Birgitte Lund Nielsen has a PhD in Science Education, and is presently Research Fellow at Centre for Science Education, Aarhus University, and Associate Professor at VIA University College. Her research interests concern science teachers' professional development, pre-service and in-service, and students' conceptual understanding. Before changing to teacher education and research Birgitte was teaching lower secondary Physics & Chemistry and Geography. Her background is MSc in Geoscience and in Science Education.

BIRGITTE LUND NIELSEN

Centre for Science Education (CSE), Aarhus University & VIA University College, Denmark
bln@cse.au.dk

Students' annotated drawings as a mediating artefact in science teachers' professional development

Abstract

This paper presents a case study of a teacher examining her 4th graders' conceptual understanding of factors causing day and night, seasons, and the phases of the Moon both pre- and post-teaching, as a part of participating in the continuous professional development (CPD) project QUEST. The study is framed in reference to the extant research in the two fields of CPD and students' alternative conceptions in science. The findings pertain to both the 4th graders' conceptual understanding and the teacher's meaning-making when examining the students' annotated drawings and discussing them with colleagues. The teaching in general seems to be efficient concerning challenging students' alternative conceptions; however not in relation to the phases of the Moon. The teacher re-designed her teaching and emphasized the insight gained from looking into a structured analysis. Nonetheless, she questioned whether teachers would find time for such analyses. While there are promising indications that this teacher will continue using pre- and post-assessment based on the insights gained, the collaborative analysis seemed rather superficial. The spreading to colleagues is discussed referring to this inquiry as supporting individual but probably not collaborative agency.

INTRODUCTION

Continuous Professional Development (CPD) has the potential to play a crucial role in qualifying science teaching by supporting in-service teachers in developing their competence to learn from practice. It appears that some of the most powerful teacher learning experiences can be based on facilitated inquiries from the teachers' own classrooms (Borko, 2004; Putman & Borko, 2000). Extant research suggests a broad consensus pertaining to the core features of effective CPD, which include focus on teaching and learning of subject matter, active teachers involved in inquiry-based and collaborative learning, and duration and sustainability (Desimone, 2009; van Driel, Meirink, van Veen, & Zwart, 2012). In relation to duration and sustainability, long term interventions combined with follow-up support of local teacher collaboration appear to be crucial (van Driel et al., 2012). Hence, internationally, the importance of supporting teachers in analysing teaching in terms of its effects on student learning is acknowledged. Research indicates that *artefacts from practice* such as classroom video can be a mediating factor in science teachers' collaborative inquiries, supporting them in developing a deeper understanding of student learning in science (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Loucks-Horsley & Matsumoto, 1999; Sherin & Han, 2004). The focus of most extant interna-

tional studies has been the sharing of classroom video in so-called video-clubs (Sherin & Han, 2004). However, in recent Danish research teachers from a local science team participating in a video-club also highlight positive outcomes from collaboratively analysing and discussing *annotated drawings*. For example, one teacher used this approach when examining her students' alternative conceptions related to electric circuits and found sharing students' drawings with colleagues in the science team beneficial (Nielsen, 2012b).

Alternative conceptions arising from students' attempts to explain the natural world have long been found to be extremely resistant and difficult to change and to have a profound influence on what is learned (Driver, 1989; Scott, Asoko, & Leach, 2007). In addition to the significant body of research on students' alternative conceptions in various science subjects, many publications targeting pre- and in-service teacher education have also emerged (Andersson, 2008). However there may still be a gap between research and practice in the Danish context. It is suggested that the collaborative work with concrete artefacts from practice might create awareness of relevance in own classroom by supporting the teachers in linking own experience-based, practical knowledge and the research-based knowledge (Nielsen, 2012a).

The purpose of this paper is to further understand teachers' meaning-making when their inquiries into students' alternative conceptions in science are a part of CPD, designed according to the mentioned consensus criteria. The research is framed by a large-scale, longitudinal and collaborative Danish CPD project called QUEST—an acronym for “Qualifying in-service Education of Science Teachers” (Nielsen, Pontoppidan, Sillasen, Mogensen, & Nielsen, 2013). Data presented here pertain to one teacher teaching a 4th grade class about familiar astronomical events (day and night, seasons, phases of the Moon) as a part of the Science & Technology subject. As a consequence of participating in QUEST she collected pre- and post-teaching annotated drawings from the students, and discussed those with colleagues in the local science team and in a network with science teachers from other schools.

BACKGROUND

Before describing in more detail the QUEST project, i.e. teachers' individual and collaborative work with annotated drawings, first the research background related to using annotated drawings to elicit alternative conceptions is described.

Annotated drawings and alternative conceptions in science

The term “annotated drawing” refers to a drawing of a scientific phenomenon accompanied by some written text, often made with the purpose of identifying alternative conceptions (Bannister, 1998; Georgiades, 2004; Parker & Heywood, 1998). Students can as part of science teaching be asked by their teacher or a researcher to make a drawing in relation to a given concept and/or phenomena, and to produce brief annotations to explain their drawings (Georgiades, 2004). Students' work on annotated drawings might be initiated by a specific question, such as “What does a plant need to grow?” (McNair & Stein, 2001), or “Why is there day and night on the Earth?”. The latter is one of the questions used in the drawings analysed here. Students could also be asked to make annotated drawings as a part of their practical activities in science in order to, for example, describe their hypotheses.

Throughout the 1980s, there was intensive research eliciting students' alternative conceptions, also called preconceptions, misconceptions, alternative frameworks, etc. (Driver, 1989). In the area of familiar astronomical events Baxter (1989) and Jones, Lynch and Reesink (1987) emphasized that around 25 % of students aged 9–10 explain day and night as caused by the Sun orbiting the Earth, and 30 % by the Earth orbiting the Sun. In relation to the seasons student explanations referring to the distance to the Sun instead of the tilt of the Earth are widespread, and shadow explanations have been shown to dominate the understanding of the phases of the Moon held by children and many adults.

Annotated drawings have been used as a research tool to identify alternative conceptions, as they are considered a simple research instrument that enables easy comparisons at the international level (Bannister, 1998). Multiple-choice diagnostic tests, student interviews and concept-maps are examples of other research tools (Bannister, 1998; Georgiades, 2004). More recent studies and publications for practitioners have focused on how to diagnose and challenge students' alternative conceptions as a part of science teaching, for example, under the headline of teaching for conceptual change. In relation to diagnosing and challenging alternative conceptions in a teaching context, various instruments have been suggested (e.g. Bannister, 1998). For example, concept cartoons (Keogh & Naylor, 1999) are also used in QUEST as well as in previous Danish research examining collaborative CPD (Nielsen, 2012b).

Teachers' meaning-making concerning students' annotated drawings

Annotated drawings have also been used to elicit *teachers'* understanding of science phenomena (McNair & Stein, 2001), also in the area of familiar astronomical events (Parker & Heywood, 1998). It has been discussed how teachers hold many of the same alternative conceptions as school students; working with and discussing annotated drawings themselves can help teachers understand the strengths and limitations of using drawings also to understand student beliefs (McNair & Stein, 2001). In the research literature teachers' practical knowledge is emphasized as action- and person-bound, often tacit, and as an integrated set of knowledge, conceptions, beliefs, and values (van Driel, Beijaard, & Verloop, 2001). Knowledge about eliciting students' alternative conceptions concerning a specific science topic is referred to as a part of such practical knowledge (van Driel et al., 2001).

Furthermore, the thorough research looking into teachers' inquiries using video-artefacts (Sherin & Han, 2004; Rosaen, Lundberg, Cooper, Fritzen, & Terpstra, 2008) can guide the use of annotated drawings as an artefact in teachers collaborative inquiries into students' conceptual understanding.

In relation to CPD van Driel et al. (2001) challenge common top-down approaches to CPD, seeing teachers as just "executing" the innovative ideas of others (e.g., researchers) and emphasize the importance of acknowledging teachers' typical incremental learning. This accentuates that evaluation of CPD should include a focus on participating teachers' meaning-making, in reference to *their* interpretation of experiences and construction of understanding individually and collaboratively (Edwards, 2001; Nielsen, 2012a). We need to know more about how teachers reflect on the use of annotated drawings, individually and collaboratively, and what new initiatives they consequently may take in their classrooms to consider possibilities and challenges related to student learning. Thus, the focus of this paper is on teachers' ability to infer meaning concerning students' understanding of the science content, as presented in their annotated drawings.

A sociocultural epistemological perspective

Understanding teacher learning as situated and mediated meaning-making, and seeing teacher agency as both an individual capacity to act and change, and as socially shaped and mediated by cultural tools and artefacts, anchors the project in sociocultural theory (Edwards, 2001; Lasky 2005; Wertsch, 1991). When seeking to understand also students' construction of understanding of the science content from this sociocultural epistemological perspective, classroom interactions with a dialogic approach to the science content must be seen as essential (Mortimer & Scott, 2003). The approach with pre- and post-assessment of students' annotated drawings referring to the authoritative correct scientific view may therefore be seen as rather instrumental. I will emphasize that this is by no means advocated as the only approach to including student drawings in science teaching. These can very well be a part of what Mortimer and Scott (2003) call an interactive dialogic communicative approach, where students' exploratory talk (Barnes, 2008), generating and sharing ideas, is mediated in the process of working on the drawings. The rationale is, however, that exactly this type of structured approach might be missing in the reform pedagogical Danish tradition, implying a need for *also* including such structured pre- and post-assessments to maintain the fruitful balance between autho-

ritative and dialogic discussions about the science content. The aim is to support student learning in science by supporting science teachers' understanding of how structured assessments can provide insight into students' beliefs about the science content. In the Danish context, policy change toward more testing in school and increased accountability pressures have been heavily discussed. Still, there is a need to realize that systematic analyses of student learning *can* be wider than the typical multiple-choice test.

The local context: the training model of QUEST

The data discussed here is, as previously noted, sourced from QUEST – a longitudinal CPD project running over four years from 2012–15. Project participants are science teachers from 43 schools, totalling 450 teachers from five Danish municipalities. One of the main objectives of QUEST is to acknowledge that successful CPD needs to balance top-down and bottom-up approaches. Thus, stimulating collaboration in professional learning communities (Lumpe, 2007; McLaughlin & Talbert, 2006), where the teachers conduct and share local inquiries by attending – and in between – QUEST seminars, has been a central part of the design (Nielsen et al., 2013). All QUEST activities follow a rhythm, alternating between seminar days and individual and collaborative inquiries at local schools. At the seminars, the teachers discuss research-based knowledge. More specifically, in the actual QUEST-module the focus in the first seminar days was on research into alternative conceptions in science. This was followed by a period for local inquiries. The actual task was (1) to try out in own classroom the methods to inquire into students' conceptual understanding discussed at the seminar, (2) to discuss the ideas and share with colleagues in the science team the artefacts collected, and (3) to bring the artefacts and experiences to the follow-up QUEST seminar to be shared in the network with teachers from other schools.

RESEARCH QUESTIONS

The research questions, referring to experiences of one science teacher teaching Science & Technology in a 4th grade class and participating in QUEST, are:

- What alternative conceptions concerning factors causing day and night, seasons, and the phases of the Moon are seen in the students' annotated drawings?
- What characterizes the teacher's meaning-making?
 - How does she reflect on the students' annotated drawings and what kinds of new enactments in the class does she refer to?
 - How does she share—and reflect on sharing—the inquiries with local colleagues, and with colleagues from other schools in the QUEST network?

METHODOLOGY

Sampling and data collection

Data to answer the first research question were derived from annotated drawings collected by a science teacher in a 4th grade class pre and post teaching about familiar astronomical events. Data to answer the second research question were (1) a semi-structured interview (Kvale & Brinkmann, 2009) with the teacher after conducting this classroom inquiry, (2) observation notes from a meeting in the local science team, where the teacher shared and discussed the artefacts with her colleagues, and (3) observation notes from the CPD-workshop, where the teacher shared and discussed the artefacts with colleagues from other schools. Supplemental data for this case-study included the teaching plan, tasks for the students, reading materials, web-resources, etc.

The case-teacher was picked using purposive sampling (Cohen, Manion, & Morrison, 2007). She was chosen based on her trying out the method of annotated drawings in her class. As part of the QUEST-rhythm she systematically collected *both* pre- and post-teaching drawings from a *full* class of students using the *same* template. The primary concern was to acquire in-depth information from a teacher

in a position to give it (Cohen et al., 2007); she was as she collected data suited for the systematic analysis. So the possibility to seek to understand those artefacts as part of this teacher's individual meaning-making and the collaboratively meaning-making in the professional learning community opened up. Quality assurance was about internal validity: seeking rich, in-depth knowledge from this single case using multiple data sources, investigator triangulation and informant feedback (Cohen et al., 2007). The case being representative was not the issue. I will, however, mention that several other teachers, around half of the participants, collected some kind of annotated drawings from their classrooms, while other participants collected artefacts from practice, such as videotapes of students discussing concept cartoons. The case-teacher in some way stood-out in relation to the systematic assessment suited for the present analysis, but other teachers were collecting pre- and post-teaching data by, for example, letting students add to pre-teaching drawings after teaching. Like most of the participating teachers the case-teacher was specialized in one science subject—Science & Technology (primary science). She did not have several science specializations, and did not act in the role as a resource teacher in the science team, as some QUEST participants do. Moreover, she was neither a novice nor among the most experienced in the local science team/the QUEST network.

For the inquiry, the case-teacher designed a template called “Draw and write”, with four questions for the students:

- A Why is it day and night on the Earth?
- B Why do the seasons change?
- C Why does the Moon not always look the same?
- D Try to draw how the Sun, the Earth, and the Moon move in relation to each other.

The teaching started with a full science day, followed by two lessons the week after. Most of the time, the students worked in groups, focusing on hands-on activities, including a tellurium and web-animations, for example. Whole class teaching was used for introductions, initiating discussions, and for summing up. One of the central tasks of the full science day was for the students to dramatize the movement of the Sun, Moon, and the Earth. The post-teaching drawings were collected some weeks after.

DATA ANALYSIS

The first research question

Drawings from 3 of the 23 students in the class were not used, as these students were absent either during pre or post data collection. The remaining 80 annotated drawings were sorted using categories roughly developed based on findings from previous research in alternative conceptions in the area of familiar astronomical events, which were subsequently refined based on the data. The categories were described in a codebook, and the drawings were coded independently by a fellow researcher. The inter-coder reliability was more than 85 % in the first coding, and after discussing cases of doubt full agreement was reached in the final coding.

While all students provided some kind of answer for all questions, some answers lacked meaning. Thus, responses such as “This I never thought about” or “I don’t remember” were coded as “no answer”. Some students did not explain the reason of the phenomena but what you see and experience, e.g. summer is warm and winter is cold. Such examples were coded as “what you see-not why”.

The researchers performed the categorization and coding, while the teachers’ analysis was more holistic (see below). The findings from the systematic analysis were shared and discussed with the teacher as a part of the interview. Although the initial aim was member-checking/informant feedback, this process was so informative that it became a part of the teacher’s meaning-making, as will be seen in the findings.

The second research question

The unit of analysis, when examining and representing meaning-making was the individual teacher's utterances; however, this analysis was supplemented by analysing observation notes, where the unit of analysis was people doing things together in a social setting (Lasky, 2005). The interview was analysed in two steps, first categorizing the teacher's utterances in five domains, according to a previous developed meaning-making model (Nielsen, 2012a), and then analysing utterances belonging to *more than one* domain, as either connected by the teacher's *reflection*, or by something she did or planned to do (*enactment*).

The five domains were:

- Domain of Practice: Something the teacher did/tried out in the classroom.
- Personal Domain: Something the teacher knew or thought about (knowledge, beliefs, attitudes).
- Domain of Consequence: Something the teacher perceived as salient, positive, or negative, i.e., outcomes.
- External Domain: Something the teacher experienced (via help from) outside the school, for example, during CPD.
- Domain of Collaboration: Something the teacher experienced, mediated by cooperation with colleagues.

This last Domain of Collaboration was in previous research added to the interconnected model of teachers' professional growth (Clarke & Hollingsworth, 2002), referring to sociocultural theory and the potential synergy between individual and collaborative reflections (Nielsen, 2012a). The interconnected model has been used in a range of research to represent teachers' reflections and enactments, i.e. when involved in CPD (Clarke & Hollingsworth, 2002; Witterholt, Goedhart, Suhre, & van Streun, 2012).

This analysis, seeking to understand the individual teacher's meaning-making as mediated by the interaction between the individual and the tools and structures of the social setting (Lasky, 2005), was supplemented by a condensation of observations from a local team meeting and a QUEST seminar, where the artefacts were discussed.

FINDINGS

The findings refer to the double focus of the 4th graders' understanding of the astronomical factors causing day and night, seasons, and the phases of the Moon, and the meaning-making of their teacher when looking into and sharing these artefacts with colleagues.

Students' understanding of familiar astronomical events

The results from analysing the annotated pre- and post-teaching drawings are presented in Table 1.

Table 1. Analysis of pre- and post-teaching drawings.

A: Day and night	Pre-teaching		Post-teaching	
	Number	%	Number	%
What you see-not why	5	25	0	0
The Sun orbiting the Earth (geocentric)	4	20	0	0
The Earth orbiting the Sun	5	25	2	10
The Earth spinning ("scientifically correct")	6	30	18	90

Table cont.

Table 1 cont.

B: Seasons	Pre-teaching		Post-teaching	
	Number	%	Number	%
No answer	8	40	1	5
What you see-not why	2	10	0	0
The Sun orbiting the Earth (geocentric)	1	5	0	0
The Earth spinning	3	15	0	0
Distance from the Earth to the Sun	3	15	1	5
The Earth out of the solar system	1	5	0	0
The Sun's spinning velocity	1	5	0	0
Shadow from the Moon	1	5	0	0
The Earth orbiting the Sun (no clear tilt)	0	0	10	50
Tilt of the Earth (not orbiting the Sun)	0	0	3	15
Both the tilt of the Earth and the Earth orbiting the Sun ("scientifically correct")	0	0	5	25
C: Phases of the Moon	Pre-teaching		Post-teaching	
	Number	%	Number	%
No answer	3	15	3	15
What you see-not why	4	20	0	0
Shadow from the Earth	5	25	16	80
Clouds covering	3	15	0	0
Listing multiple hypotheses: the Moon spinning, the Earth spinning, the Sun covering	2	10	0	0
Sunlight making it possible to see the Moon	3	15	1	5
What part of the - by the Sun enlightened - Moon, is seen from the Earth ("scientifically correct")	0	0	0	0
D: Movement of the Sun, Moon and Earth	Pre-teaching		Post-teaching	
	Number	%	Number	%
The Earth spinning, The Moon and the Sun static	6	30	0	0
The Sun moving around the Earth (geocentric)	4	20	0	0
The Earth moving around both the Sun and the Moon	1	5	0	0
The Moon orbiting the Earth, no moving of the Earth	1	5	0	0
The Earth orbiting the Sun, no Moon or no moving of the Moon	5	25	0	0
The Earth spinning, and orbiting the Sun – the Moon orbiting the Earth ("scientifically correct")	3	15	20	100

As evident from the data presented in Table 1, the teaching must be seen as rather efficient in most areas concerning challenging students' alternative conceptions. Before teaching four students provided geo-centric explanations, one of which is shown in Fig. 1, and five students referred to the orbit around the Sun when explaining the day and night. Prior to teaching, 30% of the students' explanations (as indicated by the pre-teaching drawings) could be seen as "scientifically correct", compared to 90% achieved in the post-teaching drawings. The geo-centric explanations were absent in the post-teaching drawings; however, two students still seemed to confuse the spinning of the Earth and the Earth orbiting the Sun. Several students explained what they see, instead of stating the reason behind their observation. For example, they noted that it is day when the light is on and it is night when it is dark. Moreover, many of the characteristics of children's thinking are emphasized by Driver (1989), and in a Danish context by Paludan (2000); for example, anthropocentric explanations, as seen in Fig. 1.

Figure 1. Pre-teaching drawing from a student using a geo-centric explanation, where the Sun and the Moon change places rotating around the Earth. The text says: "There is day and night at the Earth because people need the sunrays, but they also need to sleep and this they do at night." This explanation illustrates the typical anthropocentric character of children's alternative conceptions.

In relation to the seasons, 40% of the students referred to not thinking about this before. Among the rest, the pre-teaching drawings showed many very fanciful explanations. For example, one student wrote:

The seasons are changing when the Earth moves out of the solar system, then it is winter, and when the Earth returns into the solar system, it is summer.

The shadow from the Moon was also mentioned, and three students referred to the well known, and in some ways logical, explanation of varying distance between the Earth and the Sun. In the post-teaching drawings, five students specifically emphasized both the tilt of the axis and the Earth orbiting the Sun. Thirteen other students might also have understood this, but the drawings/writings focused only on one of the two. One student, however, kept on using the distance explanation.

The students' explanation of the phases of the Moon stands out as particularly interesting and versatile. The pre-teaching drawings showed a range of explanations, whereby 25% of the students confused the phases of the Moon with lunar eclipse. In the post-teaching drawings, 80% of the students made this mistake, indicating that a typical alternative conception related to the phases of the Moon was strengthened. In the interview, the teacher attributed this lack of progress to using more time on the other phenomena than on the phases of the Moon. She mentioned a website, where the students, according to her, tried an animation, but this site appears to have a dominant animation of a lunar

eclipse, which might have strengthened the students' alternative conception. However, given that the demands for abstract thinking required to fully understand the phases of the Moon are quite high, as a whole, this teaching can be seen as rather efficient.

Teacher's meaning-making: interpreting and sharing artefacts

The teacher's meaning-making is represented in Fig. 2. She emphasized that she designed the particular template, and collected pre- and post drawings, as a consequence of the task from QUEST. However, she added that she had always focused on eliciting students' pre-conceptions, mainly in full-class discussions. She was nonetheless rather surprised when looking into the pre-teaching drawings:

I have done this before (...) collaboratively (...) but when it is individual you can see what each student can (...) it is fun to see if the teaching works

We started at a lower level than I expected (...) not many knew about (...) the Sun the Moon and the Earth related to each other (...) I was surprised to find that many placed the Earth in the centre (...) Based on this, I knew where to start

She re-designed the teaching based on this insight and argued about using many types of modelling tools, such as tellurium and animations. Moreover, she emphasized that the students were supported to dramatize the movement of Earth, Sun, and Moon (Analysis 1 in Fig. 2).

In relation to the science team at the school, she briefly referred to the team-meeting. She mentioned presenting her classroom inquiry at the meeting, where some colleagues expressed that they found it interesting. However, as many issues had to be discussed at the meeting, her presentation only lasted around 10 minutes. When prompted, she elaborated further, stating that she did not remember getting input or ideas from colleagues related to her teaching. Moreover, she could not recall any collaborative generation of ideas about other ways to elicit student ideas (no arrow back to Domain of Practice or Personal Domain from Domain of Collaboration in Analysis 2, Fig. 2). She, however, referred to feeling supported in her belief that this was a good approach, and in particular, she positively emphasized that a colleague from 8th grade asked for the template to use in his class.

..they received it positively (...) said it was interesting (...) then you grow to be yourself more confident that this was an OK approach (...) and it was nice that one from 8th asked for the template

Looking forward, she would like to keep on sharing inquiries like this in the science team based on artefacts from this 8th grade class or other colleagues' practice.

Observation notes from the team meeting at the school verified that discussion of the artefacts was only a small part of a two-hour long and rather compressed meeting. The colleagues shortly discussed, in groups of two, the students' conceptual understanding based on the drawings, but they did not go into in-depth analysis. The colleagues' questions were more related to the teaching, than to student learning. For example, one asked a question about the use of the tellurium in primary science.

Observation notes from the later QUEST seminar revealed that more time was used on the drawings when sharing and discussing artefacts in a group with four colleagues from other schools who also brought artefacts from their classes. However, the group did not systematically categorize students' explanations. The analysis was more holistic, emphasizing particular distinctive examples, such as the quoted student referring to the Earth going in and out of the solar system. Still, the network-teachers also acknowledged the template and the pre- and post-approach. The case-teacher positively evaluated the QUEST-module in general, and referred to gaining insight to use in her own science

Students' annotated drawings as a mediating artefact

Figure 2. Meaning-making map representing the teacher's construction of understanding and interpretation of experiences – shown in steps. ANALYSIS 1 illustrates the teacher's reference to planning and re-designing the teaching. Reference to Domain of Collaboration is added in the representation ANALYSIS 2 (analysis 1 shaded). In the full meaning-making map, ANALYSIS 3, the teacher's reference to seeing a structured analysis is also added (analysis 1 and 2 shaded).

teaching. However, she did not refer to specific outcomes from this group discussion at the QUEST seminar. But when prompted, she did note that the group agreed that methods to elicit alternative conceptions are valuable and useful in practice.

When, during the interview, discussing the structured categorisation provided by the researchers (Table 1 above), the teacher found this interesting. She positively referred to gaining further insight, indicating the apparent efficacy of her own teaching in some areas, and exemplified both what the students learned and what they did not learn (Analysis 3 in Fig. 2). Furthermore, she focused specifically on issues challenging 4th graders cognitively, as for example the models, and how such considerations affected her planning of the teaching:

.. a “flat” model (...) it is difficult for some children to understand why there are suddenly four globes (...) so we used many different representations (...) also the tellurium

She reiterated that the phases of the Moon were not the main focus of her instruction, and identified this as an area where more time must be spent. However, she also reflected on the drama-experiences using the students’ own bodies as Sun, Moon, and Earth, as apparently supporting their learning. She argued about this, highlighting specific elements in the post-teaching drawings, which she believed were due to students’ eager discussions during the drama exercise. For example, when learning about the fact that the Moon is in synchronous rotation with Earth, always showing the same face, the student acting as the Moon had to look at the student acting as the Earth all the time. This clarified some distinctive elements at the post-teaching drawings for the researcher.

In general, in relation to using pre and post drawings, she talked about gaining much insight from a little effort. On the other hand, in relation to the structured analysis, she also stated that:

...comparing those two drawings, I mean, for each student, is a giant work, and the question is if you have time for this...as a teacher

In sum, the teacher seemed to be able to consolidate her knowledge (Personal Domain) based on discussing a systematic analysis of the results from her own pre- and post-assessment. She also meta-reflected on future use of such systematic analysis of assessment data, but taking into account barriers from everyday demands in her job as a teacher.

DISCUSSION AND CONCLUSIONS

In relation to the first research question about students’ alternative conceptions concerning familiar astronomical events, based on an overview of the findings presented above, the conclusion must be that the teacher’s experience-based practical knowledge helped her efficiently support student learning in most of the areas included in this rather short teaching session.

Moving to the second research question, it is not possible to conclude that the input from QUEST helped the teacher in her *first* planning of the teaching: the enactment arrow is *not* oriented from External Domain over Personal Domain to Domain of Practice, but the other way around. The new insight came *after* trying the method and experiencing salient outcomes — a valuable insight into students’ conceptual understanding. The importance of teachers being facilitated in trying new methods, rather than just being told about them, is in line with the findings of previous research (Clarke & Hollingsworth, 2002). Thus, while the planning was based on the teacher’s existing practical knowledge, the insight from being urged by the QUEST design to try out the new ideas in own classroom was helpful. It prompted her to thoroughly re-design her teaching based on her new and surprising insight into students’ conceptual understanding. Consequently, the teacher seemingly developed her knowledge base, situated in relation to how students in 4th grade think about familiar astronomical events.

Realising that top-down approaches to CPD seldom change anything in the long run, neither in the classroom nor in the collaborative culture, one of the main aims of the QUEST project is to support sustainability by focusing on teachers trying new tools and approaches, both in own classroom and as a collaborative endeavour to build strong learning communities over time (Nielsen et al, 2013). No final conclusions can yet be reached with respect to success in doing so as QUEST is still running. There *are* QUEST schools where not many changes in the collaborative culture can be seen so far. However, 75 % of the teachers currently report changes, e.g., team-meetings where student learning in science is discussed, rather than focusing on practical issues only; at some of those schools teachers are now collaboratively re-designing teaching based on research criteria from QUEST (Nielsen & Sil-lasen, 2013). The case school referred to here is, like most schools, somewhere in between those two poles. The ability to infer meaning of the teacher in this case-study illustrated that she gained new insight into student learning based on the inquiry in her own class. However, this does *not* imply that she gained much new insight from the collaborative discussions of artefacts, though her experience of her work being acknowledged by the colleagues might be an important driver looking forward. So - this is an example of an individual mastery enactment experience (Bandura, 1997), which can be quite important in relation to *this teacher* continuing to generatively develop own practice. However, it seems to be a pity that not more effort was put into collaborative analysis of the annotated drawings, as they provide wealth of information related to student learning. A systematic analysis of the drawings, and a collaborative generation of ideas about other ways to inquire into student learning, might have deepened the teacher's understanding of her students' learning even more. This is in particular true, given her ideas for future practice, and her ability to benefit from this opportunity to gain professionally in a *two-way process*, not just through presenting *to* the colleagues. It might be argued that the QUEST-teachers could have been better guided by the CPD facilitators, both in relation to framing the local team meeting and in analysing data systematically at the seminar. While this is not the main issue here, it should still be noted that considerations in relation to generative changes growing from keeping some locus of control by the teachers are among the reasons for not "controlling" the local inquiry in more detail.

The case-teacher's mastery enactment experience seemed to be further supported by seeing a systematic analysis indicating a significant gain in student understanding in many areas, as well as the students' lack of correct scientific understanding of the phases of the Moon.

An additional dimension of findings concerning teacher knowledge meeting researcher knowledge emerged from the interview, as it illustrated how those two kinds of knowledge and insight can be mutually supportive. The teacher held rich action-bound and contextualised knowledge, and explained in-depth specific elements on the drawings. On the other hand, she was also inspired by the systematic research-like analysis.

To sum up, the students evidently learned some science, and the teacher emphasized salient outcomes from applying and re-designing her teaching based on an approach she had learned during the CPD project QUEST. It seems as though she more fully understood the potential insight, which could be gained from her own inquiry-design, when seeing the systematic analysis. But she also pointed to barriers, indicating that such systematic analysis would be impractical for a teacher, as it is very time-consuming. The teacher shared artefacts from her classroom inquiry with colleagues at the school and in the network, and appeared to feel supported in her view of this approach being beneficial. She stated that this interest in her work is reflected in her colleagues asking for her template, for example. Overall, there are promising indications in relation to this teacher continuing the use of different types of systematic assessment of her students' conceptual understanding. However, in the data presented here, there are no indications that the sharing of these artefacts grew into a genuine collaborative inquiry contributing to the development of *collaborative agency* (Bandura, 1997). There seems to be some un-exploited possibilities for synergy between individual and social learning. Some time-delay must be expected, and the collaborative use of artefacts — such as students' annotated drawings

in the science team at this case school, and the potential spreading to colleagues from other schools – needs to be followed looking forward. This will facilitate gaining in-depth understanding of the potential of cultural tools, including annotated drawings, in relation to mediating *collaborative* agency.

LOOKING FORWARD

This case study emphasizes that systematic analysis of data from pre- and post-assessment is not a natural part of these Danish science teachers' practice, neither individually nor collaboratively. Based on what is known about teachers' typical incremental and evolutionary – not revolutionary – way of developing practice (van Driel et al., 2001), and given the everyday demands of the teaching profession, it is quite natural to grasp at quick ideas, when colleagues present. The practice – to try to cover a broad range of themes in a team meeting, instead of delving too deeply into only one aspect – also seems natural taking into account the everyday demands. Nonetheless, developing further tools and approaches to scaffold teachers' collaborative analyses of student learning is surely a focus area in QUEST looking forward. Returning to the findings presented, the method of using annotated drawings to inquire into students' conceptual understanding refers to "old" research findings from science education research. Nonetheless, this case-study imply that the discussion about how this can be a meaningful part of science teachers' individual and collaborative inquiries can still produce new insights related to how to frame CPD.

REFERENCES

- Andersson, B. (2008). *Att förstå skolans naturvetenskap – forskningsresultat och nya idéer*. Lund: Studentlitteratur.
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.
- Bannister, S. (1998). Concept maps and annotated drawings: a comparative study of two assessment tools. *Primary Science Review*, 51, 3-5.
- Barnes, D. (2008). Exploratory talk for learning. In N. Mercer and S. Hodgkinson (Eds.). *Exploring talk in school*, 1-16. London: SAGE.
- Baxter, J. (1989). Children's understanding of familiar astronomical events. *International Journal of Science Education*, 11(5), 502-513.
- Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, 33(8), 3-15.
- Borko, H.; Jacobs, J.; Eiteljorg, E.; & Pittman, M.E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, 24(2), 417-436.
- Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, 18, 948-967.
- Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. London: Routledge.
- Desimone, L. M. (2009). Improving impact studies of teachers professional development: Toward better conceptualizations and measures. *Educational Researcher*, 38, 181-199.
- Driver, R. (1989). Students' conceptions and the learning of science. *International Journal of Science Education*, 11(5), 481-490.
- Edwards, A. (2001). Researching pedagogy: a sociocultural agenda. *Pedagogy, Culture and Society*, 9(2), 161-186.
- Georghiades, P. (2004). Making pupils' conceptions of electricity more durable by means of situated metacognition. *International Journal of Science Education*, 26(1), 85-99.
- Jones, B.L., Lynch, P.P. & Reesink, C. (1987). Children's conceptions of Earth, Sun and Moon. *International Journal of Science Education*, 9(1), 43-53.
- Keogh, B. & Naylor, S. (1999). Concept cartoons, teaching and learning in science: an evaluation. *International Journal of Science Education*, 21 (4), 431-446.
- Kvale, S., & Brinkmann, S. (2009). *InterView* (2nd ed.). Copenhagen: Hans Reitzel.

- Lasky, S. (2005). A sociocultural approach to understanding teacher identity, agency and professional vulnerability in a context of secondary school reform. *Teaching and Teacher Education*, 21(8), 899-916.
- Loucks-Horsley, S. & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science: the state of the scene. *School Science and Mathematics*, 99(5), 258-271.
- Lumpe, A. (2007). Research-Based Professional Development: Teachers Engaged in Professional Learning Communities. *Journal of Science Teacher Education* 18(1), 125-128.
- McLaughlin, M. W. & Talbert, J. E. (2006). *Building school-based teacher learning communities—professional strategies to improve students' achievement*. New York: Teachers College Press.
- McNair, S. & Stein, M. (2001). Drawing on their understanding: using illustrations to invoke deeper thinking about plants. In P.A. Rubba, et al. (Eds). *Proceedings of the 2001 annual international conference of the association for the education of teachers in science* (pp. 1364-1375). Costa Mesa, California: Association for the Education of Teachers in Science.
- Mortimer, E.F. & Scott, P.H. (2003). *Meaning making in secondary science classrooms*. Maidenhead: Open University Press.
- Nielsen, B.L. (2012a). *Science teachers' meaning-making of teaching practice, collaboration and professional development*. PhD dissertation, retrieved April 2014, from Aarhus University, Centre for Science Education Web site: www.cse.au.dk/blnphd
- Nielsen, B.L. (2012b). Science teachers' meaning-making when involved in a school-based professional development project. *Journal of Science Teacher Education*, 23(6), 621-649.
- Nielsen, B.L., Pontoppidan, B., Sillasen, M., Mogensen, A., & Nielsen, K. (2013). QUEST - et storskalaprojekt til udvikling af naturfagsundervisning. *MONA*, 2013(2), 49-66.
- Nielsen, B.L. & Sillasen, M. (2013). *Science teachers' individual and social learning related to IBSE in a large-scale, long-term, collaborative TPD project*. Paper presented at ESERA September 2-7 2013, University of Cyprus, Nicosia, Cyprus.
- Paludan, K. (2000). *Videnskabens verden og vi – om naturvidenskab og hverdagstænkning*. Aarhus: Aarhus Universitetsforlag.
- Parker, J. & Heywood, D. (1998). The earth and beyond: developing primary teachers' understanding of astronomical events. *International Journal of Science Education*, 20(5), 503-520.
- Putman, R.T. & Borko, H. (2000). What do new views of knowledge and thinking has to say about research on teacher learning? *Educational Researcher*, 29(1), 4-15.
- Rosaen, C.L., Lundeberg, M., Cooper, M., Fritzen, A. & Terpstra, M. (2008). Noticing noticing – how does investigation of video records change how teachers reflect on their experiences? *Journal of Teacher Education*, 59(4), 347-360.
- Scott, P., Asoko, H., & Leach, J. (2007). Students conceptions and conceptual learning in science. In S. Abell & N. Lederman (Eds.). *Handbook of research on science education*. London: Lawrence Erlbaum Associates.
- Sherin, M.G. & Han, S.Y. (2004). Teacher learning in the context of a video club. *Teaching and Teacher Education*, 20(2), 163-83.
- Van Driel, J.H., Beijaard, D., & Verloop, N. (2001). Professional Development and Reform in Science Education: The Role of Teachers' Practical Knowledge. *Journal of Research in Science Teaching*, 38(2), 137-158.
- Van Driel, J.H., Meirink, J.A., van Veen, K., & Zwart, R.C. (2012). Current trends and missing links in studies on teacher professional development in science education: a review of design features and quality of research. *Studies in Science Education*, 48(2), 129-160.
- Wertsch, J.V. (1991). *Voices of the mind – a sociocultural approach to mediated action*. Hempstead: Harvester Wheatsheaf.
- Witterholt, M., Goedhart, M., Suhre, M. & van Streun, A. (2012). The interconnected model of professional growth as a means to assess the development of a mathematics teacher. *Teaching and Teacher education*, 28 (5), 661-674.