Feasible Ways to Personal Meaning Mapping in Out-Of-School Contexts?

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Abstract: Though most teachers find formal learning activities an important part of a class visit to a science center, research shows that formal learning is seldom the outcome. Instead, school visits tend to become “soda visits” without preparation and learning goals, and are rarely with explicit connection to the subjects taught back in school. To accommodate these challenges at the science center Experimentarium, a partnership with University College Copenhagen was initiated in 2017. In collaboration, ten Flipped Learning based teaching materials were developed to assist visiting teachers in supporting students’ learning before, during, and after the visit. To evaluate this intervention, a tool was developed to assess students’ learning outcomes using Personal Meaning Mapping (Falk, Moussouri and Coulson, 1998). This paper investigates and discusses this tool as an effective means for measuring ‘actual learning’ (Bundsgaard and Hansen, 2011) in contexts involving interventions aimed to integrate out-of-school visits with in-school activities. Specifically, a pre- and post-test setup was conducted in order to measure development in students conceptual understanding. Data from students’ Personal Meaning Maps were analysed quantitatively using four defined dimensions for coding: extent, breadth, depth, and mastery. The empirical data were collected from 26 students in the same class, of which 12 provided full data sets. Two central results are presented 1) the data shows development in students learning when engaging in the learning material 2) extent and breadth seem to be able to predict depth and mastery, opening up for adjustments to research method. While Personal Meaning Mapping is rather resource-intensive, and although some of these learning outcomes will remain hidden using this method, we still find it a useful and powerful tool for gaining nuanced insights into the development of students’ conceptual understanding. In conclusion, we offer some suggested modifications to the method to make it more feasible in more feasible to integrate in out-of-school contexts focussing on formal learning.

Keywords: personal meaning mapping, flipped learning, museum, out-of-school, blended learning

1. Introduction

In 1916, Dewey suggested that school should embrace society around the school: “For when the schools depart from the educational conditions effective in the out-of-school environment, they necessarily substitute a bookish, a pseudo-intellectual spirit for a social spirit” (p. 46). This opening movement is still valid today. In 2014, the Danish Ministry of Education reformed the school system, emphasising the schools focus on out-of-school learning activities. According to the Danish minister of education, the teacher is responsible for connecting the school visit to the overall purpose of school (Riisager, 2017, p. 103).

An investigation from 2004 show how most teachers visiting the Copenhagen science center Experimentarium also find a connection between the visit and the school curriculum important, but the actual visits tend to be “soda visits” with no related school activities before or after the visit to bridge the experience of out-of-school contexts with that of the school (Sørensen & Kofod, 2004, p. 529). This find is echoed internationally (cf. Griffin and Symington, 1997; Falk and Storksdieck, 2002; Storksdieck, 2002, cited in Sørensen & Kofod, 2004, s. 529). To accommodate this disconnect at the Copenhagen science center Experimentarium, a partnership with the teacher education at University College Copenhagen was started in 2017. In a joint effort, ten flipped learning lesson plans were developed to assist the visiting teachers in framing the teaching before, during, and after the visit (see Lie, 2018). This study makes use of data collected as part of this collaboration to evaluate and discuss the practical feasibility of methods to assess students’ learning outcomes in science based out-of-school context (Philipps, 2018).
1.1 Research question

Evaluating students’ learning outcomes from any teaching-learning activity makes great demands of both researcher, teacher and students involved in the activity. One method that has gained some traction in this regard makes use of methodologies to map out students’ personal meaning making (Dolin 2002; Falk and Storksdieck, 2005). However, when comparing results from different studies of this kind, a pattern seems to emerge:

Figure 1: PMM study mean comparison

In figure 1 above, four studies that compare results of students’ personal meaning mapping pre- and post learning activities, reveal that large gains are observed on the first dimension (extent), while smaller gains are consistently, albeit differently, recorded on three other dimensions (breath, depth and mastery). Considering the time and effort it takes to record gains across each variable, it seems prudent to ask if one or two of these variables might predict outcomes on other variables. This is what this study aims to investigate.

Main question: How can Personal Meaning Mapping (PMM) methodologies support evaluation of learning materials used in an out-of-school science context as a feasible, reliable and valid tool for measuring students’ learning outcome.

Sub-questions:

- How interdependent are the four “semi-dependent” dimensions in the PMM-method?
- What adjustments could be made to the PMM-methodology and what implications would these adjustments entail?
- Could PMM methods combine researchers investigations and teachers pedagogical praxis to mutual benefit?

Feasibility refers to the effectiveness of the method in regard to the overall effort put into the application of the method, compared to its reliability and validity within the research scope. A feasible application of the tool needs to be both practical and precise in the given context.

2. Flipped learning in external learning environments

The study’s most central theories of flipped learning, informal learning and concept mapping is presented here.

2.1 Formal learning in informal contexts

Ansbacher (2002) developed a non-definitive list of visitors learning outcome which falls into 8 categories: 1) No outcome, 2) add to experience bank, 3) develop physical knowledge, 4) change feelings or attitudes, 5) lead to active curiosity, interest, or awareness, 6) achieve understanding, 7) develop skills, and 8) acquire information or factual knowledge. All of these are valid, albeit not necessarily desirable outcomes for visiting guests. Even “no outcome”, since regular guests might have a strictly social agenda or the like. However, for visiting schools it is another matter. These 8 categories includes tacit, explicit and effective change. Developing students’ physical knowledge, adding to the experience bank or becoming more curious, can later on lead to motivation and more formal learning within school curriculum - if the learning processes are scaffolded and framed properly (Busch, 2004, p. 169).

Compared to the relatively controlled classroom environment, the museum context is not an easy place to frame and scaffold the learning processes given the many impressions from the exhibition, noise level, the novelty of the location for both students and teachers, lack of physical space for classes etc. (Bush, 2004, p. 169). Due to these challenges, the teacher often let the students follow their own individual interests (Sørensen and Kofod,
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2004, p. 529). This will often lead to students “zapping” around in the exhibition instead of focussing their energy on a few select models (Bush, 2004, p. 169). The “zapping” students can be described more positively as “zapping explorers”. A more constructive mode would be for the teacher to help students act as “curious young science students”, transforming the exhibition into a laboratory for systematic investigation (Andersen et al, 2018, p. 13). The flipped learning materials developed for Experimentarium is an attempt to facilitate this transformation in mode using flipped learning strategies (Lie, 2018), which was consequently evaluated using PMM (Philipps, 2018).

2.2 Flipped learning

Flipped learning is a didactical set of methods that blends ICT and teacher presence in order to facilitate students active learning (Eppard & Rochdi, 2017). The “flip” in flipped learning refers to a reverse of a traditional way of teaching, where the teacher prepare students in-class to carry out tasks as individual homework. Instead, teaching flipped, means using videos to instruct students before class, to thus allow the teacher to guide students with their tasks in-class (Bishoo & Verleger, 2013, p. 9). Most academic definitions and practitioners mention the video media as central for the concept (Eppard and Rochdi, 2017, p. 35), and Bishop & Verleger explicitly reject definitions of flipped learning which do not include video (Bishop and Verleger, 2013, p. 5). However, close-ended problems or quizzes are often used to supplement and ensure students’ understanding of the preparatory video materials (Bishop & Verleger, 2013, p. 5).

Videos are easily distributed and has a lot of possibilities as a media for conveying abstract or contextualized content. The purpose of the video is to scaffold the students’ active learning processes. The video is typically made or carefully selected by the teacher to introduce students to a given subject. Typically videos are instructional (Eppard and Rochdi, 2017, p. 35), but since the main purpose is to engage students in active learning (Bishoo & Verleger, 2013), other video types and components should be considered equally valid, e.g. videos that guide, inspire or motivate. Together with quizzes that help students evaluate their outcome or help them focus on the material as intended such practice is “... touted as a highly successful practice” (Bishop & Verleger, 2013, p. 10).

To guide scaffolding efforts, Puntambekar and Hübscher (2005) suggest helping students to structure the task, arguments, or scientific explanations or to structure and make the scientific process more transparent. Furthermore, the video itself constitutes an invaluable resource to students, when the teacher is with other students during the activity.

Ideally, the technological scaffolding tools fit most students’ needs as a hard scaffolding “blanket” facilitating most students active learning, and the teachers time is freed for soft scaffolding, e.g. to diagnose and adapt different scaffolding options to the various constellations of students in need (cf. Brush and Saye, 2002). Thus, “to orchestrate all the activities and integrate the tools, the teacher [still] plays the most important role.” (Puntambekar and Hübscher, 2005, p. 10).

2.2.1 The FLIP experimentarium model

The challenge in out-of-school contexts is to connect the visit to the school curriculum. To this extent, Experimentarium and University College Copenhagen developed and used a three phase model based on the flipped learning framework. The following model is an adaptation of a four phase model applicable for teachers who flip their teaching (See Levinsen et al, 2017):

![Figure 2: FLIP experimentarium - model for teaching exhibit. Adapted from Andersen et al., 2018, p. 8](image_url)

If used as intended, the class prepares at home by engaging with video materials and materials for scaffolding the preparational learning processes, prepared by the external learning environment. In theory, this will prepare the students to engage in meaningfully scaffolded learning activities in the exhibit. After the visit, the students...
might bring home data or notes from a shared and investigative experience. Having the teacher positioned as a professional guide, this material can then be used to contextualise the curriculum.

Another central element for definitions of flipped learning are pedagogical approaches like “hands-on activities”, “engaging students” and “solve students’ problems” (Eppard and Rochdi, 2017, p. 35). Bishop and Verleger (2013, p. 7) sums these different approaches up to the term of active learning. This includes Cooperative Learning, Collaborative Learning, Peer Tutoring, Peer-Assisted Learning, and Problem Based Learning that are all considered student-centered pedagogical approaches to help students develop conceptual understanding and make personal meaning of learning activities (Bishop & Verleger, 2013, p. 7).

2.3 Concept maps represent a cognitive structure

A way to evaluate students’ conceptual understanding and their construction of personal meaning of learning activities that is commonly used within natural sciences, is concept maps (Dolin, 2002). Concept maps are created by a learner to express the relation between concepts within a certain subject. Traditionally, these maps are constructed as part of learning activities to scaffold reflection and dialogue. In the later years, they have also been used in research to measure learners conceptual knowledge, assuming that the maps reflect an inner cognitive structure (Dolin, 2002, p. 261). “The ability to construct a concept map also illustrates two essential properties of understanding, the representation and the organization of ideas” (Kinchin, Hay and Adams, 2000, p. 44). Multiple learning theories within natural sciences focus on the development of students’ conceptual understanding, which makes this method valid within science curricula (Dolin, 2002, p. 91). The PMM methodologies are based on the concept maps and are designed to measure students’ conceptual understanding.

3. Study design

In the sections describing the methodology, we will frame how the study uses PMM in a pre- and post-test design, and how data is created and analyzed. The application of the PMM method is an effort to measure “actual learning”, as a part of a more holistic research design which could also include a learning materials “the potential learning potential” or “the actualized learning potential” (Bundsgaard and Hansen, 2011, p. 33). Looking for “actual learning”, we focus solely on what PMM can tell us about learning, well aware that this method will not measure all which is relevant for learning, e.g. tacit knowledge or affectional change.

Students and teachers engage in one of ten flipped learning-based learning material called “Dikes and gates”. A video and questionnaire offer instruction and scaffolding to help the students engage in the learning activities before, during and after the visit.

3.1 Pre- and post-test setup

In order to measure the development in conceptual understanding, this study is based on a pre and post-test setup. The learning material “Dikes and gates” facilitates learning in the three phases: Before, during and after a visit at the science center Experimentarium in Copenhagen. The learning material scaffolds the students’ work with measuring and calculating the potential energy of a water stream flowing over a watermill.

Figure 3: Study setup

3.2 Personal Meaning Mapping

PMM is a research method based on concept mapping. It was developed by John Falk in 2003 to measure regular visitors learning outcome in informal learning environments (Lellilot., 2007, p. 204). Few studies explorer PMM in a formal learning setting (Hartmeyer et al., 2017). Whereas concept mapping requires a specific technique, PMM can be used with a simple instruction (Lellilot., 2007, p. 204). The method starts with the learner prerequisites, and is therefore very flexible in relation to the respondents prior knowledge (Mortensen and Quistgaard, 2011, p. 65). Lellilot (2007, p. 217) claim that “It generates a lot of data, and is therefore time-consuming to transcribe and analyse, and requires knowledge of analysis procedures on the part of the
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researcher. Issues of validity and reliability are similar to other techniques which involve coding during analysis, and require careful attention to the selection of the initial words or phrases used as prompts, and to inter-rater agreement.”.

3.2.1 Data generation process

The Pre-test is established before the students engage in the lesson plan which effect is under investigation. Normally an introduction is required to the students in order for them to understand how to engage in the meaning maps - e.g. with examples from other topics. Each student gets the template framing their concept map - e.g. with a subject, or with a model showing the core of the topic in hand. In this case, an illustration of a water power plant.

After the introduction to concept mapping, but prior to the students being introduced to the topic of the learning materials “Dikes and gates”, the student go through the following data generation process:

- **A1:** Each individual student write down concepts relevant for water power and potential energy.
- **A2:** On turn, each student is interviewed based on their exact written concepts, letting them explain the different concepts inter connection. The interviewer follows a consistent interviewing technique, and add notes on each students concept map with a new distinct colour.

The Post-test follow the same procedure on a new blank template. A less detailed introduction is given.

- **B1:** Repeat A1
- **B2:** Repeat A2

The pre-test and the visit happened the same day, and after-phase and the post-test were conducted a week later. The below should cover an example of a single students’ pre- and post-test. This particular student has a somewhat average development, except for breadth witch goes from 4 to 3.

![Figure 4: Example of a pre-post test, quantified and translated](image)

3.2.2 Quantification process

The concept maps generated by the respondents are analysed and quantified within four dimensions: “The four constructs extent, breadth, depth, and mastery were designed to be independent and complementary measures of learning, capturing different aspects of cognitive gain in a free-choice learning environment.” (Falk and Storksdieck, 2005, p. 753). Often a specific tool is developed in an iterative process between multiple raters, creating Inter rater reliability. According to Falk & Storksdieck (2004, p. 758), the PMM dimensions extent and breadth are statistically semi-dependent to PMM depth and mastery.

- **1. Extent:** Every relevant term where counted. Some terms overlap, and only count once (e.g. potential energy and stored energy). Scale, from 0 to an undefined cap of approx. 31 (top score 13).
- **2. Breadth:** Gives one point for every relevant category where a term has been mentioned (e.g. students mentioning “water current” or “movement energy” has proved that they considered the “Kinetic energy” category). Scale 0-5.
- **3. Depth:** Depth expresses the students’ in depth understanding, and is interpreted on the basis of how scientifically accurate terms are used, and the connection of these in the concept map. Scale 0-5.
4. Mastery: Is an overall assessment of the students’ understanding. “Mastery can thus be seen as a more traditional measure of learning, it is designed to be a holistic measure, taking into account all of things an individual said during the PMM process in order to gauge where an individual falls along a continuum between novice and expert relative to the specific concept or phenomenon represented by the prompt.” (Falk and Storksdieck, 2005, p. 753). Score 0-5.

Some terms didn’t give points, mostly because they were judged outside the scope of “water power” and “potential energy” or was already stated on the PMM handout, e.g. Water pipes, power station, water filtering, fresh water, salter water etc.

Figure 5: Scoring chart for PMM used to assess conceptual learning within “Dikes and gates”)

In our case, we didn’t use an intercoder procedure as recommended (Falk and Storksdieck, 2005, p. 753), but instead we developed a scoring chart for consistent interpretation. Every written term was compared to the chart. This tool gave a high consistency to the interpretation of Extent and breadth which are interpreted simply by counting. The depth and mastery interpretation was supported by the tool as well, but still required more interpretation, with a potential error margin which an inter coder procedure would have minimized.

4. Analysis of data and results

4.1 Data evaluation

The PMM-methodologies give insights to cognitive schemas of concepts and their relations, though only as far as the respondents are able to express them under the given circumstances. Thus not saying much about tacit knowledge, motivation, affections or other equally important factors of learning. The PMM process itself should be considered a learning activity and might it selv influence both cognitive structure and the students further engagement between the pre- and post-test. “Teaching to the test” or “looking for what the researchers want” might apply to this method as well. This could possibly result in respondents wildly guessing, wrongly censoring out terms or simply be too nervous. All of this should be taken into consideration when interpreting the results of a PMM-based study. This study is based on a very limited sample from a homogeneous group, and the quantification process does not use intercoder reliability. The results should therefore be interpreted carefully.

4.2 Analyzing quantified data

The quantified data gave each student a pre-test and post-test score in each of the 4 dimensions. Out of the class of 26 students, 19 students managed to complete both pre- and post-test concept maps, and only 12 also completed the interview. Thus, 12 full datasets where collected, which comprise the data used for this study.
4.3 Scatter chart

The below four scatter charts each represent the full sample. Each plot represents a single student’s pre- and post-test score, indicating the learning development. Multiple points may stack. Data points on the red dotted “no learning” curve show no development in conceptual understanding, dots above the line show learning progress. The blue line is a linear trend line inserted to emphasise the average difference between students’ learning gains and the “no learning” curve. All four PMM dimensions show an overall learning progression that in some dimensions seems to vary depending on pre-test score. Extent’s trend line lies parallel to the “no learning” curve, which could indicate that students learn to the same degree invariably of their prior knowledge. On breadth, depth and mastery it seems as if high pre-test scores means lower learning gains. This is likely an artificial pattern created by the instrument, a “ceiling effect”, since 5 is the maximum possible score on both pre- and post test.

![ Scatter charts for Extent, Breadth, Depth, and Mastery ]

**Figure 6:** Plot diagram of pre- vs post in four dimensions: Extent, breadth, depth and mastery

4.4 Statistical correlation across PMM dimensions

In order to investigate how well the semi-dependents dimensions correlate, a two tailed correlation analysis was carried out as is recommended in educational science (Pillemer, 1991). Results from the pre-test were compared, as were the post-test results. It shows a significant, moderate to strong correlation from the PMM pair extent and breadth to the PMM pair depth and mastery in both the pre- and post-test, with the exception of post-breadth to post-depth.

<table>
<thead>
<tr>
<th>Pre-test</th>
<th>Extent</th>
<th>Breadth</th>
<th>Depth</th>
<th>Mastery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent Pearson</td>
<td>1.00</td>
<td><strong>.83</strong></td>
<td>*.64</td>
<td><strong>.79</strong></td>
</tr>
<tr>
<td>Sig.</td>
<td>.001</td>
<td>.015</td>
<td>&lt;.001</td>
<td>.001</td>
</tr>
<tr>
<td>Breadth Pearson</td>
<td><strong>.83</strong></td>
<td>1.00</td>
<td>*.68</td>
<td><strong>.82</strong></td>
</tr>
<tr>
<td>Sig.</td>
<td>.001</td>
<td>&lt;.001</td>
<td>.015</td>
<td>.001</td>
</tr>
<tr>
<td>Depth Pearson</td>
<td>*.64</td>
<td>*.68</td>
<td>1.00</td>
<td><strong>.93</strong></td>
</tr>
<tr>
<td>Sig.</td>
<td>.025</td>
<td>.015</td>
<td>&lt;.001</td>
<td>.001</td>
</tr>
<tr>
<td>Mastery Pearson</td>
<td><strong>.79</strong></td>
<td><strong>.82</strong></td>
<td><strong>.93</strong></td>
<td>1.00</td>
</tr>
<tr>
<td>Sig.</td>
<td>.002</td>
<td>.001</td>
<td>&lt;.001</td>
<td>.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Post-test</th>
<th>Extent</th>
<th>Breadth</th>
<th>Depth</th>
<th>Mastery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent Pearson</td>
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<td><strong>.86</strong></td>
<td><strong>.75</strong></td>
<td><strong>.72</strong></td>
</tr>
<tr>
<td>Sig.</td>
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<td>.005</td>
<td>.009</td>
<td></td>
</tr>
<tr>
<td>Breadth Pearson</td>
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<td>1.00</td>
<td>*.47</td>
<td>*.59</td>
</tr>
<tr>
<td>Sig.</td>
<td>&lt;.001</td>
<td>.121</td>
<td>.041</td>
<td></td>
</tr>
<tr>
<td>Depth Pearson</td>
<td><strong>.75</strong></td>
<td>*.47</td>
<td>1.00</td>
<td>*.69</td>
</tr>
<tr>
<td>Sig.</td>
<td>.005</td>
<td>.121</td>
<td>.012</td>
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</tr>
<tr>
<td>Mastery Pearson</td>
<td><strong>.72</strong></td>
<td><strong>.59</strong></td>
<td>*.69</td>
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<tr>
<td>Sig.</td>
<td>.009</td>
<td>.041</td>
<td>.012</td>
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</tbody>
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* p < .05, ** p < .01, n = 12

**Figure 7:** Pearsons two tailed correlation analysis across the four PMM dimensions
5. Conclusion and discussion

This study investigates the application and feasibility of PMM as a means to measure learning in out-of-school contexts, as a difficult frame for teachers to facilitate and ensure student learning. Especially two dimensions (depth and mastery) are resource demanding task, as they rely on interviews and qualitative coding. Although this study is based on a small sample, we observe moderate to high correlation across the two pairs of PMM dimensions: PMM extent/breadth and PMM depth/mastery. Furthermore, since such correlations across dimensions correlate with of constructivist learning theories, there is good reason to suggest further studies into these apparent dependencies across contexts, to better understand the relation between the four “independent” or “semi-dependent” dimensions (as Falk and Storksdieck 2005 also describe them). If the correlation reported here can be echoed by future studies, it might help researchers adjust the methodology in different ways to accommodate their needs. Hopefully even help lessen heavy time and resource constraints in educational studies and the systematic development of teaching activities.

To this end, a list of possible adjustments to the PMM methodology are discussed. However, these should be applied with respect for reliability and validity, or studied further to develop the PMM methodologies.

5.1 PMM and feasibility

On the basis of this study, a variety of different PMM adjustments are discussed in relation to feasibility. These adjustments mainly consider out-of-school contexts. However, the discussed adjustments are not examined in relation to reliability and validity which need careful consideration. Due to reliability issues in research, the PMM design should ensure consistency in data collection and interpretation. This can especially be an issue if multiple researchers or non-researchers, or the lack of precise scoring charts.

Consider only measuring extent and breadth, while skipping depth and mastery. A very precise score chart can be made for coding extent and breadth, thus reducing the need for an intercoder procedure and making the coding process lighter. Skipping depth and mastery can make some of the other suggestions less intrusive to the original PMM methodologies, e.g. skipping the interview. Some details from depth and mastery will get lost, rendering such an adjustment a less detailed version, albeit the resource demands could be decreased substantially, and directed towards other means of evaluating. Though some evidence is presented here as extent and breadth being predictors of breadth and mastery, further research is needed to better understand the correlation, and thus what consequences the implication of such and amputation of the PMM method.

Consider concept mapping without interview, due to the high logistical and resource pressure. This will influence all four dimensions, since the interview can pull forward almost active concepts from the learners, but it will most likely influence the dimensions of depth and mastery, since they take concept connections into consideration.

Consider using videos and online templates for print to initiate the process, due to the uniform, scalable and accessible nature of the online media as a hard scaffold. This adjustment could be used in conjunction with a responsible adult acting as a soft scaffold - e.g. the teacher or research assistant.

Consider PMM as a part of the learning design, since it is considered a meaningful learning activity by itself. A combination of empirical data creation and pedagogical praxis could both accommodate difficult logistics in an out-of-school research setup and help render meaning in the PMM activity for both students and teachers.

Consider af combination of the suggestions above. This could highly reduce resource costs, especially if the teacher facilitates the concept map process. Though this is intriguing, a combination putting the teacher in charge is likely to highly affect the students responses and lower consistency of the data across contexts.

Also consider:
- a research based PMM design, improving in iterations
- adjusting the PMM measure points differently than a pre- and post-test setup
- a peer-learning PMM model allowing multiple learners to collaborate on the concept maps
- complementary research methods, for inspiration see Falk and Storksdieck (2005) or Philipps (2018)
5.2 PMM and quality

Though focus in this study has been on PMM adaptations that are practical and applicable, a focus on the qualities of the PMM methodologies seem a relevant path to explore as well. One aspect of quality could be longitudinal studies, investigating the long term development of conceptual knowledge when the learners are exposed to different learning- and exhibition designs. Another dimension of quality could be latitudinal studies, exploring development in conceptual understanding of a particular activity design, e.g. robustness, perceived relevance, interconnectedness etc. Longitudinal and latitudinal approaches to PMM based studies, could help build larger investigational frameworks. Such frameworks should carefully address the reliability and validity issues, as should researchers and practitioners deploying adjustments mentioned in this paper.

References
Andersen, M.F., Møller, H., Levinsen, H. & Thomsen, A.V. (2018) FLIP – Experimentarium A case study of the exhibit “Hot or Not?”
Norge: PowerPrint AS, Steinkjer.