. The program control is convinced, that with EduNaT a meaningful project for the Northwestern
Some concrete output including strong interdisciplinary work:

- E-Learning-offers and didactic/pedagogical material for primary classes with topics about connection techniques are available through a website.
- Two interdisciplinary courses about experiencing, understanding and teaching technology within the degree course primary teacher at the School of Teacher Education for three ECTS (European Credit Transfer System).
- Four completed workshops including teaching materials about concept-orientated exploration of the field 3D-modelation and 3D-print for students of education professions at the Academy of Art and Design and School of Teacher Education.
- Teaching practice for students at the School of Teacher Education through development and realization of eight workshops for 8 to 11 year old kids in cooperation with students of the School of Engineering.
- Application of an open-source-software for didactic support of the programming class in degree courses of the FHNW.
- Three completed tutorials about “particulates in the air”, “micro pollution in the water” and “noise pollution” on an online-platform for secondary teachers.
- Recommendation of actions for political and school authorities for the promotion of general technical education at elementary schools.
- Three courses for seniors to explore natural science and technology with kids. A concept, which combines the promotion of our kids in the STEM field, the lifelong learning and the dialogue of two generations.
- Two 4-days summer camps with workshops on the campus of FHNW for kids between seven and eleven years.

PRESENTATION OF THREE DIFFERENT PROJECTS OF EduNaT

After this introduction about the program EduNaT, three projects are presented to show the interdisciplinary work and the experiences with it. The reader learns about new instructional methods in pre-service teacher education and the relation of theory with practice in it, and about the development of professional knowledge of teachers by integrating results of interdisciplinary research projects in their studies. Finally, a large-scale project of factors of success in technology education will be presented in detail.

Project "Technology education of primary teachers"

With this project the education of primary teacher students of the FHNW School of Teacher Education should get improved relating to technology perspectives. The focus of the project is to develop a lecture about technology and therefore to improve the understanding of technology education on the level of primary school by more relation to practice. To reach this goal the FHNW School of Teacher Education, the FHNW School of Engineering and FHNW School of Architecture, Civil Engineering and Geomatics work and teach together.
Project "STEM interests in preschoolers and primary school children"

The development of vocational interests is an important task in childhood and adolescence. Vocational interests combined with self-efficacy expectations have been established as major factors for future career choices. Various studies show considerable gender differences in interests and self-efficacy expectations in sciences, technology, engineering, and mathematics (STEM). These differences are one important factor to explain the lasting inequalities in the distribution of women and men in STEM majors and STEM occupations. At what age level gender differences in interests precisely occur and whether there are certain sensitive periods for the promotion of STEM interests has not been established. The project therefore wants to investigate these research questions with a longitudinal study with preschool and primary school children.

Project "Factors of success in general technology education"

In Switzerland pupils are educated first at school and, if they do not continue to upper-secondary education at school in order to graduate with a university entrance examination, they do a three-year dual vocational professional educational training (VPET), i.e. they are meant learn practical theory at a school combined with practical training in an enterprise. The current compulsory school system (= kindergarten, primary and lower-secondary school) is supposed to prepare pupils for either of the two tracks. Yet, often VPET teachers complain that school does not provide a solid basis of technological knowledge to smooth the transition from school to VPET. This problem has been tackled in the new Swiss curriculum (so-called Lehrplan 21, D-EDK, 2016). There, technology education is supposed to be taught at a basic level and is now newly integrated in the subject science and technology, besides the subject technical design or information technology. In Figure 1 the problem of coherence in school-to-practice transition is shown. This means, if transition from school to profession is supposed to be coherent, then we need to agree on a basic technology education, based on practical norms as well as professional standards. These standards then have to be implemented in pre-service teacher education.

Figure 1. The problem of coherence in school-work transition

Research and methodological questions

The central research question in the project aims to get insight into the factors of success in
technology education. So what is "technology education", what is "success" and who determines "success"?

If one takes a look at technology itself, several groups may come to one's mind: professionals, that deal with technology. For example, engineers, architects or technicians; schools and teachers that have to transmit the nitty gritty of technology to students and pupils; and the students and pupils that are the recipients of education and instruction. From our point of view, these key groups need to be considered if one wants to get a comprehensive idea of good technology education.

The project we describe here, aims to evaluate factors of success for school technology instruction. Thus, we ask three major groups:

1. Professionals in technology (e. g. engineers) and professionals with a teaching assignment (i. e. professionals teaching in vocational professional educational training)
2. Teachers in compulsory school (kindergarten, primary and lower-secondary school) and teachers in upper-secondary school

One of the major methodological questions that has to be solved is: How can one generalize factor of success in a heterogeneous field of technology definitions?

In the following section we want to briefly explain the evaluation variables that are used in the study. An overview of the evaluation groups and the most relevant variables is presented in Table 1.

Levels of evaluation

The evaluation of professionals in the field of technology as well as VPET teachers (professionals with a teaching position) aims to assess their idea of what technology-oriented content school should teach. This should give an impression of professional demands and standards that should be approached by school education.

Additionally, we ask school teachers about their conception of technology content in school as well as the obstacles they see in implementing technology-oriented instruction. This allows to compare professional standards and educational standards. Evaluating constraints of technology instruction also sheds light on factors of technology instruction implementation. Research projects may build up on these findings and support potential variables.

Another group that is evaluated are pupils and university students. They are asked for their biography and interest in technology in general and about technology content that they experienced during compulsory school. In a questionnaire they are given a content (e. g.: I learnt how a steam engine works.) and had to rate how intense they went through the topic and how interested they were in the topic. The idea is to find out how well school met interests. Also, students and pupils are asked for their "technology idols", i. e. the names of persons on TV, in movies, on the internet, media etc. This item can be used as a proximal indicator for their understanding of technology.
**Expected data analyses and results**

After evaluation, we will try to correlate quantitative data in an explorative framework. At first, we expect differences in pupils' interest and contents taught at school. Also, with reference to qualitative data, differences are expected in the definition of technology and especially educational standards between professionals and school staff, but also between teachers and pupils at compulsory schools.

Table 1: Overview of groups and variables assessed in the project

<table>
<thead>
<tr>
<th>Level</th>
<th>What is/ was taught at school?</th>
<th>How is VPET preparation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>School teachers</td>
<td>If at all, how do you teach technology?</td>
<td>What is basic knowledge everyone should have in technology?</td>
</tr>
<tr>
<td></td>
<td>What support do you need for more technology classes?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What are barriers that hinder your technology instruction?</td>
<td></td>
</tr>
<tr>
<td>Students/ pupils</td>
<td>What did you learn in compulsory school, how did you like it?</td>
<td>What is basic knowledge everyone should have in technology?</td>
</tr>
<tr>
<td></td>
<td>Who are your &quot;technology idols&quot;?</td>
<td></td>
</tr>
<tr>
<td>Professionals</td>
<td>What are essential aspect of a future subject technology?</td>
<td>What is basic knowledge everyone should have in technology?</td>
</tr>
</tbody>
</table>

We expect to find connecting variables that allow to improve the coherence of technological knowledge. Hypothetically, we could approach educational standards from two perspectives: the professional norm and the pupils' interest.

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The assessment of simple experiment by preservice primary teachers

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Inquiry science education is usually accompanied by performing of simple experiments. This empirical study is focused on the investigation whether the pre-service primary teachers are able to design simple experiment oriented on photosynthesis and if they are able to provide formative assessment by the written peer-feedback related to the design of experiment. Pre-service teachers of integrated sciences (n=35) were introduced to the principles of the photosynthesis, respiration and physiology of green plants. After it each pre-service teacher designed his/her simple experiment, which could demonstrate importance of the light for green plants and which was realizable in the classroom. Peer assessment of the experimental design was the second step of the research. The results show that: (1) Experimental design can be useful tool for the identification of knowledge or competence level as well. (2) Pre-service primary teachers are able to prepare relevant experiment but with some mistakes corresponding with lack of the understanding of basic biological principles. (3) This research shows difficulties in the process of formative assessment, lack of experience with assessment and need of better background and support for implementation of formative assessment. Final peer assessment of experiment and additional tasks are often very different in comparison with expected “correct” evaluation.

Keywords: inquiry, primary science, school experiment, peer assessment

Introduction

The subject Integrated sciences taught at primary level consist from parts aimed on topics related to nature and social sciences. The better understanding of basic natural principles can be supported by inquiry and many studies indicate an effectiveness of inquiry-based instructional practices.

Inquiry is an opportunity to improve students’ understanding of key scientific concepts (Rocard et al., 2007). Inquiry science education is usually accompanied by performing of simple experiments. Some experiments are available in textbooks, books, methodical guidelines, web pages etc. Teachers frequently design their own experiments, which fit the concrete specific conditions of class, school or curriculum.

The main challenge for teacher education is to implement inquiry principles into their preparation and encourage teachers to use simple experiments with students’ initiative activities in their lessons (Hart, 2000, Lord, Orkwiszewski, 2006). Simultaneously, when pupils design their own experiment, teacher should assess rightness and quality of experiment with respect to educational goals and pupils’ motivation.

This research investigates whether Czech pre-service primary teachers are able to design simple experiments and whether they are able to assess experimental design created by their classmates. The photosynthesis was selected as convenient subject matter for this research. It represents one of basic principles of life (Reece, Campbell, 2011). The photosynthesis is
commonly explained as a complex of reactions in which solar energy is converted into the chemical energy stored in ATP bonds or other organic molecules, namely sugar (glucose). This process is connected with the nutrition of autotrophic organisms but it is very important for all organisms as main source of energy circulating in ecosystems (Reece, Campbell, 2011). It is possible to specify the photosynthesis (and cellular respiration as well) as process which is associated with systems at multiple biological levels from cells to ecosystems and which illustrates transport of energy through biological systems (Akcay, 2017). Moreover the respiration is associated with the photosynthesis immediately.

Only the essential principles of the photosynthesis are appropriate at primary educational level. Students should understand a conversion of inorganic substances represented by water and carbon dioxide to organic substances such as sugar and the essential role of the light energy as well. They should understand uniqueness of this process and its importance for life. The energy transformations are one of the essentials attributes of the life.

This topic is considered as difficult for teachers and their students (Akcay, 2017). This is accompanied by some additional effects: (1) the problem of choice of a suitable experiment, which is simple, illustrative and well comprehensible for students, (2) is it possible to prepare inquiry lesson(s) and which way, (3) how to assess a students’ work when they design their own experiments oriented on the principles of photosynthesis or respiration.

Research questions:

1) Do pre-service teachers understand basic natural principles? Is it possible to discover it from their products like the design of the experiments?

2) Are pre-service teachers able to design simple experiments aimed on these principles?

3) Do pre-service teachers assess designed experiment as suitable, illustrative, reliable etc.?

METHOD

Pre-service teachers (n = 35) were introduced to the principles of photosynthesis 5 months before start of the research. They designed simple experiment realizable in the classroom, which demonstrate one aspect of the plant physiology – the importance of the light for green plants. Simple drawing in the worksheet was used as a tool for the planning of the experiment. They used two fields in the worksheet for better readability and easier assessment of final drawing. There was prepared simple drawing of the plant in the boxes. The experimental design was presented by sketches and it was accompanied by information about necessary aids, anticipated results of experiment and some other factors affected plant growth in next three fields.

In the second stage, protocols were assigned randomly to pre-service teachers in the same group for the implementation of the peer assessment process with use of evaluative protocol containing the formative and summative part.

Design (sketch), other answers of respondents and evaluative protocols were coded and analysed with basic statistical methods (frequency, percentage). Afterwards the additional data obtained by the questionnaire were also considered in relation to the results of analysis.
RESULTS

The role of the light in photosynthesis was explained by the pre-service teachers (respondents) in the first part of worksheet.

Q: “Why the light is needed by plants?”

Relative large group of respondents (26 %) made mistakes or explained it incorrectly or vaguely. In most incorrect cases, respondents took the light for the respiration as necessary. One respondent considered the oxygen production as main process in the photosynthesis and the light as the essential condition for this. Most incorrect answers laid in an inaccurate formulation within the meaning the light is necessary for plant growth. No answer was referred to basic principles of the photosynthesis, such energy conversion or synthesis of organic substances.

Assessment:

In contrast to this finding all assessors found it as correct explanation (Figure 1). For example assessors did not recognize neutral role of the light in plant respiration. The non-specific answer mentioning the light as condition of life was considered as correct although it do not contain more detailed explanation or reasons. The answers “The light is necessary” or “The light represents one of condition” was found as correct by assessors although it was de facto repetition of the question only. The positive emotional statements were used by all assessors.

![Figure 1](image_url)

Figure 1. The comparison of the explanation of role of the light in photosynthesis stated by respondents (worksheets) and the assessment of assessors (assessment).

Q: “How we can discover that the plants need the light?”

About one half of respondents (49 %) incorrectly defined effect of the light or its deficiency on green plants. For example the flowering or opening/closing of flowers were considered as the phenomenon directly influenced by the light. Some respondents stated the rotation of the flowers or leafs towards the light as the evidence of the light needs not as a result of this. In individual cases respondents connected the light abundance with fruit quality (sweetness) or flower quality (smell), considered visible vaporization (?) as the manifestation of the light...
influence. Many respondents (31%) considered the growth or stopping of growth as an effect related to the light.

Assessment:

About 83% of assessors assessed the answers correctly. That means they evaluated correct answers as correct and vice versa. When negative feedback was used, assessor provided information about deficiencies in the answer of respondent.

Q: “Design an experiment which can demonstrate need of the light for green plants. Experiment should be realized in the classroom.”

Respondents used simple sketches for presentation of experimental design. Design of experiment was usually correct when rough draft is assessed. But completely correct design with all required terms was presented in 4 cases only (11%) (Figure 2). Technical quality of the sketches was not assessed. The assessors focused on the content of picture and its items related to the planned experiment.

Figure 2. Considerable contrast between really correct design of the experiment (worksheets) and the design which was considered by assessors as correct (assessment).

Design of the experiments was very different and varied from incomplete drawings without some necessary details to relative correct drawings with parts which indicate students’ ideas and understanding of the photosynthesis or rather the effect of the light on the plants.

Some sketches represented correct experimental design (Figures 3, 4) and they are representing suitable arrangement but can be incorrect in details. For example flowering or opening/closing of flowers were considered as the phenomenon directly caused by the light. Usually typical can be symbolization of the night or darkness by picture of the Moon (Figure 3). Other sketches contain non-important details on the one hand and crucial items are missed on the other hand (Figure 4).

In several cases, the design/picture included only hint of experimental design. Figure 5 shows experimental design, which represents main idea consisting in comparison of plant lit by the Sun and shaded plant. However, there is not any information about other aids or equipment necessary for the experiment and about condition of the plant.
Table 1. Other factors (except the light) which were considered as important for plant growth (by respondents).

<table>
<thead>
<tr>
<th></th>
<th>Feasibility in the classroom</th>
<th>Light source</th>
<th>Correct shading</th>
<th>Flowering</th>
<th>Leaves look</th>
<th>Soil or flowerpot</th>
<th>Design clarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>34</td>
<td>25</td>
<td>24</td>
<td>12</td>
<td>10</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>%</td>
<td>97</td>
<td>71</td>
<td>69</td>
<td>34</td>
<td>29</td>
<td>40</td>
<td>66</td>
</tr>
</tbody>
</table>

Assessment:

The sketches provide opportunity for recognition of understanding the basic principles of plant physiology connected with the light and allow the easier assessment of the experimental design. But, the assessment is sometimes complicated because it can run into problems with picture quality. At university level, it was not serious problem but demands on skills in reading of the pictures by assessors are important at primary level.

Assessors usually considered design as correct but failed to provide feedback in details, e.g. when necessary aids for plant growing were missing in the experimental design.

In great contrast with number of tiny mistakes, inaccuracies and vagueness most respondents assessed experimental design as fully correct (94%). Nine assessors provided written feedback with additional information, 8 of them expressed positive emotional statement and only one was negative with recommendation of some improvement of the experimental design.

Figure 3. The example of sketch representing suitable experimental design.

Figure 4. The example of sketch representing experimental design with the emphasis on flowerpot, window and light source but without any indication of light effect on the plant.
Figure 5. The example representing incomplete sketch without details.

Q: “Necessary aids for the experiment.”

Respondents presented necessary aids for plant growing. Nobody wrote all needed materials and equipment (Table 2). Respondents considered the light source and shading of the plant as most important but other equipment needed for the experiment was mentioned partly.

It seems that respondents understood main principle of experimental design consisting in comparison of two plants grown in different light conditions but they are not sufficiently careful in details.

Table 2. The overview of necessary experimental equipment presented by respondents.

<table>
<thead>
<tr>
<th></th>
<th>Plant</th>
<th>Light source</th>
<th>Shading</th>
<th>Soil</th>
<th>Water</th>
<th>Flowerpot</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>22</td>
<td>17</td>
<td>26</td>
<td>3</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>%</td>
<td>0.63</td>
<td>0.49</td>
<td>0.74</td>
<td>0.09</td>
<td>0.14</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Assessment:
Assessors stated presented equipment as satisfactory in 89% of cases. They frequently ignored some missing equipment. In contrast, when they recommended completing equipment, it was in 10 cases only. Usually assessors recommended to complete water, flowerpot and better shading or blackout.

Q: “Other factors influenced plant growth.”

Identification of next factors, which affect plant growing (except the light), showed varied spectrum of statements. Water (in 91%) and enough of nutrients (in 63%) were considered as the most important factors. Some respondents mentioned incorrectly relative problematic factors as enough of oxygen, altitude or air etc. (Table 3). This question was not assessed by assessors and inform in fact about knowledge background or problem understanding.
Table 3. Other factors (except the light) which respondent considered as important for plant growth by respondents.

<table>
<thead>
<tr>
<th>Factor</th>
<th>n</th>
<th>%</th>
<th>Factor</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>2</td>
<td>0.06</td>
<td>Cutting</td>
<td>3</td>
<td>0.09</td>
</tr>
<tr>
<td>Animals</td>
<td>6</td>
<td>0.17</td>
<td>Season</td>
<td>1</td>
<td>0.03</td>
</tr>
<tr>
<td>Human</td>
<td>3</td>
<td>0.09</td>
<td>Gravitation</td>
<td>1</td>
<td>0.03</td>
</tr>
<tr>
<td>Saccharides</td>
<td>1</td>
<td>0.03</td>
<td>Altitude</td>
<td>2</td>
<td>0.06</td>
</tr>
<tr>
<td>Biome</td>
<td>1</td>
<td>0.03</td>
<td>Species</td>
<td>2</td>
<td>0.06</td>
</tr>
<tr>
<td>Oxygen</td>
<td>3</td>
<td>0.09</td>
<td>The elements</td>
<td>1</td>
<td>0.03</td>
</tr>
</tbody>
</table>

**DISCUSSION AND CONCLUSIONS**

Designing of simply experiments is very important tool for better understanding of principles of life. Above all, it is crucial part of dynamic disciplines like plant physiology and it is often the best way of instruction for understanding some phenomena. It was found that pre-service teachers are able to prepare simple experiment but with (some) misconceptions.

The answers to research questions stated above are following:

1) Preservice teachers do not understand some basic natural principles correctly. Experimental design could be useful as indicator of understanding of problems by pre-service teachers because they have to apply their own theoretical knowledge in concrete problems or situations. This research supports the assumption that some pre-service teachers work sometimes incorrectly or inaccurately with theoretical knowledge.

2) Especially future primary teachers do not have strong background in science (e.g. biology). Therefore, designing of simple experiments or labs is necessary component of their preparation (at faculty of education). Most of pre-service teachers are able to prepare simple experiment but they are not careful in details and can have problems with correct explanations what happens during experiment and what is the core of the experiment.

3) Assessment of inquiry is not easy and it is impracticable without deep understanding of basic principles and theoretical background of experiments. It is necessary to develop competence in assessment too. This research shows difficulties in the process of formative assessment, lack of experience with this assessing approach and the need for better background and bigger support for implementation of formative assessment in teacher’s future instruction. This statement corresponds with findings of the research realized in the frame of the project ASSIST-ME (Stuchlikova et al., 2015).
ACKNOWLEDGEMENT

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Classroom lesson delivery is generally more complex than lesson planning. In science education, Pedagogical Content Knowledge (PCK) is valued as the teacher professional knowledge for teaching science. However, little is known about how the complexity of classroom delivery from a well pedagogically reasoned lesson plan is exhibited and explained through the lens of PCK, particularly when the topic specific nature of PCK is considered and distinguished as Topic Specific PCK (TSPCK). This study sought to illuminate the complexity of component interaction in pedagogically reasoned lesson plans of (N=4) physical science pre-service teachers and in their subsequent classrooms delivery during a practicum. The pre-service teachers were exposed to a 6-week long intervention targeting the development of the competence to pedagogically transform content knowledge in stoichiometry. On completion of the intervention pre-service teachers were placed in secondary schools where they taught different topics to the intervention. Data collected comprised of lesson plans, lesson recordings and self-review reports. All the data were analyzed for episodes of component interactions using a qualitative in-depth analysis. Findings revealed that (i) more episodes of component interactions were identified in the classroom lessons than in the original lesson plans as could be expected, however more interestingly (ii) original, pre-determined episodes from the lesson plans were identifiable emerging as a cluster of TSPCK episode however with the initial lesson intention retained. Pre-service teachers were found to have observed the development. Recommendations for teacher education programmes for explicit attention to component interactions and the clustering effect are made.

Keywords: TSPCK component interactions; enacted TSPCK.

AIM

The gap between theory and practice identified by Korthagen (2007) as a perennial problem in teacher education a century later since Dewey’s (1904) explicit outcry, remains as the today’s (Hennissen, Beckers, & Moerkerke, 2017) “Achilles heel of teacher education” (Darling-Hammond, 2013, p. 12, 12). Other education researchers have framed it as ‘the transfer problem’ (Korthagen & Kessels, 1999), others as the ‘connection or disconnection’ between teacher education and practice (Huang, Lubin, & Ge, 2011). At the heart of the problem is the recognition of the dissonance between preparation to teach and the actual teaching experience. This incongruence talks to the lack of connections between what Aristotle named episteme and phronesis. Accordingly, the conception of knowledge as episteme refers to a body of knowledge about many different concepts. It is similar to what Kislov (2014) called ‘knowing that’. Episteme is conceptual and abstract. On the other hand, knowledge as phronesis is used for action in specific situations. It refers to prudence, practical wisdom and what Kislov (2014) called ‘knowing how’. The possession of one over another would naturally exasperate the theory-practice gap. In science education the experience is not different to this widely observed trend. Pedagogical Content Knowledge (PCK) has emerged as the theoretical construct that
Strand 13

offers science education practitioners a framework to bridge the theory-practice divide. The key benefit of PCK is the pedagogical transformation (Shulman, 1987) of 'knowing that' to 'knowing how to teach it' with the evidence of learner understanding. By virtue of its theory-practice bridging nature, PCK is in agreement with Dewey’s stand in viewing practicum in Initial Teacher Education (ITE) development programmes as an integration of both the ‘apprentice model’ and the idea of ‘Bildung’ (Nelsen, 2016). In this view both the technical aspects of classroom delivery and the reasoning behind actions are mutually complimentary and informing each other. The challenge within the PCK studies remains however, in capturing and understanding fully how the complexity of classroom practice is reflected by PCK acquired within specific topics as presented in structured courses. In the refined consensus model of PCK (Carlson & Daehler, in press), PCK is acknowledged as having multidimensional nature that could be described by grainsize as PCK generally in the discipline and PCK within specific topics termed topic specific PCK (TSPCK). The model further distinguishes between PCK acquired from the shared knowledge such as from courses based on literature is called collective PCK (cPCK), by reference if acquired within a specific topic as collective topic specific PCK (cTSPCK). The development of PCK in specific topics is highly recommended within science education (Abel, 2008). In this study we sought to illuminate pre-service teachers’ cTSPCK as it develops in a structured course from reasoning about teaching a specific topic into their classroom delivery as enacted personal TSPCK (pTSPCK). Our starting point acknowledged that the classroom teaching process is not simply a transmission of the reasoned plan, nor an additive process but requires the transformation of ‘core practices’ (Darling-Hammond, 2013) that have been displayed in the pedagogical reasoning and planning of the lesson, to be carried into the classroom delivery. We argue in this study that the success towards narrowing the theory-practice gap lies in capturing and understanding how these imported 'core-practices' reasoned-out from a planning perspective withstand and/or change in nature in the face of classroom dynamics.

BACKGROUND AND FRAMEWORK

Core practices in learning to acquire TSPCK

The key competence in developing the theoretical construct PCK, particularly TSPCK, lies in the 'know how’ of drawing interactively on the different content specific components of the construct when formulating teacher explanations and responses. When the knowledge components of the construct are used this way, the resulting effect is evident coherency and depth that promote learner understanding. This 'know-how’, interactive usage of knowledge components lead to transformation of content knowledge (Geddis 1993; Nilsson 2008) which is a key benefit of PCK (Shulman,1987) and by reference TSPCK. Thus the mastery of using TSPCK component interactions is key in TSPCK studies. Pre-service teachers are widely expected not to have this competence because of their limited classroom experience as a teacher (Cetin-Dindar, Boz, Yildiran Sonmez, & Demirci Celep, 2018). Many PCK based ITE programmes share the goal of teaching cTSPCK knowledge to pre-service teacher often starting from a reasoning and planning context followed by an exposure to pTSPCK classroom teaching (Chan & Yung, 2015). The rationale is based on Shulman’s (1987) conception that targeting the development of pedagogically sound reasons that would be used as rationale to
classroom teacher actions is as important as the actual delivery. In relation to the theory-practice divide narrative, we argue that assisting pre-service teachers to import the core practice of component interactions developed in eTSPCK successfully into their classroom practice (pTSPCK), given its complexity, will work towards narrowing the current divide.

**Strategies to narrow the theory-divide**

The persistency of the theory-practice divide problem has evoked a number of different responses from a number of education researchers. Many studies in science education (e.g. Nilsson, 2014; Rollnick & Mavhunga, 2015) and in mathematics education (e.g. Ball & Forzani, 2009) have offered empirically informed recommendations to the dilemma. Kinyaduka (2017) argued that perhaps the reason we are not winning the battle is linked to what the author calls “Human being Action Theory”. This theory acknowledges that there are always circumstances and acting forces influencing an individual or organization not to act according to laid down plans, beliefs, and/or principles, thus resulting in theory practice gap. As such, the circumstances can be contextual (temporal), and the forces can be from within or from outside an individual or an organization (Kinyaduka, 2017, p.104). This line of thinking may sound like throwing the towel into the ring, however, it borders along that expressed by Nelsen (2016) in the quotation below, where the author advocated teaching methods that explicitly reveal and allow pre-service teachers to feel the tension as actually working towards closing it.

> “I purposefully teach my students in ways that widen the gulf between my classroom and those of the public schools around us. I want my students both to understand and feel that gap-that tension between what we are exploring and what they have and most likely will experience when they venture into schools as student teachers.” (Nelsen, 2016, pg. 498)

Nelsen (2016), argued that the practice-theory gap is actually in Deweyen’s terms the growth point. The author points out that Dewey’s work encouraged us not to avoid tensions and the apparent gap but to embrace them and consider them as catalysts for growth. Thus, accordingly, teacher educators are to open up to the tension and exose their students to it. Furthermore, they are to help pre-service teachers to understand how what is learnt in class significantly influences the classroom rather than matching it.

While in this study we see merit in both Kinyaduka and Nelsen’s line of thought, particularly the relief to the painful burden imposed by of the theory-practice divide, we argue that there is however virtue in the purposeful linking of the classroom dynamics and complexity into the strategies of learning how to teach. This does not amount to matching the classroom, as it is naturally impossible, but offers an opportunity to infuse the knowledge for teaching to be learnt in ITE with understanding of the formats and versions of how it looks when in action. We argue that when such versions are fully known they could be made explicit in the first place.

Within PCK studies, the effort to close the practice-theory have been reported in a number of empirical studies where combinations of coursework or structured interventions with practicum is explored. A close review of few cases reporting sucess, refer to coherency in understanding and using different knowledge components associate with PCK or TSPCK. For example, Nilsson (2008) invetsigated the development of PCK in four (4) pre-service teachers in
mathematics and science in their final year of study who participated in a project teaching physics to students aged 9–11 years. At the time of the project the pre-service teachers had completed their discipline courses and were studying general pedagogy. The findings indicated that through reflection pre-service teachers had begun to develop understanding of the different teacher knowledge bases, particular that are in concert with another and are to be used as an interplay. In a similar case, Hume and Berry (2015) reported on the development of four(4) chemistry pre-service teachers’ PCK through planning using Content Representations (CoRe) (Loughran, Berry, & Mulhall, 2006) and teaching out of it (the CoRe) in a practicum with the assistance of mentor teachers. The authors highlight that the practicum offered the pre-service teachers’ an opportunity for aspects of their PCK to be explored and expanded upon in classroom settings. Furthermore, they report on pre-service positive reviews and recognition of the transformation of the CoRe into the classroom teaching. Our own research study with science pre-service teachers points to evidence of them importing from a structured intervention, the interactive use of certain knowledge components of TSPCK into the classroom practice, demonstrating transformation of content knowledge (Rollnick & Mavhunga, 2016). These cases indicate potential for narrowing the gap through importing of the kind of knowledge that do significantly influence classroom teaching. However, what is yet to be understood and needed for strengthening the observed potential, is the understanding of how the PCK component interplay observed in classroom action relate back to those seen in the reasoning and planning of the lesson. Furthermore, what factors related to classroom activities influence how the evidence is manifested. These are aspects explored in this study through the research design outline below.

THEORETICAL FRAMEWORK

The study was based on the theoretical construct of Pedagogical Content Knowledge (PCK). According to Shulman, (2015), "PCK is an attribute that teachers develop, and it cannot be found among mere subject matter experts or among those who are good with kids". In his review of PCK, Shulman referred to a realization driven from his earlier projects in the field of medicine and law, that there are ‘Signature Pedagogies’ (Shulman, 2005). These are profession-specific modes of teaching that are associated with that profession, that seem to fit what it means to learn to be a member of that profession. Furthermore, these signature pedagogies are, domain specific. The implication of this was that PCK as the theory for teaching is domain specific, distinct to teaching teachers, and different from teaching layers or medical practitioners. Furthermore, its value is observed when teaching within topics, providing further insight that PCK is topic specific. In this study, we acknowledge both the discipline and topic specificity of PCK. In our earlier studies we defined TSPCK as the knowledge needed to transform content knowledge of specific topics (Mavhunga & Rollnick, 2013). We identified Learner Prior Knowledge, Curricular Saliency, What is difficult to understand, Representations and Conceptual Teaching Strategies as five content specific components of TSPCK. In this study we employed TSPCK within the the model of Teacher professional knowledge and skill commonly known as the consensus PCK model (Gess-Newsome, 2015), and explored the link of TSPCK to classroom practice.
METHOD

The study employed a basic qualitative study design, using a case study strategy as described by Yin (2003). Participants were four (4) pre-service teachers who were in their final year of study commonly bound by their desire to complete the teacher qualification. They were drawn from a methodology course that targeted the development of TSPCK in core topics of chemistry and physics. A sample of 4 was purposefully selected based on access to the schools allocated for their practicum. The sample together with a whole class were exposed to an intervention treatment which explicitly introduced the idea of transforming content knowledge (CK) using the ‘different kinds of knowledge’ identified by Geddis and Wood, 1997 as enablers of content transformation. These are within a specific chemistry topic, stoichiometry. Stoichiometry was chosen as it is fundamental in understanding other chemistry topics especially in chemical equilibrium. The key feature of the intervention was explicit discussions on how the constituent components, once understood could be used interactively to transform CK when planning to teach a topic. As a result, the intervention was made upon carefully planned series of explicit discussions on the understanding of TSPCK components that happened over a period of 6 weeks. The 6 weeks period was organized into a total of 12 sessions of about 1 hour each. In each week there were three sessions structured as a single lecture period early in the week and a tutorial double period at the end of the week. On completion of the intervention pre-service teachers were placed in different secondary schools where they taught various chemistry and physics topics as determined by the individual schools. Data were collected from each participant during the practicum. It included various forms of qualitative evidence such as lesson plans, audio recordings of the lessons from the collected lesson plans, and pre-service teacher self-analysis reports. The self-analysis reports were part of an assignment where pre-service teachers were to analyze for TSPCK episodes in their lessons plans and determine how these were visible in their classroom teaching. The self-analysis reports were developed and submitted at the end of the practicum. Analysis entailed authentication of pre-service teachers’ findings reported in self-analysis reports and analysis of their raw data using in-depth qualitative method for TSPCK Episodes (Park & Oliver, 2008). In this approach, two or more components of TSPCK demonstrated in a specific teacher task segment, are first identified and labelled as ‘TSPCK Episodes’. Thus, a TSPCK Episode was operationally defined after Park and Chen (2012) as a teacher task segment that displays the use of two or more components of TSPCK. Each identified TSPCK Episode was then described in detail in terms of (i) what the pre-service teacher had written (in the case of lesson plans) or said and done (in the case of actual classroom lessons), (ii) what components are at play in the TSPCK Episode, and (iii) the nature of the sequence or emergence of the components in an interaction. The identification of TSPCK episodes happen from two video recorded lessons per participant. Two rators analysed the data for TSPCK Episodes following a discussion on rules for coding and a practice run with data from two pre-service teachers in the study.

RESULTS

Key findings about the journey of TSPCK episodes from lesson plans into classroom teaching indicated three salient points. They first is that TSPCK episodes initially identified from lessons plans re-emerged in classroom teaching as clusters of TSPCK episodes where the original
episode was still identifiable. The second observations is related to the first in that new TSPCK episodes emerge in classroom teaching making the number of TSPCK Episodes to increase as compared to the original lesson plan. The final observation was the confirmation that pre-service teachers were authentically able to identify these changes in the journey of TSPCK episodes from their lesson plans into their classroom teaching. In the section below we provide the overview of the findings and a sample qualitative demonstration.

Table 1 presents the overview pattern in terms of quantity of TSPCK episode identified from the planning to the enactment context by the four pre-service teachers in the study. The table also present the extent of qualitativ agreements between the pre-service teachers and the researchers on the quantity and the composition analysis for of the identified episodes. The TSPCK components are abbreviated for ease of reference: Learner Prior Knowledge (LP); Curriculal Saliency (CS), What is difficult to understand (DIF), Representations (RP) and Conceptual Teaching Strategies (CTS). The sequence in which the TSPCK components were observed to appear was represented by a forward slash (/) to represent an interwoven sequence and a dash (-) to represent a linear sequence. The interwoven nature meant a sense was established that the components appeared integrated in the identified TSPCK episode.

Table 1. An overview of the TSPCK episodes in planning vs. in classroom enactment

<table>
<thead>
<tr>
<th>Pre-service teacher</th>
<th>Lesson planning</th>
<th>Classroom teaching</th>
<th>Verdict (PST vs. Researchers)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Episodes identified by PST</td>
<td>Episodes identified by researchers</td>
<td>Episodes identified by PST</td>
</tr>
<tr>
<td>Sipho</td>
<td>R/DIF-CS, LP-DIF/CTS</td>
<td>same</td>
<td>R/DIF-CS, R/DIF/CTS, R/DIF/CS, LP/CS</td>
</tr>
<tr>
<td>Jane</td>
<td>CS/LP/CS, LP/CS/R, LP-CS</td>
<td>same</td>
<td>LP/CS/R, LP/DIF/CTS-CS, CTS/CS, CTS/CS/CTS/CS, LP/CTS/DIF</td>
</tr>
</tbody>
</table>

1849
Table 1 indicates a good agreement for all 4 of the participants on TSPCK identification and analysis of composition and sequence in which the TSPCK components appeared in the episodes. It is noted that the quantity of TSPCK episodes initially found in the lesson plans increased when the lesson was enacted out. An example is made with an extract from Zandi’s identified TSPCK Episodes. Zandi taught planned and subsequently taught a lesson on electrostatics. The extract below was lifted-up from her planning lesson as a segment of her planning that contained a TSPCK episode. It demonstrated a TSPCK episode with 3 components found interacting.

![Figure 1. TSPCK episode from Zandi’s planning.](image)

Given in Figure 2, is Zandi’s TSPCK in enactment where the intention of the lesson is retained but expanded.

**DISCUSSIONS AND CONCLUSIONS**

In this study we raised the issue of the practice-theory gap as a continued concern in education generally, and our focus was in science education as an example. We pointed at the fact that the knowledge for teaching, cTSPCK, taught in structured science teacher education programmes courses from a planning pedagogical reasoning perspective, is often taught without reference to how its format changes or withstands classrooms dynamics and complexity. Also that factors that influence its format in classroom situations are not fully understood thus the purpose of the study to illuminate these aspects. The findings revealed that in a classroom context, the initial intentions reasoned —out in a lesson plan as a neat stand alone TSPCK episode, emerge in a classroom context as a cluster of TSPCK episodes that flow into each other to set a scene and support the original intention. The episodes are also seen to expand and increase in quantity responsive to learner interactions. The revelation of the episode clustering effect points to the succinct feature that distinguishes the format in which the learnt knowledge to teach (cTSPCK) emerges in theory vs. Practice (eTSPCK). Learner interactions emerge as a strong visible factor having a direct influence to the manner in which TSPCK episodes emerged. Our recommendations are that teacher educators are to explore for more similar features that shape the format of TSPCK in classroom contexts. For the
understanding of such features will inform the content and emphasis to be explicitly discussed in teacher education programmes working towards narrowing the practice–theory gap.

Figure 2. TSPCK episode cluster from Zandi’s enactment.

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INTERDISCIPLINARITY AND THE TRANSFORMATION OF
DIDACTIC CULTURE IN THE TEACHING OF SCIENCES

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This article presents the results of an approach applied to - and by - students in initial formation of Licentiate degree in Physics under the theme of Interdisciplinary. Twelve students enrolled in the subject of Methodology of Physics Teaching II at the University of São Paulo and participated in the elaboration of projects guided by the Interdisciplinary Islands of Rationality - IIR (FOUREZ, 1994) model. There were four phases of implementation, which were monitored and mediated by two research monitors and by the discipline/subject teacher. In the qualitative data analysis, the students' arguments - obtained through an online open questionnaire and a semi-structured interview - are explained in relation to: (i) the significant differences of the proposal in contrast to the thematic and strongly traditional approach associated with interdisciplinary school projects; (ii) the development of similar activity in Basic Education and (iii) the potential of this approach on learning and on exploring interdisciplinary in science. The implications of this proposal evidenced that the approach based on Interdisciplinary Islands of Rationality - IIR presents promising elements for the transformation of the didactic culture in the teaching of sciences and a distancing in relation to the reproduction of thematic models of disciplinary approach.

Keywords: initial teaching education, teaching methodology, interdisciplinary.

INTRODUCTION

Interdisciplinarity is a subject that raises many discussions between specialists and scholars in the educational field, besides its definition goes through many perspectives and its importance is justified by the expectation of a greater integration between the disciplinary contents (Morin, 1996; Pombo, 2008). In Brazil, there is a tradition both in research and in teaching about interdisciplinarity. The first publications with interdisciplinary reports appeared in the 1960s (Vieira & Durval, 1965), and in the 1970s more consistent investigations (Japiassu, 1976) emerged in the research scenario, followed by the works published by Paviani and Batomé (1993) and Fazenda (2003), to name some of the most relevant.

The existence of a consistent set of experience and research, however, does not make the task of understanding what is interdisciplinarity intelligible. Perhaps, we can here rehearse, paraphrasing Pombo (2004a, 2004b), something of what we think about interdisciplinarity. The origin of the word lies in the subjects and in the desire to reconstruct the totality of knowledge, it is an "attempt to break with the stagnant character of the disciplines" (Pombo, 2004a: p.4). It can be said that "interdisciplinarity is the place where one thinks of the fragmented condition of the sciences today and, at the same time, expresses our nostalgia for a unified knowledge" (Pombo, 2004a: p5).

Nonetheless, the most friendly feature of interdisciplinarity lies in its ability to establish cognitive and attitudinal relationships. In cognitive terms, it opens the world of sensibilities to complexity, attention to the deep structures of Science and articulation of what initially seems
to us inarticulable. Regarding to the attitude aspect, it stimulates curiosity, appreciation for collaboration and team work (Pombo, 2004a: 16). These are important aspects to resist the exponential trend of Modern Science, which was inaugurated in the seventeenth century, which is specialization.

The adoption of an analytical method that allowed to divide the whole into small parts led to the fragmentation of knowledge, with the underlying idea that it would be possible to recompose this whole and that the whole is equal to the sum of the parts.

Science today continues along this way and we have more and more super specialized areas. In the teaching of science, for example, the didactic-pedagogical difficulties are remarkable in order to overcome the fragmentation of knowledge, which, every day, becomes more intense, due to the result of fragmentation and the development of scientific and technological knowledge. Among the factors is the existence of many topics in a planned curriculum structure with few classes.

The teaching of Physics fits within this curricular structure and, in general, the attempts to insert activities of other disciplines to the physical contents in school projects have contributed little to approximate effectively such areas. In this scenario, we perceive the need to seek for a greater articulation between the concepts of the different disciplines, exploring their potential for integration of the content taught, besides enabling them to understand that knowledge is neither compartmentalized nor "disconnected".

Among the new interdisciplinary proposals to work with while teaching science that were developed over the last few years we have the Interdisciplinary Rationality Islands (IIR), by Gerard Fourez (1994). Such an approach stands out, basically, for two essential points: (a) it does not separate scientific knowledge from technological knowledge (b) integrates interdisciplinary knowledge into its development. Still, according to Fourez (1994), the IIR aims to achieve an appropriate theoretical representation in a precise situation and in function of a determined project.

This means that developing a knowledge by making use of IIR is, in some way, developing a theorization that fits the problem of interdisciplinarity in teaching.

Everything indicates that this approach is a possible way for integration of different knowledges in the construction of a knowledge. Whereas IIRs fall into two categories, namely: (1) those that organize around a concept and (2) those that organize around a project (Fourez, 1994) and this second category has guided a theoretical work developed by Nehring et al. (2000), in which we verified the authors' reflection on the science teaching and the meaningful knowledge. Also, that these in detailing a project proposal based on the IIR approach indicate the need for practical application of the proposal, for its evaluation in real classroom situations.

This article, in parts, meets the authors' indication through the application of an activity developed with physics teachers in initial formation, as well as being anchored around the organization of projects following the proposal of Fourez (1994), as well as, the fundamentals of socio-cultural analysis of Sewell Jr. (2005). The following question was asked: What are the implications of the Interdisciplinary Islands Rationality approach in the process of transforming didactic disciplinary culture into Interdisciplinary culture in science teaching?
Transformation and reproduction: theoretical aspects for the study of didactic culture

Sociological theories have been an important path, supported by the concept of structuring, to understand how social practices are produced, reproduced, and transformed. The theory of structuration, which has in Anthony Giddens (1979) one of its main exponents, emerged between the late 1970s and the early 1980s as an alternative to the structuralist-functionalist and interactionist thoughts.

Giddens' formulations on the duality of structures present striking points of dialogue with the theory of Alfred Schutz and Fernand Braudel as they seek to integrate different temporal scales of analysis. A durée, by Schutz to express the daily nature of life and the longue durée, by Braudel in the dialogue with the little variable structures that extend over long periods. The introduction of different temporal levels provides an analytical reflection on how reproduction in the durée's plane contributes to reproduction to the range of the longue durée, in the particularity of the relations between human action and social structure.

Human action by this theoretical bias is characterized as a "continuous flow of conduct." Action and intentionality, however, are separate acts, according to the author "... action does not refer to individuals' intentions on doing things, but to their ability to do these things ..." (Giddens, 1984: 9). Expressed in this way, action is conceived as a "servant of a goal," although without clearly defined intentions in daily life people regularly pay attention to their own actions and the actions of other people. In short, man has the capacity to transform situations, it is precisely human action or agency that allows him to choose between intervening or not doing so. Sewell Junior (1992, 2005) presents an important contribution to the extension of Giddens' notion of the duality of human structure and action.

For this author, structures are mutually constituted by schemes of action and resources, aspects that both enable and restrict social actions, as they tend to be reproduced by these actions. The action is established by structures, both given by the knowledge of cultural schemes, which allows the agency to mobilize resources as well as access to resources that enables the promulgation of schemes (Sewell Jr, 1992). This process reflects the dynamism of human structure and practice. In this point, the author distinguishes Giddens by recognizing that the same structures that shape human conduct are constituted by human beings and are therefore not static, that is, the action that supports the reproduction of the structures is the same that also facilitates their transformation.

In transformation, however, we do not have a disruption, breakdown, but its occurrence comes from the reproduction of the properties of available structures. These theoretical reflections apply to the study of the didactic practice regarding the transposition of action schemes and the mobilization of resources, being pertinent on understanding how reproduction occurs and the transformation of the structure when an innovation is introduced in the teaching activity, for example of the research we analyze here.

METHODOLOGY

The epistemological posture assumed in this qualitative research is interpretivism (Schwandt, 2003). According to which, the researcher, by engaging in data interpretation activities to
enumerate doubts as to what the actors are doing or saying and transforming it into public knowledge, will be assuming theoretical perspectives on what constitutes knowledge, reconfiguring the theory itself and also the objectives that guide it. Thus, the scope of interpretivism is to redraw the self-understanding of historical actors in certain actions, under the participatory / cooperative paradigm and criteria of authenticity (Guba and Lincoln, 1994). In this sense the ways in which actors understand their experience are relevant to the researcher for social scientific understanding, since the ways in which actors understand their actions are also part of this action (Giddens, 1993).

The present study initially involved 52 physics teachers in initial formation, enrolled in the discipline of Methodology of Physics Teaching II at University of São Paulo. Divided into 4 teams, each one received a theme to build the project through the IIR approach. In Fourez’s original proposal (1994) eight steps are taken to construct an IIR, namely: 1) Situation Cliché Studied; 2) Spontaneous Panorama; 3) Consultation with Specialists and Specialties; 4) Going to Practice; 5) Opening some black boxes; 6) Global technology outlining; 7) Opening of black boxes without the help of specialists; 8) Synthesis of the Island of Rationality produced. In the developed activity four stages were adequate and integrated to the others, once the project happened concomitantly to the planning of classes and the accomplishment of the obligatory stage to be realized in the discipline. The four stages were synthesized in three moments / class, of approximately 90 minutes each, and two monitors investigated and recorded notes on the research in development.

We selected the project, which was composed of twelve students, and their statements about the execution process, obtained in two intervals: (a) a semi-structured interview and (b) an online open questionnaire for categorization and qualitative analysis of reflections.

THE DIDACTIC SCHOOL CULTURE AND THE APPROACH IIR

The teaching of teaching science, as mentioned previously, has some problems regarding to the methodologies adopted to work with and it is often questioned among students by distancing the disciplinary contents in relation to the social issues relevant to learning. Thus, the way the contents are worked and their fragmentation are some of the factors pointed out as a source of discouragement for learning science. The inclusion of broader topics related to everyday life and that stimulate the analysis of society and the possibilities of transforming it signal ways for students to join this knowledge. Pursuing this idea of an approximation between the teaching of science and the field of interest of the students is that the IIR approach was proposed (Fourez, 1994), through the simulation of a public announcement.

The problem to be solved by team 4 in the form of an IIR project was materialized in a Public Notice that included the preparation of a booklet with information on the development and installation of small photovoltaic systems in peripheral neighborhoods of metropolitan regions. With this, it inserts the daily problematic in this application characterized by the use of irregular installations of sources of energy to the physical content.

The execution of the project followed four stages, synthesizing the eight that integrate the construction of Interdisciplinary Islands of Rationality from Fourez’s perspective (1994). Being that, after the elaboration of the final product [booklet], the participating students developed a
reflection on their practice that was oriented in the form of a semi-structured interview by the research monitors. The aim of the interview was to make students co-participants in the process by discussing their own difficulties and successes, evaluating the practical implementation of the project step-by-step, in real classroom conditions, and understanding the implications of the IIR approach to disciplinary school culture.

In the interview, Team 4 described the main obstacles to the implementation of the first two phases. Stage 1, called cliché, was the moment that had the greatest difficulty to present the spontaneous ideas about the photovoltaic systems. In his reflections, student 3 states that even though he had read the theoretical article of support to the activity, his actions were guided more by knowing "what we were going to produce [...] 'this is not going to solve' '(Student 3) than to the spontaneous understanding of the situation. The other participants agreed that the rationality that prevailed in their training was preponderant to the exclusion of more open questions and related to daily experience, since they focused their questions on the most relevant hypotheses, understanding that they led them more quickly the construction of the final product. Sewell Junior (2005) contributes to the analysis of the action schemes mobilized during the execution of this stage, while allowing an evaluation in which it is identified in the students' speech that the schemes originated in the training trajectories and these were reproduced in their conduct during practically the whole cliché stage and the first moment of stage 2, of elaborating the spontaneous panorama [both defined in the first lesson]. The students concluded that the approach to the issue of the Notice was also cited as one of the possible causes for the team to discard the initial problematization, important for a first picture of the situation. All of them evaluated that the cliché stage in the execution of the project should not be burned and that the choice of subjects beyond the training area could constitute a more plausible way for the emergence and exposition of intuitive ideas in the group. According to student 5: "The cliché stage is a democratic moment that stimulates the initial debate on the subject" and student 1 complements "[...] it guarantees in part that you have covered the problem from visions different about the proposed situation ". This is considered to be the relevance of these notes, since they are indicative that the choice of a topic mixing knowledge from other areas would concentrate greater chances for the transformation of the action schemes and resources to be triggered by the students, including for stage 2.

Step 2, in the perception of team 4 was also partially impaired, still in the cliché phase these had already proceeded by refinement. This stage, which should still be very spontaneous, was directive and, for the most part, students sought to provide explanations. Subsequently, understanding how and why these difficulties arose to implement the two steps provided a set of information for the composition of the experience of the research monitors, who in the case experienced their first application of the IIR approach. This is a two-way path in which team 4 and the monitors have had and have the opportunity to evaluate their involvement and conduct during production. Several reflections were stimulated to think of suppressing some of the developments in Step 2, but in the end the team concluded that these were essential for the realization of an interdisciplinary road map.

Step 3, from the consultation to the specialists, happened in the second class. The team was less anxious about the first two stages. The students opted for the division of tasks, each pair
was responsible for the visit and consultation of one of the specialists and the confirmation of the rules and legislation in force on the subject. The considerations on this stage were that with the division of tasks among the team members, some of them were dedicated to subjects very close to the training area, damaging the idea of interdisciplinarity, which was the focus of production. This perception only changed when the set of specialists consulted and the relevance of each information for product finalization were scored. As an example, specialists were consulted in: languages, for the production of the text of the booklet; comic book graphic designs, for story illustration; meteorological conditions, to verify the climatic and atmospheric conditions favorable to the use of the energy potential of the supposed region of installation of the photovoltaic and technical systems in installations of the system. It is understood that analyzing the data obtained in this stage is significant for the formation of a holistic view of the process, it also follows that it is necessary to consider and stimulate collective participation at this stage and, if possible, this will depend a lot on the product defined in the edict create means for the visit of specialists in the school. This indicative is largely due to the financial and human difficulties encountered in public schools, in general, for field trips. The team composed of university students did not experience this confrontation, but this was understood as a point to be well thought by the teacher before the execution of the project in high school classes.

Step 4, developed here as the finalization, delivery and synthesis of IIR, resulted in the production of a primer, available at: <https://www.dropbox.com/s/06e1v3jly1ntfia/Cartilha.pdf?dl=0>, with basic and accessible guidelines for the population regarding the criteria and norms for residential installation of residential photovoltaic systems. The plausibility of the IIR produced was registered by the participant team's identification of how the knowledge obtained in each one of the stages presented benefits for the student's autonomy in relation to the decision-making process. Comparatively the approaches of strongly subject school thematic projects often reproduced in school.

Interdisciplinarity, that is, the interlocution with other areas of knowledge, provided a framework of information that, in a way, a disciplinary model would not cover. In short, the practical implementation of the IIR approach with physics teachers in initial training allowed a general assessment of their viability, their mishaps and the need for improvement of the process by the island's producers of rationality in order for it to be effective. terms, thus broadening its potential for transforming subject culture into interdisciplinary culture into scientific education. In the light of Sewell Junior's theory (1992, 2005), the production of the island made explicit the relations between reproduction and the transformation of human action, the generated characteristic of these concepts, which in practice one is necessarily extinct for the other to happen. On the contrary, even the most radical transformation happens framed by the reproduction of the accessible structures.

In addition to the interview, teachers of physics in initial formation were given a second moment of reflection specifically on the implementation of the IIR approach, through an online open questionnaire; eleven students, from the twelve who participated, answered and their answers were organized into categories and subcategories (Strauss and Corbin, 2015), which
are grouped into three frames corresponding to each question. The first question had as objective to verify if the students identified elements of transformation between the school approach of interdisciplinary projects and the methodology of Islands of Rationality, the answers are presented in Table 1, below.

Table 1. IIR approach

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Nº Answers</th>
<th>Representative Excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assign Differentials</td>
<td>9</td>
<td>“[...]Had a great differential, in relation to projects, where routinely the work is sliced in subjects. In the IIR the various areas of knowledge integrate more naturally” (Student 3).</td>
</tr>
<tr>
<td>Do not assign</td>
<td>2</td>
<td>“No. The part in which I was entrusted with the activity was directed to my subject area and I ended up developing my activity in the same way that I would do in other activities related to physics” (Student 1).</td>
</tr>
</tbody>
</table>

In the subcategory "assign differentials", 82% of students perceived that the consultation of specialists, the range of technical, social, marketing, financial aspects and critical reflection on the stages that required the elaboration of the IIR project distanced them from the school approach which in itself has strongly disciplinary characteristics. According to Fourez (1997), IIRs enhance interdisciplinary dialogue by starting from the notion of a project, characterized by a set of steps to be followed, as well as the integration among several areas of knowledge. In addition, the activity acquires meaning when related to a theoretical representation presented in a given situation as the initial project (Fourez, 1994).

The subcategory "do not assign differentials", indicated by 18% of the students, was fundamental to think about the development of the IIR, as exemplified by the answer in evidence in Table 1, some of the students attribute to similar areas the extreme difficulty of working in areas that are not yet known, even if they are used to support them in a thematic project. Moreover, this response was significant for the critical reflection of the thematic selection made by the researchers who applied it be considered by the teacher in the thematic choice, so that it is not so close to the area of knowledge of the participating students, to the point of generating in them the feeling of not being involved in an interdisciplinary culture, as it does not opt for such a distant subject to the point of discouraging student participation.

The intention of question 2 was to evaluate if the future professors of physics wanted to insert in their didactic practice IIR approach in Basic Education (Table 2).

---

1 Question 1 - In your evaluation did the approach to elaborating Interdisciplinary Islands of Rationality projects provide significant differentials in relation to the thematic and strongly disciplinary approach, which in general guide interdisciplinary projects in the school? What were these differentials?

2 Question 2 - Do you consider it feasible to apply this approach to high school students?
Table 2. Viability of IIR

<table>
<thead>
<tr>
<th>Category - Perceptions about the viability of IIR in High School</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcategory</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>Consider feasible</td>
</tr>
<tr>
<td>Do not consider feasible</td>
</tr>
</tbody>
</table>

The "consider feasible" subcategory, weighted by 73% of respondents, gives us an overview of how early teachers interpreted the IIR approach as they emphasized their feasibility of implementation. Factors such as motivation of students with the methodology to develop their classes, topics of interest and possibilities of technical visits characterized their arguments as to the relevance of the proposal. Despite the interest, and to defend their application, contradictorily in their statements many considered the time factor and the teaching structure disciplinary limiting points for the proper development of the project. The disciplinary structure is like a shadow that makes them retroact and rethink their own statements, intimidating the insertion of the new approach into their didactic practice as future teachers.

The subcategory "did not consider feasible" was also justified by 27% of the students, under the arguments: lack of time in class, technological difficulties and access to the network; of the course syllabus of the discipline and of the necessity of extra moments classes for the development of the projects. These answers reveal that part of the students did not understand the IIR proposal in this respect, because in its evaluation the applicability of the proposal would only be possible with the expansion of the time of completion of the disciplines and, in a certain way, fragmenting the project into fairs and / or activities. According to Fourez (1994) changes of this order do not contribute to the central idea of the IIR approach, which consists in the accomplishment of a project following stages of which the greater purpose is the search for the integration of the knowledge.

In structural terms, these statements, when illuminated by Sewell Jr's (2005) theorizing, indicate that the reproduction of disciplinary culture, originating in the formative base of the students themselves, future physics teachers, is so rooted in their practices that interject to the development of the interdisciplinary culture offered by the insertion of IIR in its future didactic practice.

In question 3, we tried to understand how the students in initial formation perceived the IIR's potential for insertion of the interdisciplinarity in the teaching of Sciences.

3 Question 3 - What is your view on the development of the Islands of Rationality project for learning and interdisciplinarity in Science Teaching?
Table 3. Implications of IR for learning in science teaching

<table>
<thead>
<tr>
<th>Category - IIR and interdisciplinary learning in science teaching</th>
<th>N° Answers</th>
<th>Representative Excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive perception</td>
<td>10</td>
<td>&quot;The work with the IIR develops in the student several skills and competences that traditional or technological classes would not achieve&quot; (Student 3).</td>
</tr>
<tr>
<td>Negative perception</td>
<td>1</td>
<td>&quot;It is interesting, but as I said, I do not know its effectiveness in the short, medium and long term [...], in relation to interdisciplinarity we do not necessarily need to use the islands of rationality&quot; (Student 8).</td>
</tr>
</tbody>
</table>

The "positive perception" sub-category indicated by 99% of the respondents gives an overview of the potential of the IIR approach to the impressions of the trainees, but also of our own findings in the researcher's perspective during the implementation phase of the project. According to the two responses highlighted in Table 3, and reinforced by other students, we have students perceive the differences of this new proposal in relation to "traditional". The students also indicated as a positive point of the approach the contruction of a holistic view of the knowledge to be discussed.

On the other hand, the subcategory "negative perception" formed by 1% of the answers, denotes that student 8 is not trusting in this, because it mobilizes other theoretical visions on interdisciplinarity, not based on Fourez's (1994) perspective. The large number of interpretations in the literature on interdisciplinarity may have made it difficult for this student to understand the differences between the IIR-oriented project and the projects generally implemented in thematic-based schools.

CONCLUSIONS

In terms of research, our evaluation based on the analysis resulting from the implementation stages of the IIR approach, through the project applied by future physics teachers, revealed aspects about the potential of the proposal for the transformation of disciplinary didactic practice, the basis of the academic training of the students in interdisciplinary practice. From this process, we have also obtained the understanding that transformation is marked by reproduction, these two coexisting throughout the course of production of the book, sometimes emphasizing the schemes of action and resources produced by the area inherent to the formation of students, now being focus action schemes from the new IIR approach.

Which led us to reflect on the transformation as a procedural agent. Therefore, in order to be more aligned to a dialogic perspective with the daily situations of the student intertwined with the technological and scientific knowledge produced in the different curricular and extracurricular areas, it is necessary to insert the IIR in different moments of the student's formation.

Regarding the students' considerations about the potential of the IIR approach to interdisciplinary learning in Science Teaching, they concluded in a contradictory way sometimes indicating the viability of the application, on the other explaining the limits of Basic...
Education and factors such as time and resources emerged as strong barriers to the proposed challenge. This, perhaps, in keeping with Pombo's (2004a: 3) thinking, is related to "the inability we all have to go beyond our own discursive principles, theoretical perspectives and modes of functioning in which we have been trained, educated ".

Finally, we consider that, if we are willing to face our own formative limits and discourses, the IIR approach brings to the light of Science Teaching new ways of thinking about the knowledge taught, enabling discussions and ways of working on a given problem from stages, all adaptable to the reality of each class and levels of schooling, but with one objective: to carry out a given project at a time initially established. In making use of the interdisciplinarity in the teaching of Sciences by the IIR, and more specifically in the present application for the formation in physics, notably was acquired knowledge of other areas on the studied problem.

ACKNOWLEDGEMENT

To physics teachers in initial formation who agreed to cede their statements and recordings in audio and video to carry out this research.

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ANALYSIS OF PRE-SERVICE SECONDARY SCIENCE TEACHERS’ CONTEXT BASED CHEMISTRY TEACHING SEQUENCES

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This exploratory work analyzes five Chemistry Teaching-Learning sequences (TLS) designed by students enrolled in the Master of Science Teacher Training at five Catalan public universities during the 2015-16 academic year. The question guiding the research is: What are the characteristics of the contexts and how are they used in Chemistry TLSs designed by pre-service secondary science teachers? The analysis was oriented around three dimensions: (a) the extent towards activity titles are contextualized, (b) the types of contexts used in the activities of chemistry TLS, and (c) the characteristics and uses of contexts throughout the chemistry TLS. A content analysis of the TLS was performed through a process of progressive segmentation at the level of structure, activity and context. The results indicate that the TLS activity titles are mostly conceptual, and the contexts used within the activities are of a personal nature. Two levels of chemistry TLS have been identified in relation to the characteristics and uses of the contexts, based on the context criteria of authenticity, inquiry, construction, relevance and persistence.

Keywords: initial teacher education, teaching learning sequences, concept and context.

INTRODUCTION

This research focuses on the training of secondary science teachers learning to teach context based chemistry. Its objectives emerge from the difficulties secondary science teachers have in designing chemistry teaching and learning sequences (TLS) from a School Science perspective developed by (Izquierdo 2006; Caamaño 2011). This approach conceives science learning as a process that involves the development, evaluation and revision of models, explanations and theories of natural phenomena. Since the academic year 2009-10 Catalonia implemented a new Master of Secondary Teacher Training (2009-10) which represented a shift in the way to train secondary science teachers towards the promotion of context, inquiry and modeling based approaches to science education. Context-based science teaching is understood as a didactic approach that aims at linking the teaching and learning of science to real-world situation. This situation is used as a central structure to introduce scientific concepts as they are needed and thus develop a better understanding of the situation (Gilbert 2006, King and Richiec 2012). Chemistry education has supported context based chemistry teaching approaches as a way to help secondary students make sense of their learning, improve academic results and feel more attracted to chemistry (De Jong 2008; Parchmann et al. 2006). However, the design of context based TLS in chemistry that facilitates students’ construction of theoretical school science models represent an important challenge for both pre-service and in-service secondary science teachers. There is a need to consider the importance of context in the training of secondary
science teachers and to introduce the context as a necessary dimension when designing chemistry TLS.

The question addressed by this research is the following: What are the characteristics of the contexts and how are they used in Chemistry TLSs designed by pre-service secondary science teachers? Additionally, three sub questions emerge: a) How do the titles of the activities reflect a TLS of contextualized chemistry? b) What kind of contexts are used in the Chemistry TLS’s? and finally, c) What characteristics do the contexts used in the TLS of chemistry have? The present investigation is framed in a qualitative paradigm based on the analysis of texts (TLS).

**METHODOLOGY**

**Selection of pre-service secondary science teachers’ Chemistry TLS**

The participating universities included all five public universities in Catalonia offering the one year Master of Secondary Teacher Training program. Twenty-one chemistry TLS were collected during 2015-16 (Table 1) and one chemistry TLS was selected from each university to undertake an exploratory study. Of the TLS collected, one of each university was selected according to the following criteria: (a) existence of a structure in the SEA design, (b) presence of titles of both the TLS and the activities that comprise it, and (c) explicit presence of the activities that the student will develop.

Table 1. Selected TLS as data sources from 5 Master of Secondary Science Teachers Training from five universities in Catalonia (2015-16)

<table>
<thead>
<tr>
<th>University</th>
<th>University A</th>
<th>University B</th>
<th>University C</th>
<th>University D</th>
<th>University E</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° of analyzed TLS / Total number of TLS collected</td>
<td>1/1</td>
<td>1/6</td>
<td>1/3</td>
<td>1/5</td>
<td>1/6</td>
</tr>
<tr>
<td>Theme</td>
<td>Matter</td>
<td>Chemical reactions</td>
<td>Chemical reactions</td>
<td>Matter</td>
<td>Solutions</td>
</tr>
<tr>
<td>Title of TLS</td>
<td>Knowing elements is elementary</td>
<td>Chemistry in Action</td>
<td>Beyond Chemistry and Physics</td>
<td>Matter</td>
<td>Matter Classification: Pure Substances</td>
</tr>
<tr>
<td>Number of activities in the TLS</td>
<td>12</td>
<td>30</td>
<td>10</td>
<td>17</td>
<td>10</td>
</tr>
</tbody>
</table>

**Segmentation of Chemistry TLS**

A content analysis of a selected sample of chemistry TLS designed by pre-service secondary science teachers was conducted (Weber 1990). Through a process of progressive segmentation
and the construction of a system of inductive-deductive categories, we proceed to assign meaning based on the activities of the TLS as a unit of analysis. To perform the analysis of the chemistry TLSs, we proceed to segment them into three dimensions: structure, activity and context.

a) The structural segmentation of each TLS is made from the allocation of three phases: beginning, middle and end. The start phase is usually located at the beginning of the TLS and includes those activities designed to present the subject of study, explore the students' previous ideas, and present the objectives of the TLS. The middle phase consists of all those activities designed to develop the competences identified in the objectives of the TLS by the students. Finally, the final phase is made up of all those activities that aim to apply the skills acquired by the students in the previous phase and thus close the TLS.

b) Segmentation by activities is characterized by the identification of the total number of activities that constitute each structural segment of the TLS and by the delimitation of the textual segments of the TLS associated with each activity.

c) Segmentation by context involves the identification of those textual fragments associated with a context within each of the activities identified in the segmentation by activity.

**Selection and construction of categories**

The selection and construction of categories for the analysis was adjusted to the three sub-questions of the research study as follows:

**TLS activity titles**: Often the title guides a lot about what the TLS will teach and the importance given to context if any. We will consider three categories of titles based on the work of Izquierdo (2005):

- *Conceptual titles*, reflecting the conceptual entities aiming to be taught;
- *Contextual titles*, using a problem or a phenomenon of life for its TLS or activity;
- *Rhetorical titles*, characterized by embellishing the expression of concepts through a language aiming at providing delight, persuasion or move giving written or spoken language the necessary effect to delight, persuade or move.

**Types of contexts**: To categorize the types of contexts that manifest themselves in each of the activities of a SEA, the 4 domains of contexts identified by De Jong (2008) have here been considered, which include the followings:

- The *personal context*, are contexts that make a connection between science and the personal life of the student.
- The *social context and society*, referred to the role of the student in a community and social issues.
- The *professional context* related to the student's career expectation.
- The *scientific-technological context* referred to scientific innovations and discoveries.
Characteristics and uses of contexts: It includes five criteria of a good context in a science TLS adapted from the Context-Based Teaching of Science Criteria developed by the LIEC group (Language and Science Teaching; www.cienciescontext.com) (Table 2).

Table 2. Context Indicators adapted from LIEC Group

| CONTEXT INDICATORS | Authentic: It raises a situation or a real or plausible problem, which may have meaning or interest for students (Psarros, 1998) | Relevant: It is socially and personally relevant (or for their professional future) (Parchmann, 2006) | Persistent: Is the initial context still present throughout the activities? Do these activities make sense in relation to the planned problem? (LIEC, Grup) | Inquirer: It encourages to ask questions and... Wanting to know more? Possible questions that can be valid (from science as well as from action) are specified. (Tamir, García, 1992) | Constructor: It facilitates the construction of meaningful knowledge of and about science (Roca 2013) |

A rubric was constructed to identify the degree of presence in each chemistry TLS of context indicators presented in Table 2. Each indicator was associated to three levels of presence: unsatisfactory (code 1), moderately satisfactory (code 2) and satisfactory (code 3). Table 3 shows the indicators and the meaning associated to each degree of presence. To apply the context indicators each TLS was partitioned in three structural parts (initial, intermediate and final) and a score for each context indicator was assigned to these three parts.

RESULTS

Contextualization of chemistry TLS Activity titles

The titles of the TLS activities selected by the teachers of science in initial training allow us to infer about the use they make of the contextualization in the designed activity. Table 1 shows the global title of each of the five TLSs of the sample and the number of activities included in each of them (between 10 and 30). A first reading of these titles indicates that none of the 5 TLS has a contextualized title that invites the resolution of a personal or socially situated problem.

The descriptive result of the analysis of the titles of the 79 activities that make up the sample of the 5 selected chemistry TLS is shown in the graph in Figure 1. While 85% of the activities have a conceptual title (eg "The density "," Representation of the states of matter "or" Conceptual map "), 10% of them have a rhetorical title (eg "Who is right? "," Density ... is magic? "or" We know how it works? "). Only 5% of the activities show a contextual title (eg "El Náufrago", "The inheritance of Aunt Agata").
Table 3. Context Indicators and scores of chemistry TLS

<table>
<thead>
<tr>
<th>CONTEXT INDICATORS</th>
<th>INDICATORS’ SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unsatisfactory</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Authentic</td>
<td>It is unsatisfactory, when the context where the activity takes place is not real or credible and there is no problem to be solved</td>
</tr>
<tr>
<td>Relevant</td>
<td>It is unsatisfactory when the context where the activity takes place is not related to any of the dimensions (social, personal and vocational).</td>
</tr>
<tr>
<td>Persistent</td>
<td>It is unsatisfactory when the context applies only to an activity of the SEA</td>
</tr>
<tr>
<td>Inquirer</td>
<td>It is unsatisfactory when the context does not present a practical work.</td>
</tr>
<tr>
<td>Constructor</td>
<td>It is unsatisfactory when the context where the activity takes place does not present a question that allows the elaboration of the MTE.</td>
</tr>
</tbody>
</table>

Figure 1. Titles of the activities of the chemical TLSs (n = 79 titles)
Types of contexts in Chemistry TLS activities

The contexts of the TLS are conveyed through the activities and are materialized from texts constructed with different modalities of the language normally the written one, from narratives of different lengths, or the visual one, from drawings or images. Of the 79 activities analyzed that correspond to the 5 SEA of chemistry designed by the teachers of science in initial training (Table 1) only 28 activities present contexts. These 28 activities present contexts of different typology as shown in the graph of Figure 2. 86% of the activities that use contexts develop them on a personal level which means that the activities have been designed so that the student makes connection between a punctual aspect of science with a particular situation of daily life. Examples of the personal contexts selected by the teachers in initial formation are: History of the Periodic Table, heartburn, oxidation of a bicycle, shipwreck. The activities that develop contexts of social type and society represent 14%.

![Figure 2. Types of Contexts used in the activities of the chemical TLS (N = 28 activities)](image)

Characteristics and uses of contexts in Chemistry TLS activities

Table 4 reports on the five chemistry TLS’ characteristics and uses of the contexts. Each TLS was partitioned in three parts (initial, intermediate and final) and a score for each context indicator was assigned to these three parts. These same data are also represented in a line graph shown in Figure 3.

Table 4. Characteristics and uses of the contexts in chemistry TLS of pre-service secondary science teachers from five Catalan universities

<table>
<thead>
<tr>
<th>University</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TLS Segment</strong></td>
<td>I</td>
<td>M</td>
<td>F</td>
<td>T</td>
<td>I</td>
</tr>
<tr>
<td>Authentic</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Relevant</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Persistent</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Inquirer</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Constructor</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

I= Initial Context; M = Intermediate Context; F = Final Context
Satisfactory score= 2; moderately satisfactory score= 1; Unsatisfactory score= 0

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Data collected in both Table 4 and Figure 3 indicate two groups of chemistry TLS in relation to the characteristics and uses of context. One group B and D TLS show a high contextual profile since the TLS perform the highest in most of the contextual indicators. The other group show a low contextual profile A, C y E since the TLS perform the lowest in most of the contextual indicators. The most problematic contextual indicator is Persistence since the scores assigned to the TLS in both profiles are homogenous and the scoring is very different.

Figure 3. Characteristics and uses of the contexts in chemistry TLS designed by pre-service secondary science teachers from five Catalan universities

CONCLUSIONS

The structures of the chemistry TLSs analyzed are diverse, indicating that there is no uniformity in the way pre-service secondary science teachers structure its design. The TLS activity titles chosen by the pre-service secondary science teachers are mostly conceptual, and the contexts used within the activities are of a personal nature in its majority. In relation to the characteristics and uses of the contexts in the chemistry TLS analyzed, it is worth highlighting the existence of two groups, one of a higher contextualized profile, consisting of two TLSs and one of the lower profile formed by three TLSs. Within the high contextual profile can be found chemistry TLS “D” that use authentic contexts (social, environmental and scientific) which are usually highly inquirer, constructor or relevant, and persists throughout the sequence. These TLS are student centered, allowing them to investigate, construct, reason and argue scientifically about a chemistry phenomenon. In the group of lower contextual profile can be found chemistry TLS ”E” where pre-service secondary teachers select and sequence activity titles of a scholarly nature, and focus the goals on the presentation of a concept, the development of exercises, and in some cases the verification of theory through an experimental activity. The exploratory analysis points to the existence of a problem in the training of secondary science teachers in relation to the use of contexts in the design of chemistry TLS that are more authentic, constructive, inquiring, relevant and persistent throughout the TLS.
ACKNOWLEDGMENTS

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REFERENCES


PROMOTION OF SYSTEM THINKING IN PRESERVICE BIOLOGY TEACHER EDUCATION

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“INQUIRE for Teacher Students” is an innovative pre-service training course for teacher students of the Master of Education study program biology at the University of Bremen. The goal of the course is to promote inquiry-based science education (IBSE) in the field of biodiversity loss and climate change. Environmental problems are considered to be disease patterns in earth systems that can be investigated using the syndrome approach. This allows the reduction of complex global problems in distinct relations between earth elements in cause-and-effect interactions. As a problem-based environmental context the dramatically loss of the lobster population around the North Atlantic island Helgoland has been chosen. The teacher candidates of the University of Bremen (N=16) conduct an excursion to the island Helgoland. There they investigate the “Helgoland lobster syndrome” supported by science educators, geography educators and the researchers of the Alfred Wegener Institute of Helgoland. Based on their investigations they develop complex simulation games, conduct these activities with school classes of the secondary level and evaluate pupils’ learning. The evaluation of the course is based on various data sources: teacher candidates’ interviews (pre-post), syndrome approaches and concept maps. The findings demonstrate the high potential of the syndrome approach for the promotion of system thinking and subject knowledge in respect to a complex environmental problem.

Keywords: system thinking, syndrome approach, environmental education.

INTRODUCTION

The syndrome approach developed by the German Advisory Council on Global Change (WBGU) is a multidisciplinary analytic tool for identifying unsustainable developments and environmental problems in earth systems by considering them as disease patterns, the so-called “syndromes” of global change (WBGU, 1996). The syndrome approach aims in representing, reducing and returning complex environmental problems to distinct comprehensible relationships (Rempfler & Uphues, 2012). It focuses on the ecological, socio-cultural, and economic dimensions and their interactions in order to foster sustainable development.

Although the new biology and geography curricula reforms in Germany have made explicit the call for teaching system thinking in the science classroom (KMK, 2004; DGfG, 2014) the promotion of appropriate training programs for prospective biology teachers are of minor importance. Therefore, little is known about the impact of specific pre-service teacher training programs in respect to the system competences of teacher candidates and their ability to identify and analyze complex, global (and local) relations and interactions.

This study investigates the impact of the practical course “INQUIRE for Teacher Students” on teacher candidates’ content knowledge and system thinking based on the syndrome approach.
THEORETICAL FRAME

Climate Change and Biodiversity Loss are one of the key issues of Global Change (WBGU, 1996, p.116). They are driven by global transformation processes, which exert profound mutual influences upon each other, unfolding at multiple different scales. The inextricable link between the environment and development plays a central role. Humans and their environment form a tightly intertwined system (Engelhard et al., 2009): “In general, Global Change relates to variations in the key parameters of the Earth’s system […], the reduction of strategic natural resources, the shift and transformation of large-scale structures and patterns, and the alteration of large-scale processes” (Brand & Reusswig, 2007).

The principle of sustainable development (SD) provides an answer to the challenges of Global Change (Stoltenberg, 2010). SD is based on the simple idea that the earth should be developed into a better and healthier system. To achieve this, we must consider interrelated natural and anthropogenic factors from the perspective of intra- and intergenerational fairness (Hauff & Kleine, 2009). Ecological equilibrium of the earth’s system can only be achieved if economic security and social justice are pursued in equal measure (Cassel-Gintz & Bahr, 2008).

The syndrome approach as a tool for analyzing complex problems

The syndrome approach developed by the German Advisory Council on Global Change (WBGU) is based on the principle of sustainable development (WBGU, 1996). Syndrome analysis may be viewed as a conceptual answer to the transversal character of the problems associated with Global Change. The objective is to understand the interactions between changes in the natural environment and problems associated with development. Based on the findings of syndrome analysis, opportunities for early recognition and prognosis and problem-solving strategies can be derived or developed (Pilardeaux, 1997). Syndromes show us the fundamental mistakes that we should avoid on our path towards sustainable development (Cassel-Gintz & Bahr, 2008). The approach is based on the premise that global environmental and development topics can be reduced to more easily understandable relationships connecting environmental degradation trends (WBGU, 1996). Thus, syndromes are patterns of problematic human-environment relationships, represented in the form of relations between the natural and anthropogenic spheres of the earth’s system (Lauströer & Rost, 2008). The approach can be divided into the two dimensions of analysis and action: after deriving a syndrome-relationship framework from the reinforcing and inhibiting interactions between regional and global trends, research priorities can be defined with the ultimate objective of developing sustainable measures to regulate the syndrome (WBGU, 1996).

The Helgoland Lobster Syndrome

The European lobster (Humarus gammarus) is one of the heraldic animals of Helgoland, an island in the North Sea. In former days the lobster fishing was one of the main income sources of the Helgoland inhabitants. Since the 2nd World War the lobster population has dramatically decreased, nowadays the lobster is in danger of extinction.

The development of the “lobster syndrome” (see Figure 1) comprises the following steps: Based on a broad literature analysis system elements are identified and a network of
interconnections of these elements determined. The network consists of six spheres: pedosphere, biosphere, hydrosphere, atmosphere, population and social aspects and, and economy and politics. For the specific analysis of the problem, the key issues of global change “climate change”, “biodiversity loss” and “depletion and pollution of the oceans” are integrated.

In the next step the natural and socio-economic factors of disposition are determined. In respect of the “lobster syndrome” the nature of soil is of great importance as the Helgoland lobster can only live in the clifffy wadden sea. Lobsters are specialists and cannot change their habitat (like fish) if the environmental conditions (e.g. temperature, salinity, or competition) are changing. Especially the overfishing after the 2nd World War, the bombing of Helgoland, and the pollution of the North Sea by shipping traffic, oil platforms, and tourism are possible hindering factors for the constantly decrease of the Helgoland lobsters. Supporting factors for the survival of the heraldic animals of Helgoland is the resettlement program of the Alfred-Wegener-Institute of Helgoland and the tripods of the off-shore wind-parks, where resettlement is possible.

For the analysis of a complex syndrome factual knowledge is not enough (Frischknecht-Tobler, et al., 2008). There is an increased call for promoting system thinking skills when teaching biology and geography (Rieß & Mischo, 2008). In addition, approaches based on system skills have attracted an increasing amount of attention in discussions about educational standards and competency models. The reasons therefore are diverse. In the view of biologists living creatures are remarkable multi-dimensional, and are themselves components of complex systems of populations, ecosystems, and of the biosphere (Campell & Reece, 2003). Animate and inanimate systems are less predictable and cannot be fully controlled by humans. However, humans are able to analyze, influence and even to disturb them (Rieß & Mischo, 2008).

THE INQUIRE COURSE

“INQUIRE for Teacher Students” is a course in the study program Master of Education Biology at the University Bremen. It is based on the European project INQUIRE - Inquiry-based teacher training for a sustainable future (Elster, 2013). In 2015/16 the INQUIRE course took part at the island Helgoland. Goal was the development of IBSE based simulation games in the context of the dramatically decline of the Helgoland lobster (see Figure 2).

- Module 1. Investigation of the ecological background supported by scientists of the Alfred-Wegener-Institute Helgoland and science educators. To gather information about the socio-cultural background, the economic issues (fishery, tourism) and the historical and political development of Helgoland, the teacher candidates interviewed the local inhabitants and visited museums.

- Module 2. Supported by the science educators the teacher candidates conducted IBSE activities and developed the simulation games for the school classes.

- Module 3. The teacher candidates conducted the simulation games with school classes. They evaluated the pupils’ learning outcome. In addition, they reflected on the own professional development and PCK.
Figure 1. Expert syndrome approach (© Müller)
RESEARCH QUESTIONS

The research questions are about: 1) teacher candidates’ content knowledge in respect to the “Lobster syndrome”; 2) teacher candidates’ system thinking based on the syndrome approach (system-related analysis, system organization, system behavior); 3) the self-estimation of teacher candidates in respect to their system competence and working with the syndrome approach.

METHODS OF DATA SELECTION AND ANALYSIS

Sixteen teacher candidates (twelve females, four males) – all of them in the 7th or 9th semester of their pre-service teacher education program (Master of Education for Gymnasium and Oberschule) participate in the INQUIRE course. All of them are studying biology as the first subject.

The methods of data collection are partner interviews with always two teacher candidates (N=16), and the development of concept maps (in teams) and syndrome approaches (in groups of eight participants) in a pre-post-design. In addition the developed materials and simulation games form a further data basis. For the data analysis qualitative and quantitative processes were considered separately.

The interview transcripts are analyzed based on the paradigm of the qualitative content analysis (Mayring, 2010). This allows the building of deductive and inductive categories. The inter-rater reliability is determined by the Cohen’s-Kappa-coefficient (in average 0,8ĸ). Aggregate scores are calculated for the subject knowledge in respect to biodiversity, climate change, and the interconnection of biodiversity loss and climate change.

The concept maps are analyzed according to their basal structure (Kinchin, Hay & Adams, 2000), the scope and the quantitative interconnectedness (Rempfler, 2010), and qualitatively with the relation scoring method (Clausen & Christian, 2012). The analysis of the basal
structure allows insights in the cognitive thinking of the participants (Clausen & Christian, 2012). The way of connectedness (spoke is mono-causal, chain is linear, net is complex) correlates to the levels of the competence model of Rempfler et al. (2012).

The structural complexity of the syndrome approaches are determined by means of three indices: The scope (U) according to Sommer (2005), the interconnectedness index (VX) according to Ossimitz (2000), and the structure index (SX) according to Bollmann-Zuberbühler (2008). To evaluate the syndrome approaches qualitatively the relational scoring method (Clausen & Christian, 2012) was used.

FINDINGS

Impact of the INQUIRE course on teacher candidates’ content knowledge

Based on the results of the interviews a distinctive body of prior content knowledge about the consequences of climate change and its influence on the biodiversity was identified. To measure the impact of the INQUIRE course five questions were analyzed (pre-post interview). The questions were about the endangerment of the Helgoland lobster, the attitudes towards the protection initiatives (e.g. of the Alfred-Wegener-Institute), the concurrence with other species (e.g. bio-invasive crabs), the attitudes towards offshore wind parks in the North Sea (e.g. for resettlement of the Helgoland lobster), and the interaction of carbon dioxide emission and the ocean (e.g. acidification). The results demonstrate a high significant increase of syndrome specific subject knowledge (see Figure 3).

Impact of the INQUIRE course on teacher candidates’ system competence

The development of the participants’ system competence is analyzed based on the concept-maps developed during the pre-post interviews, and on the syndrome approaches (developed and completed during the ship passage to and from Helgoland).
Analysis of the concept maps

The analysis of the basic structure of the concept maps demonstrates the increase of complex structures (pre-interview: two spoke structures, two chain structures, four net structures; post-interview: eight net structures, one chain structure).

The quantitative analysis of the concept maps comprises the scope (U) according to Sommer (2005), the interconnectedness index (VX) according to Ossimitz (2000), and the structure index (SX) according to Bollermann-Zuberbühler (2008). The data show a high significant increase in the scope (all participant teams) and in the VX (seven from nine duos). There is no increase in SX. Table 1 gives an overview about the findings in respect to the indices U and VX.

Table 1. Analysis of the pre-post concept maps. U = scope, VX = interconnectedness index. Master map see Figure 3.

<table>
<thead>
<tr>
<th>Participants (teams)</th>
<th>U pre</th>
<th>U post</th>
<th>VX pre</th>
<th>VX post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duo 1</td>
<td>10.0</td>
<td>30.0</td>
<td>3.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Duo 2</td>
<td>9.0</td>
<td>23.0</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Duo 3</td>
<td>12</td>
<td>26.0</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Duo 4</td>
<td>15</td>
<td>27.0</td>
<td>0.7</td>
<td>3.5</td>
</tr>
<tr>
<td>Duo 5</td>
<td>11</td>
<td>25.0</td>
<td>2.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Duo 6</td>
<td>4</td>
<td>11.0</td>
<td>0</td>
<td>1.7</td>
</tr>
<tr>
<td>Duo 7</td>
<td>14</td>
<td>27.0</td>
<td>2.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Duo 8</td>
<td>16</td>
<td>29.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Means</td>
<td>11.4</td>
<td>24.8</td>
<td>2.0</td>
<td>2.8</td>
</tr>
<tr>
<td>SD</td>
<td>2.6</td>
<td>3.6</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Master-map</td>
<td>54.0</td>
<td>54.0</td>
<td>3.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

The qualitative analysis of the concept maps is based on the Relational Scoring Method (Clausen & Christian, 2012). The findings demonstrate an increase of the average means of the total score (n=16) from 29.3 (SD 9.1) to 65.3 (SD 2.1). That demonstrates that the INQUIRE course successful in the promotion of the system thinking.

Analysis of the syndrome approaches

During their ship passage to and from the island Helgoland (the duration of the passage is about three hours) the teacher developed in teams (duos) syndrome approaches to the Helgoland lobster syndrome (The master syndrome network is presented in Figure 1). We recognized that the average scope (U) of the syndrome approaches is higher than the scope of the concept maps. The mean of the pre-syndrome nets is 54.3, of the post-syndrome nets 100.1. The number of elements increase not so much as the number of relations (pre-mean 15.7 to post-mean 54.1). The comparison with the master syndrome network (see Figure 1) shows that the post-syndrome networks converge to the master map in its complexity. Table 2 shows the indices for scope, interconnection, and structure of the participants´ syndrome approaches.
Table 2. Analysis of the pre-post syndrome networks. U = scope, VX = interconnectedness index, SX = structure index. Master syndrome network see Figure 1.

<table>
<thead>
<tr>
<th>Participants (teams)</th>
<th>U pre</th>
<th>U post</th>
<th>VX pre</th>
<th>VX post</th>
<th>SX pre</th>
<th>SX post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duo 1</td>
<td>35</td>
<td>121</td>
<td>0</td>
<td>2.8</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Duo 2</td>
<td>71</td>
<td>87</td>
<td>1.3</td>
<td>2.0</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Duo 3</td>
<td>32</td>
<td>112</td>
<td>0</td>
<td>3.3</td>
<td>0</td>
<td>0.7</td>
</tr>
<tr>
<td>Duo 4</td>
<td>66</td>
<td>82</td>
<td>0.9</td>
<td>1.8</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Duo 5</td>
<td>68</td>
<td>110</td>
<td>2.3</td>
<td>2.2</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Duo 6</td>
<td>56</td>
<td>76</td>
<td>1.6</td>
<td>2.0</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Duo 7</td>
<td>52</td>
<td>113</td>
<td>0</td>
<td>2.4</td>
<td>0</td>
<td>0.7</td>
</tr>
<tr>
<td>Means</td>
<td>54.3</td>
<td>100.1</td>
<td>0.9</td>
<td>2.4</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>SD</td>
<td>14.6</td>
<td>16.6</td>
<td>0.8</td>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Master-syndrome</td>
<td>122</td>
<td>122</td>
<td>3.2</td>
<td>3.2</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Impact of the INQUIRE course on teacher candidates’ system thinking

The teacher candidates were asked about the self-estimation of their competences in respect to their system thinking and working with the syndrome approach by ticking a box within a 5-point-Likert scale (not informed – expert). The results demonstrate an change from mostly not informed and beginners to advanced (see Figure 4).

![Teacher candidates´ self-estimation](image)

Figure 4. Self estimation of teacher candidates in respect to their system competence and knowledge about the syndrome approach (n = 16).
DISCUSSION

The findings demonstrate the high potential of the INQUIRE course for the development of teacher candidates’ system competence and PCK in respect to teaching system thinking based on the syndrome approach. System competence can be trained with appropriate learning activities such as the simulation games. We can confirm former research results that show a direct correlation between the learner’s subject knowledge and the system competence (Ossimitz, 2000; Sommer, 2005). In this context the visualisation of the flow path and graphic representations of complex interconnections are of great importance (Sommer, 2005; Rempfler, 2010). The syndrome approach and simulation games can motivate the teacher candidates as well as the pupils for a highly networked view of earth systems.

In discussions about the applicability of the syndrome approach to the context of schools, the potential for providing a systemic representation of complex human-environment systems is often quoted (Cassel-Gintz & Bahr, 2008; Krings, 2013). Since research findings have shown that a certain time investment is required before interventions can measurably influence the system skills of pupils (Rempfler & Uphues, 2012), more long-term and in-depth studies of the syndrome method in schools as well as in teacher education programs would be beneficial.

ACKNOWLEDGEMENT

We thank the Foundation of the University Bremen and the Alfred-Wegener-Institute in Helgoland for funding and support.

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RETHINKING LESSON PLANNING – USING VIDEO VIGNETTES AS CASES IN E-LEARNING SCENARIOS

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Teachers have to deal with different and very complex situations in everyday practice often without having much time to think about adequate (re)actions. How adequate they act depends on their scientific, pedagogical, and educational theoretical knowledge but also on the repertoire of possible actions they know. Therefore, teacher education needs to provide learning opportunities to experience different learning situations, to reflect on them from the different domain-specific perspectives, and to try out various actions. In science education, students’ conceptions are seen as essential for fruitful learning processes in the context of different theoretical frameworks as constructivism, cognitive linguistics, or conceptual change approaches. If pre-service and even in-service teachers are asked to design learning activities, many of them do not reflect on students’ conceptions. They focus on scientific facts that are often classified as true and the teacher’s activities. In order to support the pre-service teachers’ understanding, we designed and evaluated case-based learning scenarios for science teacher education. A video vignette gives them access to typical students’ conceptions on biological topics. The model of educational reconstruction offered structural guidance and links to relevant theoretical aspects. To evaluate the learning processes 16 bachelor (n = 10) and master (n = 6) pre-service teachers were videotaped. Their performance and their task solutions were analysed using qualitative content analysis and metaphor analysis. The results have shown the learning scenarios as a promising tool to support rethinking processes of theoretical aspects as well as changes in the pre-service teachers’ practice. While bachelor pre-service teachers primarily reconstructed their attitudes and their knowledge, the master pre-service teachers were also able to scale up their diagnostic and design performances.

Keywords: lesson planning abilities, case-based learning, video vignettes

INTRODUCTION

Teachers have to deal with various and very complex situations in everyday practice often without having much time to think about adequate (re)actions. How adequate they act depends on their scientific, pedagogical, and educational theoretical knowledge but also on the repertoire of possible actions they know. These domains are seen as essential in many models of teacher professionalism. Therefore, teacher education needs to provide learning opportunities to experience different learning situations, to reflect on them from the different domain-specific perspectives, and to try out various actions. Looking at the key factors of effective teaching-learning processes individual students’ conceptions have been identified, especially in science education.
UNDERSTANDING THE ROLE OF STUDENTS’ CONCEPTIONS – A CHALLENGE OF TEACHER EDUCATION

For more than 40 years, students’ conceptions have been intensely investigated in science education. They are described for nearly all core subjects of biology to this day. Evidence shows that students’ conceptions need to be considered in class in order to initiate fruitful learning processes (Duit, 1995; Duit, Gropengießer, Kattmann, Komorek, & Parchmann, 2012). Therefore, integrating students’ conceptions in lesson planning is seen as a crucial part of teacher professionalism (e.g. Shulman, 1986; Abell, 2008). Students’ conceptions are often subject of university curricula for science teacher education. Several core skills are addressed frequently: Pre-service teachers ought to know typical students’ conceptions, they should be able to apply methods to not only diagnose students’ conceptions, but also to exploit the learning opportunities these offer. On the other hand it is important to respond to the learning difficulties that occur from everyday conceptions (Reinfried, Mathis, & Kattmann, 2009).

In contrast to this research evidence, students’ conceptions are still not influencing school practice enough (Abell, 2007; 2008). If pre-service teachers are asked to design learning activities, many of them do not consider students’ conceptions. They focus on scientific facts that are classified as true and on the teacher’s actions (Dannemann, Niebert, Affeldt, & Gropengießer, 2014). Many pre-service and in-service teachers lack knowledge of typical students’ conceptions – actually, they often have the same everyday conceptions as their students (Wandersee, Mintzes, & Novak, 1994). Furthermore, some teachers judge students’ conceptions as less or not important for education. Many pre- and in-service teachers classify students’ answers as incorrect or wrong and give feedback accordingly (Aufschnaiter, Alonzo & Kim, 2015; Morrison & Lederman, 2003). Due to this dichotomous thinking, they do not recognize the learning potential of the “wrong” answers for the design of learning processes. They do not mention them as starting points and mental tools for learning (Driver & Easley, 1978). However, even if teachers know about the importance of students’ conceptions for learning processes they lack possibilities to diagnose them or to refer to them in class (Abell, 2007; 2008; Borko 2004; Larkin, 2012).

Referring to this situation, case-based learning scenarios for pre-service science teacher education with video vignettes as core medium were designed and evaluated. They are supplemented with context documents and theoretical as well as methodological information. The pre-service teachers are asked to design learning activities for the students shown in the video vignette. The model of educational reconstruction is used as structural guidance for planning processes. In order to enhance the pre-service teachers’ understanding and handling of students’ conceptions in educational design processes, the scenarios aim at three different dimensions due to the current state of research: attitudes, knowledge, and performance.

THEORETICAL FRAMEWORK

Case-based learning

The learning scenarios are designed as cases. Case-based learning has been used in teacher education for more than 20 years, mainly for pedagogical issues (Koc, Peker, & Osmanoglu,
Two main reasons are assigned: On the one hand, case-based learning proceeds analogically to problem-based learning. Therefore, it is very useful for ill-structured and complex demands like school practice (Zumbach, Haider, & Mandl, 2008). On the other hand, case-based learning is seen as a possibility to bridge the gap between theory and practice (Merseth, 1991). Therefore, a long-term effect of case-based learning is that teachers are able to use and to enhance their knowledge and their performance in future situations (Aamondt & Plaza, 1994). To reach these aims the cases have to meet different general criteria: Many studies point out that an authentic situation is highly important (Merseth, 1991).

**Video vignettes**

Video vignettes are used as core components of the cases. They combine short sequences of a situation and allow an authentic, context-specific, and motivating approach to topics that are relevant for teaching-learning situations (Sherin, 2004). Many video vignettes show typical or problematic classroom situations and focus on general educational aspects. Therefore, they often focus on the teacher (Janik, Minariková & Najvar, 2013). In the current German “Qualitätsoffensive Lehrerbildung” (i.e. “Quality Campaign for Teacher Education”) many projects address this tool in order to reflect on school practice in university courses or to assess pre-service teachers’ competencies.

**The model of educational reconstruction**

To structure design processes for learning activities the model of educational reconstruction was developed (Duit et al., 2012). In this study, the model is adapted focusing on the topic-specific cognitive construct of students’ conceptions in lesson planning (Figure 1). The analytical process consists of three interacting tasks:

1) diagnosing the individual learning potentials, in this study we focus on the central topic-specific students’ conceptions,

2) critically analysing and clarifying the scientific understanding in order to reconstruct the scientific key conceptions, they can serve as basis for the topic-oriented goals of learning,

3) designing learning activities using the results of the other parts.

![Figure 1. The model of educational reconstruction structures design processes of learning activities based on bringing together students’ and scientific conceptions](image-url)
All tasks are linked to each other and performed recursively. The scientific and the students’ key conceptions both are seen as equally important bases when it comes to design learning activities. Students’ conceptions should not be understood as obstacles for learning – a closer look shows links for learning and science-oriented conceptions as well. Therefore, a differentiated diagnosis of students’ conceptions is a central ability of teachers. On the other hand, the scientific conceptions are not judged as “true” – they are seen as the current accepted explanation (Duit et al., 2012). Learning processes need to be reconstructed from an educational perspective. In contrast to Duit et al. (2012), the construction of the cognitive learning goals is here seen as a result of the scientific clarifying process.

In this study, the model of educational reconstruction is also used to structure the pre-service teachers’ learning processes. The individual learning potentials of the pre-service teachers were diagnosed while they worked on the first case. For example we analysed their understanding of teaching-learning processes. The results were compared with educational conceptions and learning activities for the following cases were designed relating to this.

Embodied cognition and conceptual metaphor theory

As theoretical framework of the analyses of the students’ and the pre-service teachers’ understanding the theory of embodied cognition was used (Lakoff and Johnson, 1980). Its main assumption is that specific biological phenomena are understood in terms of embodied conceptions. In many cases these explanations are not scientific, but everyday explanations. However, they are meaningful and satisfactory in everyday life. One well known everyday conception is the idea of two or many separated blood circulations in our body: the pulmonary and the systemic circuit (Riemeier et al. 2010). In contrast, biological explanations are often counterintuitive: That the function of our extensive blood vessel system can only be understood as one circulation that links the lung with all cells is hard to imagine. Metaphors as the circulation schema in this case can help us to make sense of abstract and complex biological phenomena. To construct scientifically adequate explanations students need to gain scientific experience and reflect on their everyday explanations. Therefore, the theory of embodied cognition allows for the analysis of understandings and the justification of learning activities and methods (Niebert, Riemeier, & Gropengießer, 2013).

KEY OBJECTIVES

We wanted to find out if case-based learning supports pre-service teachers’ diagnostic and design abilities:

- What do the pre-service teachers learn while working with the cases-based learning scenarios focusing on their attitudes, knowledge, and performance referring to students’ conceptions and educational design strategies?
- Are video vignettes helpful tools to initiate the intended learning processes? Which criteria are relevant for determining quality to reach our specific aims?

DESIGN OF THE CASE-BASED LEARNING PROCESS

To support the pre-service teachers’ planning abilities we designed a blended-learning course
that consists of a number of cases dealing with different biological phenomena such as blood circulation, nutrition, growth, evolution, microbial spoilage or photosynthesis. The pre-service teachers work individually or together in small groups. The single cases are designed differently due to various purposes:

*Diagnostic case:* The first case consists of the video vignette and context documents (transcript, information on the students and the curriculum). It is used to diagnose the pre-service teachers individual understanding of planning processes and their performance. Therefore, we ask them to design learning activities for the students in the video vignette.

*Learning cases:* The following case(s) are used to support the pre-service teachers according to their diagnosed learning needs. Often two cases are needed to allow them to reconstruct their own perspectives on learning, their knowledge about the model of educational reconstruction, and diagnostic methods, and even their performance of these tasks. To foster their learning we give them detailed tasks, theoretical and methodological information, and assistance if needed. Subsequently, their proceeding is reflected with a tutor.

*Training cases:* The pre-service teachers have the opportunity to work out other cases that are available on an e-learning platform. They can upload their solution and get double feedback, first from an exemplary solution that is sent to them, and second they can discuss their solutions with a tutor.

**METHODS**

The learning processes of bachelor and master pre-service teachers (N = 16) were videotaped. Their performance and the task solutions were analysed using qualitative content analysis (Gropengießer, 2005) and metaphor analysis (Schmitt, 2005). On the one hand, the coding categories were developed deductively from the theoretic background. On the other hand, they were supplemented by inductive categories that were derived in the analytical process. In this article the focus lies on the perspectives of teaching-learning processes and students’ conceptions. Their analysed learning processes are linked to the learning activities. The following results consist of some of the pre-service teachers’ statements that can serve as anchor citations.

**RESULTS & DISCUSSION**

The development of the pre-service teachers’ attitudes, knowledge, and performance in lesson planning while working on the case-based learning scenarios

*Pre-service teachers’ lesson planning process while working on the first case*

The analysis of the pre-service teachers’ statements (N = 16) before working on the first case shows that they judge students’ conceptions solely as obstacles of learning (Figure 2). Nora and Lara can serve as a typical example for most of the bachelor students (n = 10). Nora states on her performance: “I noted strange aspects or deficits of the student’s thinking.” Nora and her fellow student Lara laugh while watching the video vignette. They write down some students’ statements that they judge as “highly problematic”. A second view of the video vignette or the transcript is rejected. To design learning activities Nora and Lara look through
existing material in scientific textbooks, schoolbooks, or the Internet. They choose material that they judge as scientifically correct, motivating, or well known due to their own school time. All pre-service teachers put the main emphasis on science content in designing teaching activities. Many of the bachelor pre-service teachers used the school- and scientific textbooks uncritically, even if problematic representations were used like the double circulation that was mentioned above: “Double circulation – A circulatory system consisting of separate pulmonary and systemic circuits, in which blood passes through the heart after completing each circuit.” (Reece & Campbell 2011, 11). If the pre-service teachers reflect on reasons for the students’ performance, Mark stated: “If many students do not know this the teacher failed. He didn’t explain it correctly.” This has shown up to be a typical explanation when the pre-service teachers are informed that the students already dealt with the topic in class.

Comparing both sides of Figure 2 emphasizes the pre-service teachers’ learning needs in detail: They do not consider the students’ learning potentials as being important for designing learning activities – even if they are planning for these students. This is in contrast with the constructivist theories that consider learning processes mainly as active processes of the students. The second difference is about the judgment of scientific textbooks. Pre-service teachers regard them basically as correct and, therefore, as material for teaching that can remain nearly unchanged. The theory of embodied cognition points out that they need to be reconstructed consequently from an educational perspective.

![Figure 2. Comparison of the everyday and the elaborated model of pre-service teachers’ design processes of learning activities.](image)

**Pre-service teachers’ lesson planning while working on the following cases**

Looking at Nora’s and Lara’s planning abilities while working on the third case some differences occur, Nora explains her performance: “It is important to find out the current level
of the students, what they think, in order to enhance them in a scientific direction.” Nora and Lara watch the video vignette several times and formulate many concepts. They try to classify them as fostering or hindering for learning whereat they often act insecurely. Their classification tends to be inadequate sometimes from a biological perspective. Three groups used provided research articles or compilations of typical students’ conceptions (e.g. Kattmann, 2015) to ease this process. When it comes to designing learning activities, they explicitly refer to some of the diagnosed students’ conceptions but not in a systematic way. Concerning this aspect, the main difference between the bachelor and the master pre-service teachers occurred: the latter are more capable in structuring their lesson planning processes oriented at the model of educational reconstruction and bring together systematically the scientific and the students’ perspectives. They evaluate the model of educational reconstruction as follows: “It is very helpful. We are forced to bring together several layers. First, the students’ perspectives, second, our own perspectives, third, the scientific perspective. Step by step. And then we bring them all together.” (Marleen).

The results show that learning progressions concerning the pre-service teachers’ attitudes, knowledge, and performances took place. The attitudes comprise the perspective on education and, consequently, on the teacher’s performance and the students’ understanding processes. At the beginning, many pre-service teachers think teacher-centred (left side of Figure 2). While working on the cases, the teacher-centred perspective is supplemented by the perspective on the students’ understanding. The perspective on being a teacher also changes: now it is seen as providing learning opportunities. This reconstruction of the perspective on teaching-learning processes tends to be challenging for one pre-service teacher. Even in the third case Marina reflects on this aspect: “The teacher never says it like it is. How should the students know what is right? Just learning material – this is not teaching.” She was in doubt about the sense of the whole learning scenario. Her most frequent argument was that she would have never time enough to perform a diagnosis of the students’ conceptions in daily school practice and to allow them to reflect on their thinking.

The pre-service teachers improve their knowledge on diagnosing students’ conceptions referring to the latter in learning activities. But for many pre-service teachers it is hard to differentiate between scientifically adequate and inadequate conceptions. In six of eight groups the pre-service teachers themselves have everyday conceptions on the topic or were insecure concerning the scientific concept. Some of them also reflect on their perspective on scientific texts and develop a critical disposition from an educational perspective. Furthermore, master pre-service teachers also reconstruct their performance. In many cases the designed learning activities focus on a conceptual reconstruction from the students’ everyday to scientific conceptions. In these cases the model of educational reconstruction offers a helpful structure. In one group the master students begin to discuss further implications of knowing about typical students’ conceptions: “Students’ problems of understanding phenomena are also important to justify the content of instruction and curricula” (Luise). They reflect critically on conclusions on the systemic levels of school, which is a very promising attitude from the perspective of teacher education.
Design criteria of video vignettes for rethinking the role of students’ conceptions in lesson planning

Video vignettes are used as material to scale-up professional development in various ways and with various goals. In this research project they serve as cases. In this chapter, the design criteria are collected that have proven to be decisive for pre-service teachers’ learning processes.

Compared to many case studies that concentrate on multiple perspectives on classroom situations (Merseth, 1991), our video vignettes focus on students’ understanding. Therefore, the video vignettes include short sections of an interview with one or two students about a biological phenomenon. These sections are key scenes that were taken from a longer interview. The interviews ended with an instructional phase. The video vignettes have a dual purpose: 1) they allow the analysis of typical students’ conceptions for different biological topics (status diagnosis) and 2) the diagnosis of learning processes (process diagnoses). Due to these specific goals, the video vignettes have to meet different quality criteria concerning their conceptual and analytical potential (Table 1). We derived them from literature, the analyses of the pre-service teachers’ statements and of expert interviews. The video vignette has to enable pre-service teachers to interpret typical students’ conceptions. Therefore, the most important criteria are an authenticity impact and a complexity reduction. The latter has shown to be the crucial condition to make the construct of students’ conceptions accessible for analysis. To reach authenticity the interview atmosphere has to be pleasant to enhance the student’s motivation and to enable him or her to act independently. Both aspect have been described in general but not for the construct of students’ conceptions (e. g. Olson, Bruxvoort & Vande Haar, 2016). The chosen key sequences shall allow an interpretation of the student’s explanation, i.e. they have to be meaningful. This criterion is tested by comparing the conceptions with literature and by discussing the single analyses of biology educators (n = 4). It is also discussed if the video vignettes allow to reflect on theoretically and empirically described characteristics of the construct of students’ conceptions (coherent). These aspects ensure that the video vignette is readable for the pre-service teachers. The representational dimension describes supportive aspects that have been described before (e. g. Blomberg et al., 2013). As the introducing statement shows, it is very helpful for the pre-service teachers to deal with the teaching-learning situations without any need to act immediately.

Table 1. Design criteria of video vignettes for rethinking the role of students’ conceptions in teaching learning processes

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Video vignettes …</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual dimension</td>
<td>focus on the individual understanding of a few students (complexity reduced)</td>
</tr>
<tr>
<td></td>
<td>show real learning situations (authentic)</td>
</tr>
<tr>
<td>Analytical dimension</td>
<td>allow to analyse typical students’ conceptions (meaningful)</td>
</tr>
<tr>
<td></td>
<td>allow conclusions concerning theoretical characteristics of conceptions (coherent)</td>
</tr>
<tr>
<td></td>
<td>initiate the diagnosis of students’ conceptions, the scientific clarification, and the design of learning activities (relevant)</td>
</tr>
<tr>
<td>Representational dimension</td>
<td>are repeatable</td>
</tr>
<tr>
<td></td>
<td>require no need to act immediately</td>
</tr>
</tbody>
</table>
CONCLUSION

The results of the case study with bachelor and master pre-service teachers (N = 16) indicate that the learning scenarios are a promising tool to address pre-service teachers’ attitudes, knowledge, and performances on the process of lesson planning referring to students’ conceptions. Looking closer at the relationship of these three parts of the overall planning ability, the perspective on students as important parts of teaching-learning processes can be described as a condition for the reconstruction of the other parts. While bachelor pre-service teachers primarily reconstructed their own attitudes and their knowledge on students’ conceptions, master pre-service teachers were also able to scale up their diagnostic and design performances oriented at the model of educational reconstruction. Significant difficulties of the pre-service teachers are a justified differentiation between scientific adequate and inadequate conceptions and, therefore, the ability to assess the students’ learning potential and to address this accordingly in learning activities. The orientation at the model of educational reconstruction also leads to a gratifying side effect as the pre-service teachers include research results on students’ conceptions in their planning processes in all later case processing. From the perspective of a teacher educator, this model is one option to realise a research based lesson planning. This is also an indication for a successful link between theory and practice, i.e. research on students’ conceptions, and the pre-service teachers planning practice.

The results are in line with the findings of other studies. Shulman (1987) describes that the way teachers think about teaching-learning processes is an essential part of their pedagogical content knowledge (PCK). Alonzo & Kim (2015) confirmed this empirically. The results of this study provide that the pre-service teachers understanding of teaching-learning processes could be a condition for the reconstructions of knowledge and performance. As just one student (Marina) did not receive a constructivist perspective on learning processes further research is needed. At the first case processing all pre-service teachers classified students’ answers dichotomous in correct or wrong (comp. Aufschnaiter, 2015; Morrison & Lederman, 2003). This perspective on students’ conceptions may be seen as a typical teachers’ conception. While the case-based learning process all pre-service teachers begin to reconstruct this estimation. An important impulse for this rethinking was the information that the students in the video vignettes already had dealt with the topic in class. In empirical studies, it has been described for several times that the development of PCK depends on the biological understanding (CK) (Rollnick, Bennett, Rhemtula, Dharsey & Ndlovu, 2008; van Driel, Verloop & de Vos 1998; Veal & MaKinster 1999). The results of this study support this relation and account for biological understanding as decisive for diagnostic and lesson planning abilities.

The model of educational reconstruction has been discussed as both a model for planning learning activities for subject matter and for designing teacher professional education settings – but an application was emphasised as missing (Duit et al., 2012). The results of this study indicate that it provides a helpful structure for both tasks: The pre-service teachers who scale up their performance use the model as orientation. Their statements and their performance show that the structure of the MER establishes students’ conceptions as essential parts of planning processes.
The analyses of the pre-service teachers learning processes give empirical hints on some design criteria to develop video vignettes for addressing diagnostic and planning abilities. Most important is that the video vignettes are complexity reduced. They have to make students’ understanding and learning processes visible. In classroom situations, these educational aspects are often covered by e.g. social or pedagogical aspects. The compiled design criteria offer a basis for further developmental studies and research on video vignettes for educational constructs like students’ conceptions.

The case-based learning approach for teacher education is transferrable to other subjects. But it could also be transferred to other science educational themes, such as students’ thinking and performance in doing scientific work or the nature of science. At the Leibniz University in Hannover, case-based learning activities are currently integrated in the university curriculum for science education.

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REFERENCES


HOW PRIMARY SCHOOL PRE-SERVICE TEACHERS CONSTRUCT AN EDUCATIONAL PROJECT ON A COMPLEX SUBJECT: THE THEME OF TIME

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A short formative module on the theme of Time was proposed in meta-knowledge and experiential modalities to a class of Italian prospective primary school teachers. Time was chosen as a multidisciplinary and complex subject since it is a fundamental concept which allows to construct a bridge between common sense and scientific knowledge. Using a rubric developed by the Udine research unit we investigated how pre-service teachers use the proposed elements on the concept of Time to construct an educational project and how they collect and organize the on-fly suggestions received in the context of a specific situation. A marked tendency towards classification and the need to work on the logical connections among concepts are the main interesting indications of this study.

Keywords: prospective primary school teachers, physics education research

INTRODUCTION

Pre-service teachers education arose the interest and work of many researchers in the last twenty years (Pintò 2001, Michelini 2004, WCPE 2014). The Green Paper on Teacher Education in Europe (Buckberger, et al. 2000) recognizes the importance of developing teachers’ skills in constructing educational projects in spite of a limited disciplinary knowledge.

This is particularly challenging in the case of Physics education for Primary School prospective teachers (PPTs). The EU project STEPS-TWO (STEPS 2011) highlighted that there are two models for teacher education in Europe, in which disciplinary and pedagogical aspects are faced either in sequence or in parallel, but always separately. A fundamental contribution was given in this field by Shulman (Shulman, 1986), who funded the concept of Pedagogical Content Knowledge (PCK) and focussed his attention on how the teacher learns, transforms the learnt content into a content to be taught and projects a didactic path about a subject learnt for the first time. In this perspective, innovative educational proposals have been developed based on three main models: Metacultural, Experiential and Situated (Michelini 2004, 2012).

Nonetheless, the issue of a transversal educational approach that offers the opportunity to construct the epistemological bases, in order both to develop the professional competence necessary to re-elaborate a limited, although epistemologically-based, knowledge and to change the learning contexts, is still open.

In this work we studied how future Primary School teachers construct an educational project on the theme of Time, after a short formative module performed in meta-knowledge and experiential modalities. Rubrics were built in order to monitor the identification of key concepts and conceptual knots and, at the same time, to investigate the ways in which PPTs
translate these elements into a rationale that, starting from the identification of the conceptual elements, leads to organize didactic proposals on a naturally transversal theme, such as the theme of Time, which offers different perspectives of discussion and analysis, also in the scientific context. In fact, Time is a multidisciplinary and complex subject as well as a fundamental concept, and, since it is part of anybody experience, it allows to construct a bridge between common sense and scientific knowledge, which is one of the main objectives indicated by the research literature on scientific learning processes (Michelini 2006).

METHOD

A short formative module on the theme of Time was proposed to 21 prospective primary school teachers at the third year of the combined Bachelor + Master Degree Course in “Primary School Education” at the University of Verona in Italy. The intervention included two phases performed in meta-knowledge (two hours) and experiential (one hour) modality, respectively. The first phase was developed as a lecture in which the theme of Time was presented in a multidisciplinary approach inside different contexts (Philosophy, Poetry, Art, Astronomy, History, Physics, Biology) while looking at different aspects: irreversible phenomena, cyclic phenomena, construction and calibration of instruments, sequence of actions in every-day life, duration of time, use of words related to time. In the second phase, prospective teachers explored a set of hands-on and minds-on experiments within the context of the GEI exhibition (GEI - Games, Experiments and Ideas exhibition) organized by the Udine research unit. In this informal context, the activities dedicated to the theme of Time were arranged into 23 stations, in which objects and instruments were introduced and explained through worksheets planned in order to stimulate students’ observation and reflection.

For the present study, rubrics were developed to investigate the following research questions: How do PPTs use the proposed elements on the concept of Time to construct an educational project? Which elements do they indentify as key concepts and which ones do they identify as conceptual knots? How do they collect and organize the on-fly suggestions received in the context of a specific situation? How do they transfer the identified key concepts and knots in the educational project?

PPTs were required 1) to list concepts that they consider as most relevant in an educational path on the theme of Time; 2) to identify related conceptual knots; 3) to write in chronological order the questions and the related activities that they plan to perform in an educational path; 4) to list and map the physical concepts they plan to treat according with the rationale they chose.

In analyzing PPT answers we looked into 1) the frequency and the order of the listed key concepts 2) the frequency and order of the listed conceptual knots and whether they were or not related to the key concepts 3) whether the indicated concepts and knots were present in the proposed educational path; how students problematized the sequence of conceptual elements into the proposed educational path and how much the problematization affected the construction of a coherent rationale 4) whether the structure of the maps reflected either the structure of the contents or the structure of the educational path and if all the key concepts were present in the maps.
Data analysis was performed following an iterative process of Qualitative Analysis (Miles 2014) by identifying directly from students’ answers a set of categories for each specific part of the rubric (key concepts, conceptual knots, questions in the proposed educational path, activities in the proposed educational path, maps) and by refining it through successive re-readings of students’ reports.

RESULTS AND DISCUSSION

Key concepts

Students were required to list the concepts that they considered as the most relevant in their educational path on the theme of Time. The order (as colors) and frequency of the listed key concepts are reported in Figure 1.

Figure 1. Key-concepts listed by the PPTs. Colors correspond to the position of the concept in their lists. The abscissa gives the number of students who indicated that element.

Periodicity and cyclic phenomena are treated by all the students, followed by measurement of time and duration. Irreversibility is less cited although it is the one that defines the meaning of time (coherently with what we see at point 6 of the results).

Almost half of the students (9/21) choose the concept of time as the «attack angle»; other attack angles are irreversibility and periodicity (3/21); measurement, duration and sequentiality are chosen as attack angles by 2/20.

The concept of time is considered as separated from irreversibility as well as from periodicity that is listed at the second place by 6/20.

The contextual approach is chosen only by 3/20, as well as the interdisciplinary one; also the evolution of phenomena and sequentiality are treated by a minority (5/20).
As a general comment, we find that contexts are missing. Elements related to the comprehension of the concept of time are not structured in their conceptual organization: e.g. almost all PPTs speak about duration but the concept of instant, which gives sense to duration, is not treated; the same holds for contemporaneity. Although abstract concepts should not be chosen as attack angles but should instead be placed at the end, students make the opposite choice and place abstract concepts at the first place.

Conceptual knots

The order and frequency of the key concepts listed by PPTs are reported in Figure 2.

![Conceptual knots listed by the PPTs. Colors correspond to the position of the element in their lists. The abscissa gives the number of students who indicated that element.](image)

Operative aspects (how time is measured, how clocks work) and their relations with mathematics prevail.

Periodicity, cyclicity and measurement of time form a coherent cluster of knots. Measurement of time as related to how clocks work is considered the most important knot by 15/21. This knot is confirmed and strengthened by the fact that 10/21 identify as knot periodicity and cyclic phenomena and 6/21 chronological order and sequentiality.

Another cluster of knots concerns irreversibility and how to reconcile irreversibility and periodicity. Irreversibility is at the first place for the majority of the students: this is a positive indication that they have a clear idea of the need to focus on conceptual issues. Anyway, periodicity and measurements are the most cited.

Questions/arguments proposed in the educational path

PPTs were asked to write in a chronological order the questions and the related activities that they plan to perform in an educational path. In most cases, questions were in fact considered as “guide-questions”/arguments and not as inquiry questions. Only in the case of the concept of time the question “what is time” is made to the pupils never to ask for a definition but always to collect their spontaneous ideas. Other single cases where questions are posed to pupils, always to collect spontaneous ideas: which are the words of time (1), how do you measure time (1), which is irreversibility (1), which is the difference between sequentiality and contemporaneity (1), what is periodicity (3).
The order and frequency of the arguments proposed in the educational path are reported in Figure 3, where specific contexts (sun motion, language, poetry), indicated only by 7 students, are reported separately.

![Figure 3. Questions/arguments listed by the PPTs. Colors correspond to the position of the element in their lists. The abscissa gives the number of students who indicated that element.](image)

The concept of time is placed at the first position as an independent subject by the majority of the students (coherently with what we see at point 6 of the results). ‘What is time’ and ‘if it is possible to go back in time’ are at the same level of interest: there is no contextualization.

Periodicity (mainly a key concept) and irreversibility (mainly a conceptual knot) are placed at the first three places by half of the students after the general concept of time, indicating a significant orientation towards conceptual aspects and towards the distinction between the idea of time and the measurement of time.

At the second or third place 5/21 PPTs indicate chronological order and sequentiality and the knot of the relation between sequentiality and contemporaneity.

The most cited argument is ‘how do clock work?’ Almost all of PPTs place the measurement of time and the way clocks work at some point of the learning path.
History of time measurement was indicated by 7/21, for half of them at the beginning (1\textsuperscript{st} to 3\textsuperscript{rd} position), for the other half as a final argument (4\textsuperscript{th} to 6\textsuperscript{th} position): narrative aspects are important also when conceptualization could prevail.

Very few students choose to start from the concept of instant to recognize that time is composed by instants.

From these data, it emerges that PPTs have acquired the idea of an approach related to every day experience, but they haven’t acquired an inquiry based learning strategy: they tend to put general concepts at the beginning instead of starting from contexts and reaching the global concepts at the end. They tend to ask for definitions. This is known to be a non effective approach: learning should be contextualized and concepts should acquire a meaning from their correlation inside different contexts. The question ‘what is time’ is of a metacognitive type and should be posed at the end of the learning path.

![Diagram](image)

Figure 4. a) Listed themes and number of PPTs who chose them either as elements of the educational path (green line) or as key concepts (red line) or as conceptual knots (blue line). b) Relevance of each theme either as an element of the educational path (green line) or as a key concept (red line) or as a conceptual knot (blue line). For each category (argument, concept, knot) the relevance was calculated by dividing the number of students who chose a certain theme in the category by the total number of students who chose the same theme in any of the three categories. The five students who cited the difficulty in conciliating periodicity and irreversibility are considered in both the two themes.

Relevance of each element as part of the educational path, key concept or conceptual knot

The synoptical graphs reported in Figure 4a and 4b allow to see how the frequency with which each element is chosen as an argument of the educational path is related to the frequency with which the same element is identified as a key concept and as a conceptual knot.

Duration is seen as a key concept as well as a chosen argument, not as a conceptual knot.

For the other themes, there is a coherence in their relevance as key concepts, conceptual knots and proposed arguments, except for the case of periodicity, which is replaced by time measurement in the proposed arguments: this could be an indication that measurement of time and periodicity are considered as associated.
This is also confirmed considering that periodicity and time measurement have the highest relevance as conceptual knots.

Periodicity and duration are relevant concepts as well as the concept of time and the history of the measurement of time. Irreversibility has the same weight as argument, concept and knot. The measurement of time is proposed by the most part of the students although it is considered less important than periodicity and irreversibility.

The concept of time in not critical although important. Chronological order is a critical issue which has to be treated but is not considered of a conceptual type.

**Activities planned for the educational path**

PPTs were also asked to list the activities they plan to perform in the proposed educational path as related to the identified questions/arguments. The frequency of the listed activities grouped by categories and related to the subjects (as colors) to which they were referred by PPTs, is reported in Figure 5.

Answers can be divided into three groups: 1) educational tools (reading, writing, story-telling, organizing previous knowledge); 2) construction and use of instruments for time measurement; 3) exploring phenomena.

In the first group, reading and story-telling are the most utilized educational tools to understand what is time, periodicity and chronological order as well as the distinction between sequentiality and contemporaneity up to the recognition of the correct words of time. Drawings are at the second place, which is quite understandable given the age of the children. Half of the students use images, photos, poster, only 4/21 written materials.

In the second group, all the cited instruments are related to conceptual aspects of time as the wheel of time or hourglasses and pendulum, less frequent is the use of clocks and sundials; most simple instruments such as gnomons, graduated candle, are totally neglected.

As far as the exploration of phenomena is concerned, interestingly PPTs propose phenomena which are or have been historically used for time measurement only as a way for illustrating the concept of irreversibility. Elements of the calendar (seasons, days and months) are the natural phenomena chosen, although by a low number of students (2/21, a little higher, 5/21, in the case of seasons), and have the same frequency as evolution phenomena of a totally different nature such as the motion of fluids and ice fusion (3/21 or 4/21). The measurement of time is only related to a cyclic phenomenon and to periodicity, which in fact is a conceptual conquest due to modern technologies of time measurement. The most common associations to personal experience (birthday, portrait of children, changes due to their own growth or to animal or plant growth) are rare with respect to the choice of stories or technical aspects or seasons.

The relevance of each subject in terms of number of related activities is given in Figure 6, where, for each subject (same colors of Figure 5), the total number of proposed activities (of any category) was weighted by the number of students who chose at least one activity for this subject.
The aims of the proposed activities are coherent with the subjects indicated as conceptual knots. Periodicity (31%), and then irreversibility (23%), have the highest weight in the proposed activities, while activities related to measurement weigh only 15% although measurement is the most cited among critical issues and among the proposed arguments. The number of activities related to the ideas of time is comparatively low (8%). Chronological order and sequentiality related to the need of distinguish it from contemporaneity have the same weight.
(6-7 %). The weight of activities related to instant, to the relation between time and earth motion and to the words of time is much more low (2-4 %).

**Concepts and maps for the proposed educational path**

Finally, PPTs were asked to list and map the physical concepts they plan to treat in the educational path. Time is always a pre-existing general concept or entity (19/20), placed at the top (15/20, Figure 7a) or at the centre (5/20, Figure 7b) of the map. Only in one case irreversibility is introduced before the concept of Time. Inside the first group, 9/15 show a conceptual structure where time is organically related to elements which constitute the meaning of time, while 6/15 are organized into proposals of activities. In most cases, maps are collections of disconnected, or only partially linked, items. One student makes a distinction between an objective time connected with its measurement from the perception of time as irreversibility and periodicity.

Periodicity and irreversibility are both cited by 8/20, in all other cases only one of the two concepts is cited. Irreversibility (10/20) is never cited as a property of phenomena, it is always a property of time: in one case, it is defined as ‘irreversible time’. Similarly, periodicity (18/20) is a property of phenomena only in 5/18, it is more often a property of time (13/18): in 1 case periodicity is defined as ‘reversible time’.

The concept of sequentiality (before, during, after; past, present, future) is cited in 9/20, it is related to irreversibility in 2/9, it is related to the words of time in 4/9. The concepts of duration/time interval are cited by 9/20 as related to measurement (2/9), related to instant (3/9), related to periodicity (1/9).

In any case, irreversibility, periodicity, duration, sequentiality are mostly separated, independent, not interconnected: they all are properties, manifestations of time. Measurement itself is independent, it is related only to periodicity and only in 4/18.

Figure 7. Two typical maps proposed by PPTs: a) Time is placed at the top of the map; b) Time is placed at the centre of the map.
CONCLUSIONS

The importance of developing teachers’ skills in constructing learning paths on complex subjects in spite of a limited disciplinary knowledge is well known and recognized especially in Physics Education for Primary School Teachers (Buckberger, et al. 2000). Nonetheless, the issue of a transversal educational approach for PPTs, aimed at constructing the epistemological bases and developing the professional competences necessary to create a learning environment for pupils, is still open. In this context, it is important to understand how future teachers construct an educational path on a complex and transversal subject to identify key points on which to draw attention in PPTs education.

The rubrics developed by the Udine research unit allowed us to monitor the process of construction of a learning path on the theme of Time by twenty one future Primary School teachers at the third year of the combined Bachelor + Master Degree Course in “Primary School Education” at the University of Verona in Italy, and to investigate the ways in which they identify and translate key concepts and conceptual knots into didactic proposals on a multidisciplinary and complex scientific concept, even if not too far from anybody personal experience.

The present detailed analysis of PPT answers gives some interesting indications. PPTs have a marked tendency towards classification (general concepts are placed at the beginning of the learning path and are not constructed as the end-points of the educational proposal; learning is not contextualized; reference to the personal experience or to contexts in the proposed activities is relatively rare; Inquiry Based Learning strategies are not acquired) and are not able to distinguish between physical entities and phenomena (periodicity and irreversibility are mostly considered as properties of time rather than of physical phenomena). It also emerges that much attention is paid in PPT education to methodologies rather than to concepts, thus leading to a strong need to work on the coherent connections among concepts, which are the basis for organizing a coherent learning path (maps are mostly collections of disconnected, or only partially linked, items).

As a whole, these results deserve further study on other classes of PPTs in order to increase their statistical significance and confirm the identified trends.

REFERENCES


TEACHING PRACTICES IN PRESERVICE SCIENCE TEACHER EDUCATION

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Recent efforts to design and study Pre-service Science Teacher Education have focused on engaging future teachers in teaching practices. This focus on practices comes with an explicit intention to blend aspects of knowledge and doing that has been historically separate in other efforts to teach novice learners practical aspects of their profession. This intention brings particular challenges to EU preservice teacher preparation programs that need to reconsider how to incorporate aspects of practices into their science education courses. These challenges not only emerge from the novelty and interrelated nature of these practices, but also from lack of clear ways of articulating what these practices are and look like across international teacher educational contexts. This paper brings together four EU studies and an international discussant that explore possibilities to embrace and respond to these challenges and being a cross-contextual conversation about science teacher education.

Keywords: teacher education, preservice teachers, science teaching

TEACHING PRACTICES

Preparing teachers to teach science has many complications and challenges. One challenge we face as a field is that we do not have clear and well articulated set of practices defined that could help to inform the design of experiences – both courses and field-based teaching placements – to support the development of excellent science teaching practices. This challenge is exacerbated by the fact that we are working across contexts and levels of practice, in what Windschilt & Stroupe (2017) call the three-story challenge. In order to have conversations across teacher education context we need to not only articulate what kinds of practices we imagine for students in science classrooms, but also the practices their teachers use to create such a learning context, and finally the kinds of practices we as teacher educators need to engage preservice teaching in to develop appropriate teaching practices. In many countries, there are standards or national curricula that define what students are meant to learn (e.g. The Next Generation Science Standards in the United States, NGSS, 2013; the Knowledge Promotion in Norway, UDir, 2013; KMKK, in Germany, KMK, 2004; The Common Objectives in Denmark, Common Objectives, 2017); however, these standards only recently began to articulate practices that we expect students to engage in while learning science. The lack of clearly articulated definitions of student practices across national contexts means that it is even more difficult for teacher educators to articulate science teachings practice that can lead students to engage with science in productive and disciplinarily authentic ways.

For science teacher educators, the challenges in teaching play out in (at least) two instructional contexts, teacher education coursework that happens in university classrooms, and teaching
placements in the field where preservice teachers are working with practicing teachers in some way for some period of time, usually supervision from a university faculty or staff member. There is a large amount of variation across programs about how the balance between these two instructional contexts is struck, and in the particular structures that exist in the courses and in the field placements. All of this complexity makes communication across programs unproductive as we do not have a shared language of practices for us to use when comparing and discussing teacher education contexts.

This paper intends to begin to address that complexity. We hope to begin a conversation across an international group of teacher education scholar/practitioners who are attempting to characterize our own practice(s) and its relationship to the outcomes we have for our preservice teachers, and the outcomes of the K-12 students they teach. Each of the four research groups, a German, a Danish, a Norwegian and a Swedish one, will briefly describe some relevant details of the instructional context(s) or learning environments where these pedagogies and experiences are occurring and then articulate a connected chain of practices cutting across the three layers: 1) a practice students should engage in as part of learning science; 2) a practice teacher educators hope to develop in preservice teachers that is directly linked to the student science practice; and 3) a teacher education practice that teacher educators engage their preservice teachers in, in order to develop the targeted teaching practice, and ultimately student practice. By articulating the reasoning that links this chain of practices, we will make available for discussion our own thinking about how teacher education leads to changes in student learning via changes in preservice teacher teaching practices.

**GERMAN – FOCUS ON MODELLING PRACTICES**

The first study focuses on the second (teacher) and third (teacher educator) layers of the theoretical framework of this paper. However, decisions made while designing practices for these two layers are based on what is expected to happen in the first layer (student), i.e. elementary students developing scientific modeling practices. The connecting principle is problematizing, one of the four principles of the productive engagement framework (Engle and Conant, 2002). The focus is then on teacher educator practices developed to engage preservice primary teachers in learning to engage elementary students in scientific modeling practices by problematizing. I discuss students’ meaningful engagement in scientific modeling (Schwartz et. al. 2012) and examine preservice teachers’ engagements that avoid rote procedures as well as declarative knowledge to learn about these teaching practices. My focus here in one modeling teaching practice: Engaging others in performing a modeling learning goal by problematizing. Understood as an individual or collective action that encourages disciplinary uncertainness, problematizing is a known principle fostering meaningful disciplinary engagement (Engle & Conant, 2002). Here, it will be considered as a key didactical element in articulating supports for preservice teachers learning how to enact scientific modeling practices in their future classrooms. As this teaching practice is new for them, I examine their learning during the re-enculturation process they walk through. Because I want to attend to whether and how the practices are personally meaningful, I include in the research design the idea of “making sense in the doing,” choosing to confront preservice teachers to “do something”
where they attempt to see aspects of the teaching practices they are engaged in rather than make declarative statements about them.

The goal of this study is to better characterize and illustrate the designed modeling teaching practice by understanding what sense preservice teachers make of this practice in the doing. It examines the work of 24 preservice teachers in an integrated science content methods course of a German elementary preservice teacher preparation program. The course lasts two semesters and includes designed supports to make sense of scientific modeling practices, including supports in planning and enactment of short modeling-based investigations, and writing short essays to answer questions about these investigations. Data come from four groups of six students each video recorded during the enactment of their model-based investigations and reflective essays. The analysis follows a constant comparative interpretative procedure among the data sources organized around two analytical dimensions: 1) Epistemic modeling goals; 2) Epistemic modeling considerations, both general and domain-specific, students exchange while working towards epistemic goals. These dimensions are consistent with the Epistemologies in Practices (EIP) framework (Berland, et al., 2015) and highlight the pragmatic context of doing embedded in practical epistemologies supporting learning (Ostman & Wickman, 2014). These analytical dimensions can be distinguished as preservice teachers perform engagements sustained by problematizing. With the characterizations of these performances, the study aims to contribute to our understand of how preservice teachers learn the practice of teaching scientific modeling.

Relevant findings emerged when preservice teachers articulated epistemic considerations performing engagements towards model revisions. I found three patterns. In the first, the modeling goal was performed in three steps: first, through engagements in generating a diversity of ideas about explanatory aspects of the models; second, by working upon this diversity to consider the ideas as alternatives in terms of the different explanations they can produce; and a third, one where preservice teachers engage in justifying the decisions made upon mulling these alternatives. This pattern showed a productive use of problematizing in sustaining engagements for an epistemic goal. In the second pattern I found attempts at problematizing where preservice teachers couldn’t go beyond engaging others in generating diversity of explanatory ideas. In this case, further model revisions were made by direct teaching, telling others “which model revision will be better to explain what was going on,” abandoning the problematizing principle during the performances of the further engagements. The third pattern showed engagements in generating a diversity of explanatory ideas, exchanging these ideas as alternatives in the explanations but with no attempts at mulling these alternatives. This pattern gives the impression that problematizing was left aside in this last track. The three patterns suggest how problematizing was used to sustain engagements, mainly when working towards revising models with regard to the explanatory dimension of modeling. Our challenge then is to use what we learned to inform our own teacher educators practices – belonging to the third layer of this paper set. In this case, this may mean to anticipate the uses of problematizing found to improve our own teaching designs.
The second study focuses on collapsing the three layers of practice to create a teacher education practice where preservice teachers learn to teach interdisciplinary science in authentic teaching contexts. The target practice of this study is preservice teachers’ intended practice as future in-service primary science teachers. But rather than just executing pre-scribed teaching activities, the preservice teachers engage in developing and planning interdisciplinary science activities that they will subsequently teach and assess in a real classroom-context. In other words, preservice teachers experiment with interdisciplinary science practices for students in real classroom contexts. The goal of the study is to characterize how preservice teacher experimentation with interdisciplinary teaching practices can support their meaning making about the qualities of interdisciplinary teaching through action learning. As teacher educator, I hope to develop preservice teachers’ practices around how to develop, plan, teach and assess interdisciplinary science activities that they will use as coming in-service teachers. The research questions that guided this study are: How can interdisciplinary teaching practices support preservice teachers’ meaning making through action learning? Can changes in the preservice teachers’ meaning making about teaching interdisciplinary science be mapped with the SOLO-taxonomy?

Training students’ problem solving skills in science is considered as a key element in the Danish science curriculum in primary and lower secondary schools. One of the most consistent strategies to learn these skills relates to solving realistic problems in interdisciplinary science activities (Czerniak & Johnson, 2014). In Denmark interdisciplinary science relates the subjects of biology, geography, physics/chemistry and technology. The teaching strategies used in interdisciplinary science are based on inquiry and engineering-based activities.

The context of the research is an interdisciplinary science teacher-training module for primary and lower-secondary preservice teachers. Module activities are organized in three projects. In the first project, preservice teachers attend instructional activities and experiment with interdisciplinary teaching the other preservice teachers in the module. The remaining two projects consist of instructional activities, experimental teaching and action learning with 6th grade students in authentic classroom settings. Interdisciplinary science teaching practices are new to many preservice teachers so their meaning making through developing, planning, teaching and assessing these interdisciplinary activities offers evidence for how better to support their learning.

Preservice teachers’ reports from the three projects were analysed comparatively using Biggs SOLO-taxonomy (Biggs & Collins, 1982) to map preservice teachers’ meaning making of student activities during the experimental teaching situations. Focus in SOLO is neither on what the teacher does nor on what the students can, instead the focus is on what the students do. Learning outcomes are characterized by using verbs to categorize whether student learning is unistructural, multistructural, relational or extended abstract. The cohort consisted of 14 preservice teachers. During the module preservice teachers made three reports. Two of these reports contained reflections and meaning making about student learning in relation to preservice teachers’ teaching of interdisciplinary science in 6th grade science classes. The third report was made without a connected practice situation as basis for the preservice teachers’
reflections in the report. Thus, a comparative study of integration of practice situations in student learning was possible by analyzing the taxonomical levels in the reports. The comparative analysis was supplemented with observations of the preservice teachers in practice situations and group interviews to gain insights into metareflections on their meaning making process.

A recent review of strategies that support teacher professional learning provides evidence that integrating teaching practices into teacher training is a powerful tool for preservice teachers learning processes (Nielesen, 2016). A recent study also indicates that preservice teachers increase their self-efficacy by working with interdisciplinary science in practice situations (Flores, 2015). These findings are supported by the results of the present study. Analysing the preservice teachers’ reports provided evidence about the degree of their meaning making regarding different didactical items: Learning goals, assessment, quality of teaching activities, teacher role, student motivation and contextual factors. The level of preservice teacher reflections in the reports that was made on the basis of integrating action learning in practice situations were, on average, on a higher taxonomical level than the reports that did not integrate reflections from an action learning process. In interviews, preservice teachers argued that their learning outcome was considerably higher when they had experimented with teaching activities in practice situations. As one teacher student argued:

‘When we experimented with the teaching activities in the 6th grade class some of the didactical theory made much more sense. It was easier to write the reports and picturing how e.g. investigating the water quality in a pond relates to biology and chemistry.’

Observations of preservice teachers enacting interdisciplinary science teaching in practice revealed that meaning making was taking place while a group of preservice teachers conducted teaching activities. The group organized themselves in such a manner that half the group were teaching, while the other half were collecting data for their action learning. Data consisted of video recordings of practice situations, gathered artifacts, and interviews with 6th grade students about their experience with interdisciplinary teaching. The preservice teachers subsequently used the data for grounding their reflections on teaching actions in their reports.

The most important finding from this study is that preservice teachers became competent in reflecting on the qualities of interdisciplinary teaching using didactical theory. Experimenting with interdisciplinary science in practice situations proved to be important empirically that the preservice teachers used didactical theory to analyse student learning outcomes. In this sense the evidence from the practice situations was a driver for the preservice teachers’ construction of their own didactical theories about interdisciplinary science teaching. One of the aims in Danish teacher training is to develop preservice teachers to become future reflective practitioners assess and develop the quality of their own teaching practice. For this reason, another important outcome from this study is that through action learning preservice teachers became competent in collecting empiric that subsequently enabled them to reflect on their experimentation with teaching interdisciplinary science in productive ways A third outcome is that preservice teachers expressed increased confidence in using interdisciplinary teaching in their future teaching practice. These results are interesting because the process of action learning allowed the preservice teachers to connect theoretical understanding about
interdisciplinary science teaching with their enactment in practice situations. The process of collective meaning making and writing the reports were means that enabled preservice teachers to consolidate their experiences and construct their own didactical theory about how to develop, plan, teach and assess interdisciplinary science teaching. Moreover, although the preservice teachers considered experimenting with interdisciplinary science teaching in authentic settings, engaging in action learning and writing reports as a cumbersome processes, the transitions between practices that allowed the preservice teachers to experiment with developing, planning, teaching and assessing interdisciplinary science constitute a way to increase their learning and self-efficacy about becoming competent future in-service science teachers.

**NORWEGIAN – FOCUS ON INQUIRY-BASED LEARNING**

The third study addresses all the three layers of practice from the Norwegian perspective. At the first layer, i.e. in terms of practice students should engage in as part of learning science in K-12, the focus was inquiry-based learning (IBL). Indeed, the latest Norwegian policy reform in the 10-year compulsory school and in upper secondary education (UDir, 2013) embeds a new main subject area in the science curricula: the budding researcher, which models the process dimension of the Nature of Science and clearly features inquiry-based learning (IBL). The central inquiry practices described in the budding researcher bear strong similarities with the scientific practices from the US National Research Council’s (NRC) Framework (NRC, 2012), e.g. asking questions, designing investigations, analyzing data, etc. In Norway, The Norwegian Research Council has developed a guide meant to assist teachers in developing teaching practices that promote inquiry called the Nysgjerrigper Method (Nysgjerrigper, 2006). The Nysgjerrigper Method consists of six steps to research, similar to NRC’s eight scientific and engineering practices, but specially designed for use at primary schools in Norway. The six steps are: 1) I wonder why? 2) Why is it like this? 3) Draw up a plan; 4) Collect data; 5) What we found out; 6) Tell everyone else. Despite the systemic support in Norway (KD, 2016), the PISA+ classroom study reports few enactments of the budding researcher in Norwegian schools (Ødegaard and Arnesen, 2010). Thus, a discrepancy is observed between intention, planning and implementation of inquiry at the classroom level.

One possible way to overcome these obstacles is by developing preservice teachers’ ability to scaffold and teach students science using IBL pedagogy inspired by the Nysgjerrigper Method. This was the focus of the second layer of practice in this study, i.e. the practice we (teacher educators) hope to develop in preservice teachers. Windschitl and Stroupe (2017) describe four principles of instruction they consider good examples of the means by which reform goals for student learning are more likely to be achieved: 1) Provide varied opportunities for students to reason through talk; 2) Treat students’ ideas and experiences as resources to build on; 3) Make students’ thinking visible; and 4) Scaffold students’ writing, talk and participation in activity. In our context, the preservice teachers’ ability to apply these principles is considered an important practice to support students’ science practice as expressed in the Nysgjerrigper Method.

When it comes to the third layer (teacher education practices), Windschitl and Stroupe (2017) state that cycles of preparation, enactment and feedback are a good pedagogy for progressive teaching in teacher education. In our study, we address the third layer of practice by engaging
preservice teachers in using the Nysgjerrigper Method. We asked primary school preservice teachers to use the Nysgjerrigper Method as a support for structuring their inquiry-based lesson plans. In addition, we gave assignments to enact the planned lesson in their practicum followed by reflection with peers, practicing teachers and teacher educators. These pattern of planning-enactment-reflection correspond well to what Windschitl and Stroupe (2017) suggested as good pedagogy in teacher education.

We investigated: which NRC’s scientific practices were preservice teachers able to implement in early primary school when their IBL-lesson plans were based on the Nysgjerrigper Method? For the purpose of this paper, we discuss the 2nd layer of practices in light of Windschitl and Stroupe’s four principles. Our particular study is based on two cases, each case consisting of 3-4 preservice teachers, teaching 1st graders (6-7 years old) or 2nd graders (7-8 years old), each in their designated practicum school. In terms of preservice teachers’ application of these four principles, we observed that preservice teachers engaged students in various dialogues (Windschitl and Stroupe’s principle 1), e.g. (a) used children’s’ natural curiosity in a classroom discourse with the aim of setting up research questions in plenary, (b) initiated dialogue to engage students in analyzing and interpreting data, (c) encouraged students to construct explanations, (d) engaged students in building arguments from evidence. Thus, they provided opportunities for students to reason through talk.

Our preservice teachers were also focusing on treating students’ ideas and experiences as resources to build on (Windschitl and Stroupe’s principle 2). The two first steps in the Nysgjerrigper Method is “I wonder why?” and “Why is it like this?” which encourage students to set up their own research question and hypothesis, which build on their ideas and preconceptions. Preservice teachers were also using objects that were familiar for the students and activities students were experienced with and were able to adapt to students’ abilities, like offering writing or drawing depending on individual capabilities.

Preservice teachers were making students’ thinking visible (Windschitl and Stroupe’s principle 3), mainly via discourse, and recording of hypothesis and results in writing templates and drawings. Using the Nysgjerrigper Method, preservice teachers were also able to scaffold students’ writing, talk and participation in activity (Windschitl and Stroupe’s principle 4). For example, they modelled (role played what a hypothesis is and imitation played what it means to observe), used tables to differentiate hypothesis from results, offered writing templates and drawing for recording of data, and asked questions to make students wonder. During practical activities preservice teachers scaffolded group discourses, ensuring all students active participation and contributions.

In terms of connected chain of practices across the three layers our findings show that the students in lower primary have been engaged in a great range of scientific practices (student layer), since almost all of the NRC’s categories, as well as Windschitl and Stroupe’s four principles were implemented by the preservice teachers (teacher layer). We saw that preservice teachers have given careful thoughts to planning the lessons based on the Nysgjerrigper Method and the Method seemed to give them the support they needed (teacher education layer). Different strategies were applied in order to engage students in scientific practices (student layer), and in both cases preservice teachers not only used the Nysgjerrigper Method for
themselves as a guide for planning, but also encouraged 1st-2nd graders to learn (1) about the Nysgjerrigper Method; (2) how to use it; and (3) why they should use it, showing some didactic transposition from the teacher layer to student layer of practice. The implemented scientific practices and the strategies employed at the teacher educator layer seem to have resulted in gains in preservice teachers competency for implementing IBL-scientific practices at early primary school.

SWEDISH – FOCUS ON PLANNING TEACHING

The fourth study primarily focuses on the second and third layers of practice, viz., a practice that we, as teacher educators, are hoping to develop in preservice teachers (viz., planning of teaching) and a teacher education practice that we engage in to develop in preservice teachers a certain, targeted practice (viz., microteaching). Thus, unlike the three other studies, here the target practice is not primarily an intended practice for K-12 students, but rather the in-service teacher practice of planning teaching. However, the content of the teaching plans was sustainable development, so this would lie close to the intended classroom practice corresponding to the first layer (student practice) of the theoretical framework. We try to achieve the primary target practice (i.e., planning teaching for sustainable development) by engaging our preservice science teachers in the planning phase of microteaching. Thus, the study focuses on the tension between the preservice science teachers acting precisely as preservice science teachers (focusing, for instance, on “what to do to accomplish the assignment”) and the preservice science teachers, instead, acting like in-service science teachers, actually performing the actions expected by a practicing teacher.

The study was part of a larger research project focusing on science teacher education and how it may be modified and developed in collaboration with science teacher educators. Five groups of preservice teachers taking a one semester course in science and science education, focusing on sustainable development, science education for citizenship and socio-scientific issues, were video recorded as they were planning a 20-minute microteaching unit. The planned unit had to concern a content specified in the syllabus for elementary school viz. human, nature and society in interaction for sustainable development. Each group consisted of 5-6 preservice teachers. Their conversations were transcribed verbatim and analysed, using Practical Epistemology Analysis (Wickman, 2004; Wickman & Östman, 2002). PEA is established method for analysing what purposes people pursue during an activity, how they pursue these purposes as part of a practice and how the practice slowly changes as a result of this.

An interesting characteristic of microteaching is the fact that the preservice teachers need to adopt several different parallel roles, viz., as an in-service teacher, preservice teacher and student (Bell, 2007). Our analyses indicate that preservice teachers regularly moved between a preservice teacher-centered and an in-service teacher-centered practice when they were engaged in planning. The preservice teacher-centered practice was identified through the preservice teachers referring to such things as the instructions, perceived expectations from the teacher educators, or other references to the on-campus context whereas the in-service teacher-centered practice was recognised by being indistinguishable from a conceivable conversation between professional teachers. Overall, the preservice teacher-centered practice was characterized by purposes concerning how to handle and solve the assignment, whereas the in-
service teacher-centered practice consisted of the preservice teachers focusing on details of the unit and how to modify and develop the chosen content and methods. The most important finding is that the preservice teacher-centered practice, as well as the recurring transitions between the two practices, displayed unexpected opportunities for learning. A typical feature of these opportunities was that they offered possibilities for reflection in ways not conceivable within authentic teaching practice. In particular, they allowed a freedom for the preservice teachers to digress into possibilities that are simply not an option in real-life teaching, such as choose the age of their students, what kinds of experiences their students would have had before or where their 20-minute unit should be placed in a larger teaching sequence. In this way, the recourse to the preservice teachers-centereded practice offered a widened space for possible action, allowing the preservice teachers to engage in a kind of “rehearsal of various courses of conduct” (cf. Dewey, 1932/1996, p. 275).

Microteaching is evidently not mirroring authentic teaching practice, nor should it. This study supports the contention by Bell (2007) and others that microteaching should be used in science-teacher education on its own merits and for its own, particular characteristics. In particular, our results point at the potential educative value of the very transitions between practices that preservice teachers recurrently experience. We suggest that this “freedom” from the hard realities of future in-service practice constitutes an important and unique experience offered to preservice teachers through microteaching. By means of this, the preservice teachers’ horizons of action may be widened through their imaginative deliberations into various possibilities which will not be on the table in real-world settings, and which would neither have been considered, should the microteaching task have been rendered more “authentic” by the teacher educators in the first place. Thus, the transition between the two practices seems to constitute a way of increasing preservice teachers’ agency, and a way of handing over the initiative to the preservice teachers.

**DISCUSSION**

As a focus of the discussion across these international contexts, we use Grossman et al.’s (2009) key concepts around pedagogies of practice: representations, decomposition, and approximations of practice, as a way of attempting to connect commonalities and contrasts in the layers of practice across teacher education, teaching, and student practices in science. It is our hope that this discussion will lead to productive directions for the field in terms of a conversation across contexts in science teacher education.

Table 1 both summarizes the practices identified by the different authors and offers a preliminary effort to extract the key concepts around the pedagogies of practice for each context. For both decompositions and representations of practice, there is little specific detail characterized by any of the authors about the ways preservice teachers do (or do not) decompose practices (i.e. what criteria or sub-practices they use/identify) or what representations of practice are used (beyond a generic notions of a lesson plan) to help support the targeted teaching practice(s) (e.g. scientific modeling, interdisciplinary science, IBL, or civic and socio-scientific engagement).
### Table 1. Summary of Contexts and Practices.

<table>
<thead>
<tr>
<th>Layer of practice</th>
<th>Germany</th>
<th>Denmark</th>
<th>Norway</th>
<th>Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student (K-12)</strong></td>
<td>Scientific modeling practices</td>
<td>Interdisciplinary science (no specific practices named)</td>
<td>Inquiry Science (e.g. NRC science and engineering practices)</td>
<td>Sustainable development (no specific practices named)</td>
</tr>
<tr>
<td><strong>Teacher (in this case, preservice)</strong></td>
<td>Problematizing while performing a modeling learning goal.</td>
<td>Develop, plan, teach and assess interdisciplinary science activities for children.</td>
<td>Inquiry-Based Learning (IBL) pedagogy</td>
<td>Planning teaching for sustainable development</td>
</tr>
<tr>
<td><strong>Teacher Educator</strong></td>
<td>Planning, enacting, and writing short essays based on problematizing in the context of modeling-based investigations.</td>
<td>Planning, enacting, and writing reports about interdisciplinary science activities</td>
<td>Planning, enacting and reflecting IBL lessons based on Nysgjerrigper Method</td>
<td>Microteaching (specifically planning of teaching)</td>
</tr>
<tr>
<td><strong>Explicit reasoning behind the articulation of layers</strong></td>
<td>Problematizing as one of the four principles of the productive engagement Framework (Engle and Conant, 2002).</td>
<td>Interdisciplinary science in action and in natural settings</td>
<td>Nysgjerrigper Method is specifically designed to help teachers practising IBL pedagogy.</td>
<td>Different roles in order to widen preservice teachers’ horizons of action.</td>
</tr>
<tr>
<td><strong>Approximation of practice</strong></td>
<td>Peer teaching</td>
<td>Peer teaching and enactment with children in natural settings</td>
<td>Enactment with children in natural settings</td>
<td>Planning for enactment with children</td>
</tr>
<tr>
<td><strong>Decomposition of practice</strong></td>
<td>Essays about problematizing in investigations</td>
<td>Reports on interdisciplinary science activities</td>
<td>Reflections on practice</td>
<td>Planning conversations with peers</td>
</tr>
<tr>
<td><strong>Representations of practice</strong></td>
<td>Transformation boxes to support problematizing</td>
<td>Interdisciplinary lesson plans</td>
<td>IBL lesson plans</td>
<td>Microteaching lesson plans</td>
</tr>
</tbody>
</table>

While there is some degree of consistency at the highest levels of practice across layers, the devil, as they say, is in the details (or lack of specificity). For example, at the student level of practice each context names the practices of students in different ways. The German and Norwegian groups both refer to the NRC’s (2012) eight science practices, though the German group focuses on just modeling, and the Norwegians indicate that there are similarities to the NRC, but that the practices are conceptualized slightly differently. How interdisciplinary science, from the Danish group, and sustainable development from the Swedish group overlap
or map across to the NRC is not clear. Part of this is a function of space for reporting of the research work, but part of this lack of clarity and connection across is a function of a lack of specific focus on communication across contexts.

As science teacher education scholars, we hope to better understand the practices and effectiveness of those practices on some more general level. While it is not necessary for us all to conceptualize our work in the same way, it does seem that some commitment to articulating and specifying our work in more detail would allow for a broader conversation across teacher education contexts. Using Grossman’s (2009) framework might not be the solution, but it does allow for us to talk about our work in ways that encourage connection and cross-talk between teacher education contexts. It is our hope that an on-going conversation across these diverse contexts can develop a framework for communicating practices at all three levels and lead to stronger and more productive science teacher education practice and scholarship.

REFERENCES


BELIEFS ABOUT TEACHING AND LEARNING OF CHEMISTRY STUDENT TEACHERS IN CROATIA

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The importance of beliefs for teacher’s action in the classroom is well known. They influence teachers’ representation of science, science knowledge and organisation of the knowledge and information. Keeping teacher professional developments in mind, student teachers’ beliefs need to be examined and sought out by educators. They should be developed into the direction of teaching chemistry due to recent reforms and teaching and learning theories. Beliefs of both pre- and in-service teachers should be the centre of focus by teacher educators. There are different studies completed in different educational backgrounds and different educational systems about teachers’ beliefs. Due to the political system, culture and religion they are, in most of the cases, not comparable. Since the war in Croatia (the 1990s) there were many changes in the country that influenced the educational system as well. Despite that, there are no studies in Croatia focusing on the teachers’ beliefs or their development. The presented study evaluates Croatian chemistry student teachers’ beliefs about chemistry teaching and learning at the beginning, in the middle and at the end of their university chemistry teacher training program. Participants were instructed to draw themselves as chemistry teachers in a typical classroom situation in chemistry and to answer four open questions. Data analysis follows a pattern representing a range between the predominance of more traditional versus more modern teaching orientations in line with educational theory focusing on 1) Beliefs about Classroom Organization, 2) Beliefs about Teaching Objectives and 3) Epistemological Beliefs. The data depicted mostly traditional and teacher-centred knowledge by all of the participants. Changes are hardly noticeable. The date will be discussed and several implications given.

Keywords: beliefs, initial teacher education, teacher professional development

BACKGROUND, FRAMEWORK AND PURPOSE

Beliefs are defined as psychologically held understandings, premises, or prepositions about the world that are felt to be true (Richardson, 2003). Teachers’ beliefs influence how teachers represent science in general and chemistry in particular in their classrooms and the kinds of opportunities they provide for students to learn (Roth et al., 2006). Beliefs play an important role in how teachers organize knowledge and information and are essential in helping them to adapt, understand, and make sense of themselves and their world (Schommer, 1990). For that reason, teacher education must work with the beliefs that guide teachers’ actions (behaviour) with the principle and evidence that underlie the choices teachers make (Shulman, 1987). In addition, student teachers’ beliefs which are deeply held, need to be sought out by teacher educators to provide chemistry student teachers with ample opportunities to create teaching and learning that is aligned with recent reforms. The student teachers’ beliefs need to be developed into the direction that chemistry should be taught accordingly within recent teaching and learning theories. Fenstermacher (1979) argued that one goal of teacher education is to help young teachers transform tacit or unexamined beliefs about teaching, learning and the
curriculum into objectively reasonable or evidentiary beliefs. For teacher education, pre-service and in-service teachers’ beliefs should be at the centre of focus for teacher educators to challenge the belief systems about teaching and learning.

In the literature, there are different studies about (student) teachers’ beliefs about teaching and learning (e.g. Buldur, 2017; Bursal, 2010; Markic, 2008; Markic & Eilks, 2013). However, those studied are accomplished in different educational backgrounds and different educational systems. The political system, culture and religion are in most of the cases not comparable. Studies like to one from Al-Amoush et al. (2014) comparing chemistry teachers’ beliefs about teaching and learning from different countries show big differences in teachers beliefs in different countries. Similarities are to be shown in the study of Cakiroglu, Cakiroglu and Boone (2005) made among Turkish and American student teachers. Furthermore, studies like the one of Alexander (2001), Markic et al. (2016) or Woolfolk-Hoy et al. (2006) display even differences between teachers from one country but different cultural backgrounds.

In Croatia, there are many political and structural changes since the war in the 1990s which are noticeable in the educational system as well. Also in the last years, a voice of a need for a new educational reform, which is strongly oriented to the western world, has become louder. Chemistry is a mandatory subject in final two years of Primary School (grade 1-8; age 6-14/15) and all four years of High School (Grammar School, grade 9-12; age 15-18/19). In Primary School students gain basic knowledge about the matter, atom, chemical reactions and basics of organic chemistry. Additionally, chemistry in High School is divided into general chemistry (9th grade), through physical and inorganic chemistry in 10th and 11th grade to organic chemistry with basics of biochemistry in the final year. Although there are connections and interweaving of the content, curriculum - especially in High School – is focusing especially on learning by heart and do not make links between the content and e.g. social issues.

In the last few years, the new educational reform (Jokic, 2016) has been presented, however it’s not yet in practice. Chemistry is presented as a mandatory subject in Primary School and first two years of High School. In final two years of high school, chemistry is optional subject for students who plan a career in Science area. The content, as suggested, is divided into three basic concepts: the Matter, the chemical process and changes and energy which are all united by Scientific Literacy. The inquiry-based learning should be seen as the main resource of knowledge and the experiment is the foundation for gaining new knowledge that should be integrated into existing one. The curriculum should be spiral and concepts are to be upgraded every year while the teaching should be student-centred.

Comparing the different way of teaching chemistry in Croatia, however, the question must be allowed, if the future chemistry teachers in Croatia are ready and prepared for implementing such a reform which follows different and – for them – new goals. However, there are no studies in Croatia focusing on the (student) teachers’ beliefs about teaching and learning chemistry and showing how the (student) teachers’ development is comparable to the development of education and new educational theories. Starting from here, the present study is focusing on closing this gap and thus to answer following research questions: (i) Which beliefs about chemistry teaching and learning do Croatian chemistry student teachers hold at the beginning, in the middle and at the end of their university teacher training? and (ii) Are
there any differences and/or similarities in the beliefs of Croatian chemistry student teachers at the different points of their university teacher education program?

**METHOD**

The participants were instructed to draw themselves as chemistry teachers in a typical classroom situation in their chosen subject and to answer four open questions. This idea relates to the ‘Draw-A-Science-Teacher-Test Checklist’ (DASTT-C) (Thomas, Pedersen & Finson, 2001) supplemented with questions about teaching objectives and prior activities. Data analysis was done following the evaluation pattern as described by Markic (2008). The evaluation pattern is based on three categories representing a range between the predominance of more traditional versus more modern teaching orientations in line with educational theory. Three 5-step scales focus on 1) Beliefs about Classroom Organization, 2) Beliefs about Teaching Objectives and 3) Epistemological Beliefs. The validity of the data was achieved through independent rating and searching for inter-subjective agreement (Swanborn, 1996). The evaluation pattern does not present linear scales. The numbers are the symbols for the descriptions that are made along the data. The short description of the three categories is presented in Table 1.

Table 1. An overview of the three scales (Markic, 2008)

<table>
<thead>
<tr>
<th></th>
<th>Traditional view</th>
<th>Modern view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belief about Classroom Organization</td>
<td>The classroom activities are mostly teacher-centred, directed, controlled and dominated by the teacher.</td>
<td>↔ -2, -1, 0, 1, 2 Classes are dominated by students’ activity and students are able to choose and control their activities.</td>
</tr>
<tr>
<td>Belief about Teaching Objectives</td>
<td>The focus of science teaching is more or less exclusively focused on content learning.</td>
<td>↔ -2, -1, 0, 1, 2 Learning of competencies, problem-solving or thinking in relevant contexts are the main focus of teaching.</td>
</tr>
<tr>
<td>Epistemological Beliefs</td>
<td>Learning is passive, directed and controlled by dissemination of knowledge.</td>
<td>↔ -2, -1, 0, 1, 2 Learning is a constructivist, autonomous and self-directed activity.</td>
</tr>
</tbody>
</table>

**SAMPLE**

50 Croatian pre-service teachers in age between 21 and 26 participated in the study. All of the participants were female. Being a teacher in Croatia is traditionally widespread by female part of the citizens. They are coming from three different Croatian universities (University of Osijek, University of Split and University of Zagreb) which are only universities for chemistry teacher education in Croatia.

In general, there are two different programs to become a Chemistry teacher in Croatia:

(a) Studying for becoming only chemistry teacher: on a Bachelor level the focus is only on pure chemistry finishing with a Bachelor of Science (B.Sc.) followed by a 2-year master finishing with a Master of Education in Chemistry.
(b) Studying for becoming chemistry and another scientific domain teacher: on a Bachelor level both subjects studied. This program last 5 years and ends with Master of Education in Chemistry and e.g. Biology or Physics. There is no Bachelor Thesis in this program. Finally, both programs have in common that in the first year of the master, teacher trainees are taking chemistry education module over two semesters. The first semester has a seminar and lecturer character and in the second semester, there are 120 hours of internship included.

In the meaning of a longitudinal study, data were collected by the same group at different points of their teacher education program at the three different Croatian universities. By collecting the data from all the student teachers in that one generation it can be said that, for Croatia, this sample is representative. Those student teachers are future science (chemistry, biology, physics) teachers and were visiting one of the two named teacher training programs (offered at the three universities). They are in the first year of their master degree, where they – next to the pure science courses - start for the first time with pedagogy, didactics and science education courses. Data collection took place before the science education courses started, in the middle of those and at the end of all three science education courses. The first point is chosen to evaluate the students’ teachers’ beliefs on which science teacher educators need to pay attention during their lessons and seminars; the middle because of seminars last more than one semester. The last point is chosen to compare the students’ teachers’ beliefs with the initial beliefs and to evaluate the influence of science teacher educators and courses on the possible change.

RESULTS AND DISCUSSION

The data were analysed considering the three named categories and will be presented here. In general, the differences between Croatian chemistry student teachers’ beliefs about teaching and learning between the three-time points are not big, however, some changes in student teachers’ beliefs during their chemistry education course are noticeable.

Figure 1 shows that majority of future chemistry teachers in Croatia hold traditional beliefs about classroom organisation regardless of the time point of the research. Beliefs about the organization are rather teacher-centred with a slight interaction with the students (-1 stands for rather teacher-centred activities with slight interaction with students). Only a low percentage of student teachers neither have teacher- or student-centred beliefs about classroom organization (0 stands for balanced teacher- and student-centred activities) at all three points of data collection. Just 5.8 % of student teachers have rather student-centred beliefs at the beginning of their science education courses, but no one has it in the middle or at the final point of the study.
Beliefs about teaching objectives (Figure 2) seem to have a more heterogeneous distribution of codes comparing to the last one. However, at the beginning and in the middle most of the student teachers’ beliefs were exclusively traditional and oriented on the content structure (-2 stands for learning of facts is the central objective and -1 stands for learning of facts is in the foreground with some non-cognitive objectives target). At the end of the science education courses, a very slight movement is noticeable towards modern beliefs such as learning of the competencies, problems solving and thinking in relevant context.

Figure 2. Beliefs about Teaching Objectives

Figure 3. shows that Epistemological Beliefs are – similar to the first category – more or less, traditional at all three points of the data collection. There is a slight movement from receptive learning (-2 stands for passive and over-directed learning; dissemination of information) towards over-directed learning with student-active phase (-1 stands for learning followed by storyboard written, organized and directed by the teacher, but conducted by the students). At the end of the science education courses, more than 80% of student teachers hold beliefs that
learning follows a storyboard written by the teacher, conducted by the students, but organized and directed by the teacher means rather teacher-centred.

Figure 3. Epistemological Belief

We can see a homogeneous distribution (Figures 1 – 3) within all three dimensions. Beliefs about Classroom Organisation, as well as about Teaching Objectives and Epistemological Beliefs, are more or less teacher-centred. This traditional view is not oriented towards problem-solving and gaining competencies for today’s (science) world but toward learning facts and science content structure. The majority of chemistry student teachers in Croatia see learning chemistry as a transmission of knowledge and facts that are strongly organized and directed by the teacher.

To explore the mutual equality of the three categories the combination of coding from each category was made for each participant of the study for each time point of the data collection. At the end, the sum of the combination was made and it is shown in Figure 4. The closer the rating for a student teacher is to the lower, front corner of the diagram the beliefs that student hold are more traditional and teacher-centred.

Figure 4. 3D- representation of the data from all three points of data collection. The size of the bubbles represents the number of student teachers.
In the beginning of their university chemistry teacher education training, the majority of the student teachers have a code combination in the front lower part of the diagram. This describes that they hold more traditional beliefs about teaching and learning. After one semester of science education courses, a slight movement to the upper part of the diagram is visible. However, the code combinations are still in the front part of the diagram. Thus, only slight change in Epistemological Beliefs is noticeable for the whole group. It is noticeable that the code combinations are more spread in the diagram as before. The 3rd time point of the data collection was the end of the courses. The difference to a prior state is that the group seems to be more homogeneous. The code combinations are about in the middle but still lower part of the diagram. The beliefs are still traditional, however not as strong as before.

In the comparison of the three diagrams some changes are visible but looking to the middle of the evaluation, the direction seems to be not really clear. A possible explanation for this result is the time point – the first semester (seminar and lecturer character) is over and the internship is to begin. At the end (after the internship, lecturers and seminars), although differences to the beginning are visible, Croatian chemistry student teachers hold a view that is less in line with modern theories. It is to be assumed that student teachers are influenced by their experience in the internship and the mentor back to the traditional beliefs.

Finally, Croatian chemistry student teachers’ beliefs are very homogeneous, independent of the university they visit. There is a tendency towards more traditional (teacher-centred classroom organisation, content-structure-oriented objectives and receptive learning) teacher beliefs with the slight movement towards modern beliefs in the middle.

Starting from the data it seems that student teachers at the beginning of their teacher training hold beliefs established on their own personal experience from the school. This indicates that the teaching and learning in the majority of Croatian schools was (and probably still is) more teacher-centred so it is no surprise that the beliefs at the start point of the research are, as well, traditional.

Data from the middle and the end of the study show that teacher training seems to have an only small impact on student teachers’ initial beliefs. Thus, this impact should be bigger and stronger because after just one semester of internship in school student teachers tend to go back to traditional ways of teaching Chemistry. However, at this point the question must be asked about the content of teacher training in Croatia as well. How much modern educational theories, modern goals of chemistry lesson and newer, student-centred methods in chemistry teaching are the focus of university chemistry teacher training at the Croatian university. This study does not evaluate this; however, it should be the focus of further research.

Additionally, on the one side, pre-service teachers are influenced by the traditionally oriented in-service teachers during their internship. But, on the other side, they need to develop more modern, student-centred and constructivist-oriented ways of teaching chemistry to follow the new education reform. Both sides seem to be paradoxes. Since in-service teachers have an influence on the education of pre-service teachers, the focus should be on in-service teachers` beliefs as well, with followup in-service teacher training.
The study shows that future chemistry teachers in Croatia are not ready and prepared yet for implementing such a reform which follows different and – for them - new goals. Further changes in the education system and especially in university teacher education in Croatia are needed. Teacher education should place more emphasis on making student teachers aware of their own beliefs and change those into a more modern direction. Those must rely on the anticipated goals of the educational reform.

REFERENCES


EDUCATIONALLY RECONSTRUCTED EVOLUTION COURSE - EVIDENCE-BASED TEACHING IN THE EDUCATION OF FUTURE GERMAN SCIENCE TEACHERS

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At German universities, a teaching student is taught scientific knowledge by scientists who are also scientific researchers in the relevant field of knowledge, i.e. for example microbiology is taught by a microbiologist. The didactical aspects of learning science is taught by science education researchers in specific courses. Typically, there is no cooperation. The presented project is an approach to use synergetic effects in teaching student teachers. The aim of this study is to clarify if and why students' ideas about evolution change while they participate in an educational reconstructed evolution course. The study uses the framework of educational reconstruction. A common evolution course (2015, sample 1, n=114) and an educational reconstructed evolution course (2016, sample 2, n=108) were compared. College students' explanations of evolutionary processes where gathered through open format writing assignments (N=222) and interviews (N=15). Data were analysed by use of qualitative content analysis and systematic metaphor analysis. The analyses of the empirical data are used to achieve an evidence-based improvement in teaching. Several evidence-based changes, developed from the results of sample 1, were implemented and tested in sample 2. The results show significantly more scientific adequate concepts in explanations given by students. E.g. they talk more often about variation of all individuals within a population than about the variation of one individual in an otherwise uniform population.

Keywords: evidence – based teaching

INTRODUCTION

Many questions in biology can be answered without using ideas of evolution: Why is a particular leaf green, how do whales swim, how do birds fly, how do babies come into existence? The understanding of the involving mechanisms is an essential part of biological knowledge. Faced with the unbelievable diversity of life often a new kind of questions comes in mind: Why are there so many different kinds of organisms. With a view to this diversity of species a new question arises: how can the similarities among organisms be explained? The answer of these questions requires a historical context - the answer needs understanding of change through time. We have to ask: what processes has created this extraordinary variety of life. In the mid-nineteenth century Charles Darwin gave an elaborated answer to these fundamental questions. German science teachers are obligated to teach evolutionary aspects and evolution in several grades – in many german curriculums evolution is defined as the red thread which links the big ideas of biology. Teaching evolution in a science classroom needs a deep understanding of the answers given to both kinds of questions and also a deep understanding of the ideas science education research gathered about how students learn evolution in an effective way. In german universities scientific knowledge is taught to students of teaching by scientists who are science researchers in this specific domain: i.e. microbiology is taught by a microbiologist. The
didactical aspect of learning science is taught by science education researchers in specific courses. Typically, there is no cooperation.

The presented project\(^1\) is an approach to use synergetic effects in teaching students of teaching. The aim of the presented study is to clarify if and why students’ ideas about evolution change by participating in an educational reconstructed evolution course. Different research methods are used to model the subject of research from different perspectives in the sense of an internal triangulation.

**THEORETICAL BACKGROUND**

Research on students’ and teachers’ conceptions and their roles in teaching and learning science has become one of the most important domains of science education research. Many studies show that students hold pre-instructional knowledge or beliefs about the phenomena which are often not compatible with the science views. These alternative conceptions are mostly rooted in everyday-experience and informal learning settings (D. Treagust & Duit, 2008).

In addition to classical conceptual change approaches, the role of metaphors and analogies in teaching and learning science has been evaluated in recent years. Lakoff and Johnson have shown that metaphors are fundamental to human thoughts and provide a basis for mental leaps (Lakoff & Johnson, 1980). The terms metaphor and analogy are used in a variety of ways in the science education literature. From grounded cognition perspective thought is embodied: Our basic categories and conceptions arise out of perception, body movement, and experience with our physical and social environment. We employ conceptions from a source domain and map it onto an abstract target. To analyze the source of the conceptions, we use a theory emerging from the field of cognitive linguistics (Lakoff & Johnson, 1980). The conceptual metaphor theory states that all knowledge is embodied (Niebert, Marsch, & Treagust, 2012). This means that every knowledge we construct about our environment – either direct or indirect – is grounded in bodily experiences. Based on Conceptual Metaphor Theory, we differ between two types of conceptions: physical conceptions and abstract conceptions (Fauconnier & Lakoff, 2013). Physical conceptions are grounded in bodily experiences with the physical and social environments, like perceptions, body movements, and social experiences. Physical conceptions are directly meaningful. Experiences as inside and outside, up and down movements, front- and backsides, and center and periphery relations are conceptualized through schemata. Schemata are conceptualizations of patterns of our perceptual interactions (Lakoff, 1987; Lakoff & Núñez, 2000).

**Abstract concepts** - which include most concepts in science - are understood imaginatively, drawing on directly meaningful concepts and schemata. Abstract conceptions get their meaning indirectly. They are not directly grounded in experience but draw on the structure of our experience. We get used of our embodied schemata to construct an understanding about abstract phenomena (Riemeier, Niebert, & Gropengießer, 2013; Unger, 2017). Conceptions from a so-called source domain are mapped onto an abstract target domain. Therefore,

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\(^1\) The LeibnizPrinzip project is being conducted at Leibniz Universität Hannover. The study presented is part of Measure 3: Scientific Reconstructed Science. The LeibnizPrinzip is funded by the Federal Ministry of Education and Research (BMBF).
schemata are the hidden hand that shapes our conceptual understanding not only in everyday life but also in science. Accordingly, scientific understanding, as abstract as it may be, is ultimately grounded in embodied conceptions - we call them grounded cognitions (Barsalou, 2008, 2010).

RESEARCH DESIGN & METHODS

The Model of Educational Reconstruction (MER) provides a fruitful framework to study college students concepts and design evidence based learning environments (Komorek & Kattmann, 2008). Using the framework of MER typical stumbling blocks on the way to scientific appropriate concepts of Evolution were analysed. Therefore, studies facing students’ concepts on evolution and evolutionary processes were reanalysed (Zabel & Gropengießer, 2011).

MER as a research program provides three research tasks: clarification of science content, investigation into students' perspectives, and analysis, design and evaluation of learning activities (Niebert & Gropengießer, 2014). Clarification of science content draws on qualitative content analysis of written sources on the subject matter - like leading textbooks. The aim is to clarify the specific structure of concepts about the scientific content from an educational point of view.

A critical analysis is essential because science textbooks address experts and present knowledge in an abstract and shortened way - they are not aimed at the specific learning starting position of novices. Often, scientific terms - which are not reflected by scientists - are misleading if students are to apply them to specific topics. Clarification of science content aims at the accurate formulation of potentially learning supportive ways to talk about specific scientific subject - we call these clarified concepts.

Investigation into students’ perspectives aims at the analysis of the pre-instructional conceptions constructed by students. There is also an interest in the of investigation of the development of these conceptions. Analysis, design and evaluation of learning activities refer to instructional materials, learning situations, and teaching and learning sequences (Kattmann, Duit, & Gropengiesser, 1998; Niebert & Gropengießer, 2014). The design is led by learning capabilities – i.e. interest, cognitive aspect, motivation, previous experience - of the students and clarification of subject specific content.

The college students’ concepts were reconstructed and contrasted with concepts of experienced scientists to identify subject matter clarified concepts. To effectively compare concepts of scientists and students, there is a need to make them comparable first – i.e. represent them in the same grain size. Several studies in the framework of MER have shown that reconstruct concepts in form of conceptions gives a deeper understanding of similarities and differences.

The evolution course is offered as part of the program in 4 semesters of the Bachelor's degree program (interdisciplinary bachelor) – i.e. in the winter semester (Figure 1).
Figure 1. Evolution course as part of the program in 4 semesters

In 2015, the data was recorded with the help of the Conceptual Inventory of Natural Selection (CINS; Anderson, Fisher, & Norman, 2002; German translation), an open-format writing assignment and an interview study after the students had attended a classical - not didactically reconstructed course. The open answer format was based on the surveys carried out by Zabel (2009) among middle school students on ideas about the evolution of whales.

To conduct the interview, the method of guided interviews was chosen. In the interview study, individual learners were asked about their ideas about evolutionary processes based on different phenomena. In addition, it was ascertained which particular aspects of the lecture and the associated seminar were particularly remembered. The students should also describe what they thought the idea of the evolutionary course helped them to understand evolution in particular.

The CINS was evaluated using descriptive data analysis in SPSS. The qualitative data was analyzed using qualitative content analysis (Mayring, 2002) and a systematic metaphor analysis (Schmitt, 2005).

The study was conducted in a pre-post-testing setting. The results of this sub-study were used to successively develop the lecture and the associated seminar in a recursive and cooperative process. The evolutionary course changed in this way was held in the winter semester 2016 (Figure 2). The presentation of the participants in this round was similarly collected and analyzed.

Figure 2. Sub-Study winter semester 2016

CLARIFICATION OF SCIENCE CONTENT

As part of the scientific clarification university textbooks were analyzed. This analysis was conducted in a mediation perspective and aimed at the development of basic concepts needed to understand evolutionary processes. On the other hand, the extent that scientists use terminology in their formulations that could be contrary to a scientifically appropriate
understanding was determined. This article only presents selected results of the scientific clarification. A more comprehensive overview can be found for example in Zabel (2009). It must also be pointed out that the module deals with a large number of evolutionary development concepts that cover a large number of different topics. Thus, not only the classical theory of evolution, but also their extensions and topics such as development of life or evolution of hominids are treated. In the summary shown here (Figure 3) only concepts of the "classical theory of evolution" are presented.

![Concepts of scientific clarification process](image)

**Figure 3. Concepts of scientific clarification process**

**INVESTIGATION INTO STUDENTS’ PERSPECTIVE: EMPIRICAL DATA**

First, the survey of conceptual knowledge carried out by the CINS in the pre-post-test procedure is presented. The purpose of this test was to determine the general understanding of students of basic concepts of evolution before and after completing the evolutionary course. The results are discussed and related to the results of the questions in the open response format.

Figure 4 shows the results of the pre- and post-test of the cohort 2015 in boxplots. The reliability of the pre-test procedure shows a very good value with a Cronbachs alpha of 0.87. It can be clearly seen that at the beginning of the module Evolution in the winter semester 2015, students have a high level of conceptual knowledge. With an average score of 11.6 with a standard deviation of 3.2, the average score shows performances comparable to those of other post-intervention studies (Athanasiou & Mavrikaki, 2014; Presley, Gehringer, & Hanuscin, 2017).

The results of the post-test show a massive ceiling effect. With an average score of 17.5 in the CINS answers the students at a very high level. The low variance is reflected in a low standard deviation. Based on this relatively high probability of correct answers by the students, some of the 20 items of the CINS are answered correctly by each of them. This affects the calculation of the reliability of the test, which therefore falls to a value of 0.64 and is therefore only appropriate.
The CINS shows that students are able to recognize the desired conceptual knowledge about evolutionary processes in a multiple choice test. However, it seems to be too simple for the sample, so that no more specific survey of individual knowledge levels is possible. Based on these results, it can be said that the CINS is an appropriate way to measure learning progress in the context of an evolutionary module at university level - but unfortunately not a very good one.

**Figure 4. Boxplots Pre-Post-Test [CINS]**

The results of the open response format show surprising results. Asked to explain how primeval land-living mammals have evolved to the recent whales over millions of years the students gave written answers, which are shown in Figure 5 as an example. These answers were summarized at the concept level with the aid of qualitative content analysis and can be compared descriptively in this way.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean (SD)</th>
<th>Cronbach’s α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre 2015</td>
<td>98</td>
<td>11.6 (3.2)</td>
<td>.87</td>
</tr>
<tr>
<td>Post 2015</td>
<td>92</td>
<td>17.5 (2.5)</td>
<td>.64</td>
</tr>
</tbody>
</table>

**Figure 5. Selected answers of the open writing assignment**

The summary of the results of the 2015 sample (Table 1) shows that significantly more inadequate answers is given by many more students than explanations. Table 1 lists the concepts used by the students in the context of the two figures of thought as causes of variation and types of variation. Thus, 89 of the students in the open answer format indicate mutations as a reason for the variation of individuals within a population. Although this is not a really
wrong answer, it is noticeable that only 10 students use the scientific much more important concept of recombination.

It is also striking that 27 students in their texts represent the concept of *Environment causes Variation*, which can be assessed as scientifically inappropriate. The concept of *Usage of Organs Causes Evolution* is also frequently used with 18 mentions, which is not appropriate from a scientific perspective.

A remarkable finding is that this is the same sample that reached an average score of 17.5 in the CINS post-test, which was conducted just before the interview with the open answer format. If one correlates the achieved CINS score with the concepts used in the open response procedure, surprising results are also found here, which are shown in Figure 5 as an example.

It becomes clear that even students with a perfect CINS score of 20 out of 20 possible points, have big problems in the open answer format to formulate a scientifically correct answer. Referring to the sample considered in Table 1, the CINS does not seem appropriate to sufficiently predict the students' answers in an open-answer format to an unknown problem. It can also be shown that for a further development of a course at university level a survey with the help of a conceptual inventory is of limited suitability.

**Table 1. Descriptive Statistic of the open writing assignment 2015**

<table>
<thead>
<tr>
<th>Causes of Variations</th>
<th>Types of Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Individuals are different from a uniform population</td>
</tr>
<tr>
<td>Intention causes Variation</td>
<td>8</td>
</tr>
<tr>
<td>Environme nt causes Variation</td>
<td>27</td>
</tr>
<tr>
<td>Usage of Organs causes Variation</td>
<td>18</td>
</tr>
<tr>
<td>Recombination causes Variation</td>
<td>10</td>
</tr>
<tr>
<td>Mutation causes Variation</td>
<td>89</td>
</tr>
</tbody>
</table>

**DESIGN AND EVALUATION: MAJOR CHANGES & IMPACT OF CHANGES**

Based on the findings from the first round, the lecture and the seminar were didactically reconstructed. After most student responses in the open response formats revealed typical technically inadequate thought patterns, typical stumbling blocks were identified in an analysis. Based on these inadequate ideas, three fundamental changes were made in the planning and implementation of lecture and seminar:

1. **The core conceptions**: Conceptions can be understood as the smallest representation of mental processes. In a conception, concepts are related to each other and thus their meaning is specified. The reciprocal determination of concepts is an integral part of any teaching-learning process. As part of the evolutionary course, we have tried in each phenomenon, those conceptions which have been identified in the context of the technical clarification as central conceptions. For this, these core conceptions were repeatedly presented and consistently applied to the different phenomena.
2. **Students alternative ideas:** In the seminar, some additional subjects and aspects were added. In the process of educational reconstruction, the decision was made to add a presentation of widespread alternative ideas on evolution and evolutionary processes found in former science education research studies. The college students were given the opportunity to deal with these scientific inadequate ideas and reflect them under use of the subject matter clarified core conceptions. In this way, it was possible for the students to reflect both the alternative ideas of pupils and in this way to question their own ideas. Through this reflection on the meta-level, students can build a critical distance to their own knowledge and thus develop their own ideas.

3. **Scientific clarified speech:** Based on the separation between the thought and the symbol (Richards & Ogden, 1923), language can be regarded as a window on thought. Thinking expresses itself in language - but at the same time speaking itself has an influence on how we understand certain abstract concepts. Since language in the teaching / learning process represents the crucial interface for the negotiation of meanings, the use of correct and professionally clarified terminology was given special attention. For example, when talking about evolutionary processes, more attention has been paid to the use of passive speech.

The analysis of college students’ answers to the question how recent whales evolve from their terrestrial ancestors’ after participating an educational reconstructed course shows significant more scientific adequate ideas than the sample in 2015. To compare sample 2016 with the answers given in 2015 the conceptual change of core conceptions will be exemplarily displayed: By way of example, the development of scientifically appropriate ideas in concepts *Individuals are different from a uniform population* and *All Individuals in a population are different* can be shown (Table 2).

In a scientific clarified way of explanation college students have to use the conceptions *all individuals in a population are different*. This Variation has its origin in the recombination, and to a smaller part in mutations (*recombination causes variation*). Students often super elevate the role of mutation as most important cause of variation. The comparison of the two samples shows that the college students in sample 1 more often uses scientific inadequate concepts in their explanation. In Sample 2 the scientific correct cause of variation and the idea of full variation in populations itself are used more often.

In open writing in the 2015 sample, many students explicitly write about a single individual who is mutated differently than his otherwise uniform conspecifics. This finding is also supported by the statements in the interview study. Here, the students often speak of a starting population out of mutation a particularly suitable individual emerges, which is superior to all others. So they are more likely to have ideas of saltationism than gradualism. Through the glasses of the theory of embodied cognitions, the learners use the everyday-world idea of an outsider. At the same time, the schemas are an application of the container schema. Here, a container is presented whose content - here the individual individuals of a population - is uniform. Only when certain characteristics are met exactly do the individuals belong in this container. A single individual, which for some reason is different, then does not belong in this container. We call this individual an outsider. The ideas of inside and outside, belonging to it
and not belonging to it, can be experienced in the everyday world - in other words, embodied cognition.

Table 2. Comparison of selected conceptions used by college students after participate in two different evolution courses. Data collected by open format writing assignment. Data analysed by means of qualitative content analysis. Double entries are possible.

<table>
<thead>
<tr>
<th>Causes of Variations</th>
<th>Types of Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intention causes Variation</td>
<td>Individuals are different from a uniform population</td>
</tr>
<tr>
<td>Environment causes Variation</td>
<td>All Individuals in a population are different</td>
</tr>
<tr>
<td>Usage of Organs causes Variation</td>
<td></td>
</tr>
<tr>
<td>Recombination causes Variation</td>
<td></td>
</tr>
<tr>
<td>Mutation causes Variation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>Causes of Variations</th>
<th>Types of Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intention causes</td>
<td>Individuals are</td>
</tr>
<tr>
<td></td>
<td>Variation</td>
<td>different from a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>uniform population</td>
</tr>
<tr>
<td></td>
<td>Environment causes</td>
<td>All Individuals in</td>
</tr>
<tr>
<td></td>
<td>Variation</td>
<td>a population are</td>
</tr>
<tr>
<td></td>
<td>Usage of Organs</td>
<td>different</td>
</tr>
<tr>
<td></td>
<td>causes Variation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recombination causes</td>
<td></td>
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<tr>
<td></td>
<td>Variation</td>
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</tr>
<tr>
<td></td>
<td>Mutation causes</td>
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<tr>
<td></td>
<td>Variation</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Mutation causes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Variation</td>
<td></td>
</tr>
</tbody>
</table>

From a scientifically clarified perspective, a metaphorical rethinking - we call that a metaphorical shift - has to happen here. The population container must be thought of as not being filled with uniform individuals, but each individual being different in trifles. It is therefore about the otherwise required typological thinking - as it is important, for example, in classical botany - to expand to a different view on living things.

**DISCUSSION**

It could be shown that the CINS as part of the evolutionary course does not seem to be an adequate survey instrument for this sample and especially for measuring the development of imagination. For the level intended here and the intended transfer of networked knowledge to new, unknown phenomena, the CINS score cannot be used for reliable predictions of answers.

This result contributes to an ongoing debate about what is measured by a conceptual inventory, and how the results of such tests correlate with the learners' actual perceptions (Smith & Tanner, 2010). With a view to the professional future of the target group, whose main task will be to initiate teaching / learning processes in an appropriate way, it should be clear that professional acting as a teacher in the classroom has much more to do with freely formulating answers to open questions, as choosing correct answers from a standardized multiple choice test.

Based on qualitative methods (open writing, interviews) and based on the theory of grounded cognitions, the learner statements could be analyzed in depth. This analysis led to the explication of typical alternative - not scientifically appropriate - ideas about evolutionary processes. These problems of understanding were taken up in the context of an educational reconstruction, in order to arrange the lecture and the seminar so that the students could be given the opportunity to reflect on these lifeworld approaches and to construct scientifically more suitable alternatives. Comparing the results of the 2015 and 2016 samples is problematic in a way because they are two different cohorts with different students who have very different ideas and learning prerequisites. In addition, it is problematic to reduce the described impacts
of change exclusively to the three changes introduced in the planning and implementation of the event. It must also be remembered that 2015 was a newly designed course with a new lecturer. Here also without didactic reconstruction corresponding improvement in the implementation would have been expected. Nonetheless, it is precisely the results of the interviews presented in case studies that show that the three central changes between 2015 and 2016 were also perceived by the students to be helpful and meaningful for their personal development of more scientifically appropriate ideas.

As a central finding of this study, it can be said that an empirical study carried out as part of a scientific reconstruction is apt to better understand students’ specific learning pathways and to use this empirical data to foster fruitful learning. Above all, the implications from the theory of grounded cognition can be used meaningfully.

Based on the presented results general recommendations for the improvement of university teaching can be shown:

1. The use of empirical data for the evidence-based further development of courses provides a deeper understanding of the special learning pathways and is a powerful tool for addressing the needs of learners.

2. The cooperation of research subject didactics and teaching specialists leads to far-reaching synergetic effects. A module developed in a common discourse shows very good results in the promotion of scientifically appropriate ideas.

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