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# TEACHING FOR COMPETENCE IN SCIENCE EDUCATION IN DENMARK

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*Abstract:* Starting in the school year 2015-2016, the idea of competence goals was introduced explicitly into the Danish comprehensive school system. In light of this development, several points call for analysis and discussion. This paper gives a short, critical account of this historical development, critically illuminating the conceptual sources and arguments for the introduction of these ideas, and a short discussion of the practical problems in realising a curriculum document that is organised around the idea of competence goals. The meaning of competence in the Danish case will be compared to different ways that the competence concept is used internationally in curricular documents. Main points are that different meanings of competence are used, but there is not a universal use, and that the complexity of existing definitions make it hard to understand how to work with competence in concrete teaching situations. Nonetheless, the idea of competence is viewed as an important and valuable way for engaging with the more general goals for science education in Denmark (and elsewhere). In service of that interest, we introduce the ideas of *germcell* and *theoretical thinking* from the developmental teaching tradition as a way to operationalise a meaning of competence that can be realised in concrete teaching situations.

*Keywords:* competence, *germcell*, *theoretical thinking*

## INTRODUCTION

The main interest in this paper is to engage with the concept of *competence*, particularly in relation to primary and lower-secondary science education in Denmark, and to offer a theoretical interpretation of the idea of competence (along with a strategy for how to approach realising this interpretation under actual schooling conditions in Denmark). A basic starting assumption is that the idea of *competence* is useful in thinking about the learning goals of science teaching, but there are many challenges to address both in formulating and using the idea.

The first part of the paper discusses briefly the status of the competence concept in relation to school science education, first in a comparative, international perspective, and then in relation to the current historical situation in Denmark, with a focus on the use of the competence concept in the national school curriculum, along with some difficulties in understanding the meaning of the concept. Rather than diverge into critical evaluation of other approaches to the concept of competence, the second part of the paper introduces ideas that Davydov developed in his approach to developmental teaching, particularly the concepts of *germcell* and *theoretical thinking* (Davydov, 2008). These ideas are viewed as useful for developing a sufficiently concrete understanding of a competence concept that could be used in developing specific instructional approaches.

## INTERNATIONAL STATUS OF “COMPETENCE” TERMS IN RELATION TO SCIENCE EDUCATION

The following brief review aims to underpin the conclusion that there is no “standard” view about the necessity to use a competence concept as part of formulating a science curriculum.

1. The notion of competence does not appear universally in curricular discussions about science education.

For example, the framework for primary and secondary science education proposed by the National Research Council (2012) in the United States does not use the idea of competence to characterise an instructional objective. Neither has it appeared as a frame of reference in recent discussions among expert science education researchers in Europe (e.g., European Commission, 2007; Harlen, 2010).

2. The notion does appear in national curriculum documents in some countries (e.g., Canada, Denmark, Germany, Norway, Switzerland).
3. Many discussions of competence (or competencies) in science education often appear in connection with or in response to OECD initiated projects (e.g., PISA).
4. A multiplicity of general definitions of competence have been developed in relation to these projects, in contrast to OECD's intention to provide "a sound conceptual framework" (OECD, 2005, p. 5). Weinert (2001) noted that there are many different approaches to competence, with no common conceptual framework (p. 46). His chapter discussed seven different theoretical interpretations of competence.

It is relevant to note that Weinert's analysis was made in connection with an OECD-related project to define competence (more generally).

There has been a particular interest, especially in Switzerland (e.g., Labudde, 2010) and Germany (e.g., Kulgemeyer & Schecker, 2014), to develop large-scale measurement systems that can assess pupil competencies in science. The technical demands of these assessments have led to diverse operationalisations of the competence concept, even if they start from common considerations. In other words, the situation described by Weinert has not improved.

5. At the same time, models devised by researchers for assessing pupil competencies (in Germany and Switzerland) "are not designed for competence-oriented teaching and it is not easy for teachers to cope with their depths of differentiation" (Kulgemeyer & Schecker, 2014, p. 266).

This brief review highlights that (a) no standard meaning of competence has been established in international educational practice, (b) no universal adoption of the concept, and (c) no indication that a satisfactory solution (or direction for a solution) is available.

## **ACTUAL SITUATION IN DENMARK – AND ITS HISTORICAL ORIGINS**

To provide a background for understanding the proposal for operationalising the competence concept, it is necessary to explain a little about the organisation of the Danish primary and lower-secondary schooling system, the origins for the introduction of competence in the school curriculum in Denmark, and the structure of the Danish national curriculum.

All children in Denmark must receive instruction until the age of 16. The legal requirement is only that they receive teaching, but most children achieve this requirement by attending the publicly-funded *Folkeskole*, a comprehensive school, with grades 0 to 9 for children between the ages 6 to 16. About 12% attend privately-organised schools (which usually receive about 75% state-funding compared to a *folkeskole*). All of these schools must meet the requirements of the national curriculum, which is set by the responsible Ministry. The administration of primary and lower-secondary education is decentralised. The Ministry specifies requirements

for the schools (e.g., in terms of the curriculum, the minimum number of instructional hours for different subject), but the *Folkeskole* is owned and managed by local authorities, and are free to formulate their own ways to meet these requirements, including personnel decisions. Teachers have freedom to choose the methods that they will use to realise the Ministry's requirements, while specific plans are evaluated and approved at the municipal (i.e., local) level.

In school year 2014-2015, competence goals were introduced into the legally-binding national curriculum document for the schools. From school year 2015-2016, these goals are obligatory for all schools in Denmark. The introduction of competence goals in Denmark can be understood as the culmination of several interrelated historical developments over the past twenty years. The main aspects have been (a) a move toward specifying explicit goals of what pupils should be able to do ('outcomes-based'), (b) an increasing detailed specification of the goals to be achieved, (c) an interest to raise the quality of the learning achieved by pupils, and (d) a shift toward quality and output control from the state, where the responsibility of realising the state's goal specifications reside with the schools. (Comparable historical developments can be observed in other countries.)

For example, a focus on learning outcomes started already with a major reform of the school law in 1993. At that time, certain topics were introduced as 'central knowledge and proficiency areas'. These areas were formulated more precisely in 2001, so that they could be understood as 'end goals' for what pupils should be able to do after instruction. In 2003, a new law made an explicit 'outcomes-based' curriculum, called 'Common Objectives' (with revisions in 2009, and then in 2014, when competence goals were introduced).

The introduction of competence goals was motivated by several unrelated reasons. In part, it was concerned with forming clear learning goals, but other processes were also involved. In 1997, parallel and independent of the *Folkeskole*, the Danish government started a programme aimed at national development of competence. This eventually culminated in the formulation of a Danish qualifications framework for lifelong learning in 2009 (Undervisningsministeriet, 2010), and connected to the European qualification framework (European Commission, 2008). This framework was an important reason for motivating (or even making it necessary to introduce) competence goals in the curriculum. These issues are discussed further in a moment.

A third contributing source developed through the Ministry of Education, which organised several expert groups to produce reports about the future of education in the early 2000s. The overall chair of the workgroups, Mogens Niss, had a special interest in the competence concept (Niss & Jensen, 2002), and he promoted the use of this idea in these groups. The workgroup in science education identified four main competences that they meant that all pupils should develop (Andersen, Busch, Horst, & Troelsen, 2003). This report was an important guiding star in the first formulation of competence goals in the national curriculum in 2014.

Transnational 'forces' also contributed to the introduction of competence goals in the Danish national curriculum. In Denmark, like some other countries, there has been a period of heightened political attention after the initial PISA results were reported in 2001. It is unclear whether it is justified or appropriate to characterise this situation as a "shock" – as some writers have done – because there was a mixed reaction in Denmark, and substantive responses were relatively slow. In 2003, the Danish government agreed to have OECD conduct a review and evaluation of the current educational policies and practices, as well as

make recommendations for improvements in primary and lower secondary education (OECD, 2004). Furthermore this review was conducted in an innovative way (compared to traditional OECD country reviews) that attempted to address the implications of the PISA results, and to include examiners from countries that achieved good results in the first PISA evaluation. This report made 35 recommendations, where many are now reflected in the Danish school reform from 2013, including a focus on raising the level of academic challenge for the pupils, and the quality of their learning.

This abbreviated history of the development of the current national curriculum in Denmark in relation to competence goals should be sufficient to show that multiple intertwined interests have contributed to the appearance of competence goals in the curriculum. At the same time it has been a slow process, if one considers that discussions about goal-directed teaching and competences were being discussed in the beginning of the 2000s, but only operationalised in the formal law in 2014.

## **GENERAL MEANING OF “COMPETENCE” IN THE DANISH SCHOOL LAW**

The meaning of *competence* in the current Danish school law is difficult to ascertain, both theoretically and substantively. The appearance of this term as a central structuring principle in the new national curriculum can be traced primarily to the fact that the national curriculum document is grounded in the “Danish Qualifications framework for lifelong learning” (formulated in 2009) (Undervisningsministeriet, 2010). This framework has been developed primarily because Denmark chose to participate in the European Qualification Framework (EQF), which is meant to facilitate comparison of formal educational qualifications between countries (European Commission, 2008, p. 3)

The EQF chose to use a distinction between knowledge, skills, and competence to describe learning outcomes after “discussions between technical experts from all countries involved in the development of the EQF” (European Commission, 2008, p. 5). This decision by consensus “because it is the most established way for categorising learning outcomes.” (s. 5) is consistent with the lack of any reference to a particular theoretical or conceptual foundation for these concepts. This interpretation is supported by their own description:

The EQF’s differentiation between knowledge, skills and competence can therefore be seen as a pragmatic agreement between the various, widespread approaches and does not oblige countries to do the same. (European Commission, 2008, p. 5).

The Danish framework adopts the tripartite distinction between knowledge, skills, and competence proposed in the European Qualifications Framework, and the learning outcomes in the new national curriculum are described in terms of knowledge, skills, and competence (Danish Evaluation Institute, 2011, pp. 16-18).

The definition of competence given in the presentation of the Danish framework is supplemented in an appendix of central concepts, which gives more detailed differentiations of competence. Here is an English translation provided by Danish Evaluation Institute (2011):

Competence is about responsibility and autonomy, and states the ability to apply knowledge and skills in a work situation or in a study-related context. Competence contains the following aspects:

Space for action: the type of work and/or study-related contexts in which the

knowledge and skills are brought into play, and the degree of unpredictability and changeability in these contexts.

Cooperation and responsibility: the ability to take responsibility for one's own work and the work of others, and the complexity of the cooperative situations in which one can engage.

Learning: the ability to take responsibility for one's own learning and that of others. (p. 18)

Given that this definition of competence must apply across the lifespan and include skilled and professional work, as well as primary education, it is not surprising this elaborated discussion is difficult to recognise as adequate or appropriate for primary and lower-secondary school pupils. In all of these discussions, there is no reference to any conceptual or theoretical source that underpins these distinctions and definitions (Undervisningsministeriet, 2010).

None of the elaborated meanings of competence found in the national framework are found in the current guidance materials that the Education Ministry provides in relation to the new competence-based curriculum for primary and lower secondary school. Similarly, no reference is given to any theoretical or conceptual sources that underpin the use of the term *competence* in the new school curriculum.

While it is possible to identify the likely origin and reasons for the use of competence to describe learning outcomes in the coming Danish school curriculum, it is not possible to find any indication that these terms are grounded in a particular theoretical interpretation tradition. There is also indication that the specific meanings are likely to be used in different ways according to national preferences or traditions.

The analysis in this section of the paper shows that the idea of 'competence' (along with the concepts of 'knowledge' and 'skills') can be understood as a set of 'foreign bodies' that have arrived externally to the primary and lower-secondary school. That is, they are motivated as part of a transnational agreement in which Denmark participates, where these categories have been accepted for descriptive purposes. In other words, their appearance in the formal curriculum documents is motivated by a general need to use these categories in describing educational programs, rather than a specific pedagogical argument for why they should be appropriate for primary and lower-secondary education.

Furthermore, it has highlighted that there does not appear to be any substantive theoretical underpinnings or analysis of how to understand the concept of *competence* in general, and more critically, how it should be understood in relation to disciplinary teaching practices. These problems are presumably solvable, but at the present moment, it is not something that the Ministry has provided. At the same time, as a global generalisation, there is presently inadequate infrastructure to support teachers to understand this new structure. The same point about inadequate professional development was also made in the 2004 OECD report. This issue of professional development must be discussed elsewhere, but for now it highlights and motivates the need for good analysis of how to work with the competence concept, if one is going to provide adequate support for teachers to realise the intentions in using competence goals.

## **SPECIFIC ROLE OF COMPETENCE IN THE CURRICULAR STRUCTURE OF SCIENCE EDUCATION IN DENMARK**

This section provides some background about the specific ways in which competence goals appear in the national curriculum. In relation to science teaching, three documents must be considered. The “subject purpose” (*fagformål*) the “Common Objectives” (*Fællesmål*) and the “Study plan” (*læseplan*). The ‘subject purpose’ is a legal document that specifies, in general phrases, the kinds of knowledge that pupils should achieve, and sometimes a little about the methods to be used. In Denmark, there are four relevant “subject purposes” in science education. One for “Nature/Technology” (grades 1-6) and for grades 7-9, there are ones respectively for biology, physics/chemistry, and geography.

The ‘subject purpose’ for all four of these subjects is written primarily in terms of competence, knowledge and skills. To a large extent, the formulation for each subject is similar, reflecting an intention to have a fairly consistent focus across the entire schooling period.

The ‘Common Objectives’ is also a legal document that specifies the goals for pupil’s learning that should be achieved for each grade level. The applicable competence goals are formulated in this document. For the natural sciences, there are only four competence goals: *investigation, modelling, contextualising, and communication*. These four competences are identical for all four science subjects, again reflecting an interest to make the science subjects aligned and reinforcing each other. Investigation competence refers to the idea that pupils can design, conduct, and evaluate investigations in the respective subjects. Modelling competence refers to the idea that pupils can apply and evaluate models. Contextualising competence involves being able to relate the scientific content to meaningful situations in the life outside of school, and to understand the development of scientific knowledge. Communication competence involves being able to communicate the natural scientific content in the different subjects.

While it is recognised that there could be many additional competences that might be considered appropriate or important for a natural science curriculum, the Ministry is pursuing a practical decision to prefer having a small number of competences, that repeat throughout the science subjects, motivated by the belief that it would be easier for teachers to work with this limited set, plus gain advantage that they repeat across the science subjects.

### **Comments on this structure**

One can probably discuss endlessly about which set of competences should be highlighted in a natural science school curriculum. While it is not entirely irrelevant which set is chosen, other considerations may be more important. The primary issue is how one is going to work with the set imposed into the teacher’s work.

In an ideal situation, national curriculum documents should serve to clarify and facilitate a teacher’s work in planning for teaching. At a political level in Denmark, there is some indication that this is also an intention with the introduction of the new Common Objectives (cf. Aftale, 2013). At present, however, the three primary documents (*fagformål*, *Fællesmål*, and *læseplan*) seem to introduce barriers, and in some cases, distortions into the way of conceptualising subject-matter content. For example, it has been interesting to see how little the new competence goals in the ‘Common Objectives’ have been connected to the ‘subject purpose’ statements, beyond the global assertion that the purpose will be realised through

development of natural science competences.

The Ministry provides one PDF file with the Common Objectives, another with the 'Study plan' and a third with advice about how to work with these objectives. None of these files contains the three short paragraphs of the 'subject purpose' statement. The Common Objectives make no mention of the 'subject purpose'. The advice asserts that the 'subject purpose' is supported by the four competence goals, but only gives one example that points to one small part of the 'subject purpose' in relation to one of the competence goals. This situation is interpreted as indicative that the person(s) who prepared these files did not have the "subject purpose" in their considerations as important or relevant, when these materials were prepared. This kind of example warns that the potential in these ideas depends on conditions for their enactment, not only their conceptual coherence.

Of course, these limitations do not prevent teachers from drawing relevant connections between the 'subject purpose' and the competence goals, but they are left with a challenging analytical problem to develop these connections concretely in teaching situations. Furthermore, there is a (presumably unintended) tension that arises between the "subject purpose" and the "Common Objectives". If a teacher focuses only on the 'Common Objectives', then there is no guarantee that this will automatically satisfy the 'subject purpose'. Similarly, attention to the "subject purpose" is likely to lead to concrete developments that are not consistent with the Common Objectives. If attention is given to the connections between "subject purpose" and Common Objectives, then it would go some distance in eliminating some of the critique that is raised in Denmark, that focusing on competence goals will be at the cost of general personal development (*dannelse* in Danish, *Bildung* in German), because the 'subject purpose' is formulated in a way that has general personal development in view.

Even if one is impaired or handicapped with an inadequate analytic foundation from the curricular documents, this does not need to hinder one from doing something meaningful from a disciplinary point of view. However, in this case, the teachers in Denmark will need to be able to interpret and supplement the documents that they are being asked to work with. And research has a possibility to contribute to developing those analytic capabilities.

## **A POSITIVE PROPOSAL FOR HOW TO WORK WITH THE 'COMPETENCE' CONCEPT**

The main challenges in working with the competence concept are (a) making clear what one is pursuing under the heading of "competence", and (b) how this conception is related to particular curricular interests. There is no expectation that it will be possible, necessary, or even desirable to establish a standard or universal meaning of the term *competence*, provided there is a transparency in the particular meaning being used in a particular context.

The basic assumption is that it is worthwhile to work with a competence concept in relation to science education, despite the difficulties that arise in defining the concept of competence, and the multiple ways in which the term is used among researchers and political documents. The research interest is to develop a way of understanding competence (and its development) that can serve at the same time as a guide for planning relevant instructional activities in relation to the demands of the Danish curriculum. A premise of the present investigation is that the multiplicity of definitions of competence is a permanent condition for educational practice and research about that practice, reflecting real and substantive differences in the interests and conceptions being pursued here. The intention is to formulate a meaning that is



adequate for the intentions of the national curriculum.

The research strategy is to focus on the spirit of the general reasons that motivate a competence concept, rather than get caught in an exercise of linguistic precision, or assume that a systematic definition will be sufficient to achieve the intentions embedded in this concept. That is, one needs to have a conceptual analysis of the meaning being employed. It is not sufficient to simply make a review of the diverse, sometimes conflicting ways in which the term has been used in different contexts, such as Kauertz, Neumann, and Haertig (2012) did for science education or Le Deist and Winterton (2005) did for human resources development. As Le Deist and Winterton noted for their field, it was not possible to find a definition that accommodated and reconciled the different ways of using the term (p. 29). Weinert (2001) made a similar conclusion within the social sciences (p. 46). The same tentative conclusion seems applicable within science education as well. That is, there does not appear to be an accepted definition or conception of competence.

The important feature of the competence concept is that it refers to a capability for action that cannot be explained solely by possession of knowledge and skill. Competence, as used here, refers to the capability of mobilizing knowledge and skills at appropriate times in appropriate ways in relation to the demands of the particular task being addressed, especially for tasks that a person has not previously encountered. In other words, *competence* is a designation used to summarise a person's actions in relation to a culturally-valued practice, where the standards of action are embodied in traditions for the qualities normally found in an acceptable practice within the tradition.

The descriptions in the previous paragraph may not be a formal definition of *competence*, but they identify essential or necessary qualities that must be encompassed by such a definition. More importantly, they highlight the "function" of the competence concept, namely to outline or delimit the kinds of performances that are expected in relation to the kinds of problems, tasks and situations that arise in a problem area.

Formulating a competence concept in this way provides a way to conceptualise expectations that pupils will develop analytic and critical capabilities that cannot be reduced to the acquisition of knowledge and skills. The idea of "competence" in this connection provides a way to refer to this capability, without necessarily having a way to specify the origin of this capability. This way of thinking is consistent with some of Weinert's (2001) "pragmatic conclusions concerning the use of the concept of competence" (p. 62). In particular, Weinert suggests that "the concept refers to the necessary prerequisites available to an individual or a group of individuals for successfully meeting complex demands" (p. 62), and that "learning processes are a necessary condition for the acquisition of prerequisites for successful mastery of complex demands", where "much must be learned, but cannot be directly taught" (p. 63).

Weinert's definition captures the idea that competence refers to an ability to handle complex tasks, but he does not define what counts as a complex task, or consider that there can be an interaction between complexity and existing knowledge (beyond acknowledging that the boundary between skill and competencies is fuzzy) (p. 62).

It is also consistent with Busch, Horst, and Elf's (2004) differentiation of a specific competence concept for describing subject-matter knowledge in an educational situation (p. 19). They define a specific academic competence as a "knowledge-based readiness to act appropriately in situations that contain a definite kind academic challenge" (p. 19). This definition emphasizes the appropriate use of knowledge, but does not highlight the novelty aspect, which implies that competence could be achieved through training in a well-defined

set of problems. As already noted, there are different ways that competence can be defined. For present purposes, we are particularly interested in these situations where persons are able to mobilise appropriate knowledge (Busch et al.'s definition), and where they can also act in situations that they have not necessarily encountered before (i.e., related to Weinert's complexity criterion).

For example, we can understand that evidence for the presence of "investigation" competence will be seen when pupils are able to propose sensible (empirically-based) approaches to investigate questions that they may never have encountered before, display appreciation for traditions of argument (e.g., repeated observations, control of extraneous variables).

The conception of competence presented here has focused primarily on the quality of a person's ability to mobilise appropriate knowledge in relation to a complex or new task. Some researchers advocate (or insist) on the need to have a volitional aspect in the definition of a competence. The following comment will argue against that view, which at the same time highlights a conceptual challenge for developing competences in schooling situations.

Historically, use of the term *competence* has usually been connected with meaningful tasks. One does not usually develop a competence in the abstract, for its own sake, unconnected to a particular purpose. Rather it is developed as part of pursuing a greater goal. This historical fact helps to understand why the competence concept has been used in relation to professional and skilled work. It is also meaningful in relation to hobbies and other amateur activities (e.g., sports, playing music). Because this notion of competence is so closely connected with meaningful action, it is understandable that some researchers want to include an aspect of intention or will as part of the definition of *competence*. For example, one would hardly call a nurse "competent" if this person knew how to create sanitary conditions in different situations, but did not want to be bothered while on the job.

In contrast, in a schooling situation, there is not the clear and immediate "greater purpose" normally found in professional, skilled, and amateur pursuits. This raises a danger that development of competence becomes an end in itself, which in turn creates difficulties both for pupil motivation to acquire different competences and pupil understanding of the function of the competence. In the Danish school system, there is, however, a way to avoid this potential difficulty, by using the "subject purpose", which formulates (in general terms) the kinds of qualities and capabilities that pupils are supposed to realise through the teaching. The practical implication is that teaching plans, oriented toward the general purposes formulated in the "subject purpose" have a way to motivate the development of competence, even if these purposes do not motivate the necessity of wanting to use these competences. However, development of motivation depends, in part, on having adequate ability to mobilise knowledge (i.e., competence), so in a developmental perspective, the development of competence can be an important requisite for the development of a volition to use this knowledge.

### **Competence as psychological concept**

The notion of competence, as presented here has a double aspect. In part, competence is grounded in a psychological capability (i.e., ability to use knowledge appropriately), but its meaning cannot be reduced to that capability. That is, although competence is grounded in psychological capabilities, an evaluation of competence is grounded in characteristics of action in relation to the tasks. That is, competence is located in the interaction between person and the situation, where an evaluation of performance in relation to a conventional standard,

where that standard could be achieved in a variety of possible ways. In this connection, the competence-performance distinction found in linguistics can be useful to consider. This distinction highlights that one can have a competence, but still make performance mistakes.

From a psychological point of view, competent performance depends on a person being able to mobilise knowledge at an appropriate time. While knowledge and skill may be prerequisites, there must be some other qualities that make it possible for persons to mobilise knowledge appropriately.

Therefore, one needs to have an account of the psychological prerequisites or conditions that make it more likely to act in a competent way.

Davydov's (1972/1990) ideas about using germcells (models of central conceptual relations in the subject matter), and 'rising to the concrete' (i.e., recognising these relations in concrete examples) are part of his analysis of theoretical thinking. The idea of theoretical thinking provides a promising way to be able to conceptualise how a person can mobilise knowledge to new and not previously encountered variations of problem situations (i.e. to display competence), while giving insight into how one can develop a teaching approach that will support the development of natural scientific competences.

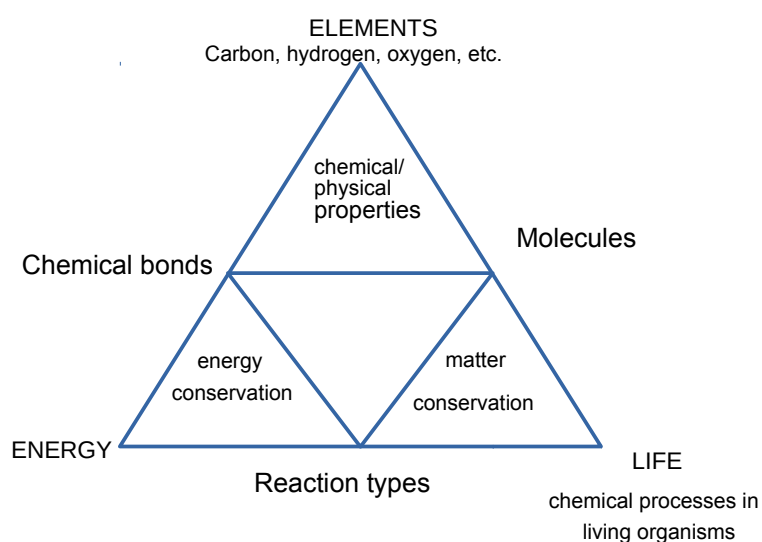
The idea of theoretical thinking is a psychological concept grounded in a conceptual analysis of the structure of knowledge, which involves being able to adapt or apply or use the essential conceptual relations in concrete situations. This adaptation is called "rising to the concrete", where the general or abstract relation is interpreted in the concrete situation. Vasili Davydov (1972/1990) presented an extensive analysis of types of generalisation, introducing the idea of substantive generalisation, which comes from the so-called primary general relationship. For example, in relation to the concept of number, Davydov argued that "measure" should be the primary relationship, because this includes all forms of number, including fractions.

Hedegaard (1988) extended Davydov's focus on the relation to the idea of *germ cell*, where a system of relations can be used to analyse a problem area. She uses the example of 'species – population – individual' and the relation between species and niche in analysing the development of animals. From these general relations, one should be able to think theoretically by rising to the concrete in relation to concrete examples. For example, if you are asked what will happen to the polar bear if it is moved to the Sahara desert, then you will need to mobilise your knowledge about polar bears, including what they eat, what conditions they need for survival, along with your knowledge about the conditions of the Sahara desert, and make an evaluation of the interactions between the needs of the bear and the conditions provided in the desert (see Hedegaard, 1996). For present purposes, the main point of the example is to highlight that a person may never have encountered this question before, but from knowing that there is a general relation between species and niche, and knowing that particular relationships (e.g., water needs, food needs, shelter, temperature) are needed for survival, then it is possible to make an evaluation of this particular case. This is an example of theoretical thinking, where a person has an understanding of general relationships (between population and species, between niche and species), and is able to use these general relations as a way to organise knowledge in relation to the concrete case. This concrete organisation is called rising to the concrete, because the general relations are being instantiated concretely in the particular situation.

This quality of being able to mobilise and organise knowledge in a concrete situation is similar to the quality expected in a competence, where a person is able to mobilise knowledge and skill in an appropriate way in situations that have not been previously encountered.

However, thinking theoretically is not necessarily the same as having a competence, because again, it is necessary to use this form of thinking in appropriate situations. The hypothesis is that in being able to rise to the concrete (i.e., to mobilise appropriate knowledge about important relationships in novel situations), then a person will be in a better position to act competently. The theoretical thinking serves as a kind of “bridge” in which a person can relate their conceptual knowledge to problem situations.

To concretise these ideas, we have been attempting to develop a germcell model for chemistry (see Figure 1), which can be used as part of developing competence for investigation and modelling (i.e., part of the Common Objectives). The key idea with this model is that it provides a general structure for understanding or characterising relationships between elements, molecules and the conditions that must be met for particular molecular forms to appear in life processes. In effect, this model provides a way to organise knowledge in conceptual relations. At the same time, the general relations in the model provide a way to rise to the concrete in considering the chemistry in particular life processes. The ability to rise to the concrete is the psychological form in which knowledge is used. This form is what provides a performance that can be evaluated against a disciplinary standard. In being able to mobilise knowledge in rising to the concrete, a person starts to display the kinds of performance that are interpreted as indicating competence. The use of a germcell model is especially relevant to the modelling competence that is expected in the Common Objectives, because theoretical thinking is a form of modelling, while the model that is constructed from the theoretical analysis, provides a structure that can be used to motivate investigations (e.g., to test assumptions in the model), which in turn give a substantive foundation for mobilising knowledge in relation to that investigation (which is interpreted as evidence for an investigation competence). All of these examples are meant to illustrate that while theoretical thinking in itself is not a competence, it provides the psychological foundation for organising knowledge in novel or unfamiliar situations, such that persons can produce competent performance in addressing these situations.



**Figure 1. Hypothesised Germcell Model for Chemistry of Life (developed by Lars Sejersgård Jakobsen)**

## CONCLUDING SUMMARY

This paper has engaged with the notion of competence, in part because it has become a required part of the national curriculum in Denmark, and in part because of the conceptual problems in finding a meaningful way to conceptualise the idea so that it is possible to make meaningful interventions in school teaching. The idea of theoretical thinking was introduced, as a psychological concept, that provides a way to give a concrete direction for teaching that concurrently provides a foundation for the development of competence. The idea of theoretical thinking is grounded in being able to consider basic relationships in the problem field, which are organised analytically in a model (germcell) of these relations. If pupils are able to master the basic relations in this cell, then they are in a better position to mobilise their knowledge when they are asked to investigate problems that involve relations in that cell (e.g., the model of chemistry in life processes).

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