The historical and situated nature of design experiments – Implications for data analysis

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Abstract

This article is a methodological contribution to the use of design experiments in educational research. We will discuss the implications of a historical and situated interpretation to design experiments, the consequences this has for the analysis of the collected data and empirically based suggestions to improve the designs of the computer-based learning resources. This interpretation differs from that of the majority of other researchers who consider design experiments as fixed interventions. Our interpretation allows for an understanding of students’ learning trajectories as part of the school’s overall activities, which in turn has implications for suggestions regarding the improvement of computer-based learning resources. We develop argument in three different ways. First, we discuss our interpretation of design experiments and compare it with the dominant debate about design experiments as a methodological approach. Second, we discuss the implications this position has for interaction analysis methods. Finally, we empirically demonstrate this methodological implication by illustrating how vital it might be to consider data collected as part of design experiments as an element of a larger, established institutional setting characterized by inherent socio-cultural features. A conclusion that may be drawn from our situated interpretation of this design experiment is that, to improve students’ knowledge constructions, it is not enough – nor is it in principle possible – to perfect the design of the technology. We also need to improve institutional aspects on how schools support students’ knowledge constructions when using these technological tools, where the teacher’s role in this work is invaluable. A historical and situated interpretation of design experiments provides insight into how these improvements may be made.

Keywords

computer-based 3D models, design experiment, interaction analysis, science education, situated computer-supported collaborative learning, socio-cultural interpretations of knowledge constructions.

Introduction

This article aims to contribute to the understanding of design experiments. We will illustrate what implications a historical and situated approach has for the analysis of students’ knowledge constructions, and what kinds of empirically based suggestions such an approach can offer in regard to improving knowledge construction through the design of learning resources and the educational setting. We start out by giving a short review of the literature about design experiments as a methodological approach. We then draft in light of this review our interaction analysis approach. Finally, we give an empirical example gathered from one of our articles (Krange & Ludvigsen 2008) to illustrate the decisive role a situative interpretation might have in explaining students’ knowledge constructions, and in formulating design input for particular computer-supported learning resources.
Historical and situated aspects of the introduction of new technology in classroom settings have been an important theme in the research community working with computer-assisted instruction and learning (Cuban 2001; Arnseth & Ludvigsen 2006; Arnseth & Säljö 2007). However, this perspective is less explored in the literature about design experiments as a methodological approach. It is nonetheless worth mentioning a couple of issues that have been raised. Back in the late 1990s, Fjuk (1997) made an important observation based on empirical data from distance educational settings. Fjuk argued that contextual issues strongly influenced the learning situation in distributed computer-supported collaborative learning (CSCL) situations. Later, this argument was taken a step further when critiquing the CSCL research for not including institutional issues when data pointed to factors that obviously were unrelated to experiments themselves (Fjuk & Ludvigsen 2001). A conclusion drawn from these studies is that institutional factors are vital to include as a level of description when analysing students’ interactions in CSCL environments.

This problem is taken up from a design perspective by Ruthven et al. (2008), Rabardel (2003) and Rabardel and Bourmaud (2003), all of whom are concerned with a concept that they call ‘interpretive flexibility’, which aims to focus beyond the design of the technology to concentrate on how the technologies actually come into play during use. Engeström (2007) has raised a number of concerns about the mainstream interpretation of design experiments and the need to address the historical and open-ended character of educational change processes. In this article, we follow up both of these issues. Specifically, we intend to develop a methodological contribution to the understanding of design experiments by including institutional aspects of the school as curriculum deliverer, and to discuss how these issues come into play during students’ use of technology in knowledge construction settings. By the school as a curriculum deliverer, we refer to the fact that one of the school’s main aims is to ensure that their students actually solve problems that are defined as part of their syllabus.

Part one: a review of the design experiment literature

Using design experiments to study different educational settings has received increasing attention as it was introduced as an approach about 15 years ago (Brown 1992; Collins 1992). Ann Brown is the contributor most often referred to in discussions aiming to define the term ‘design experiments’. Her definition is ‘to engineer innovative educational environments and simultaneously conduct experimental studies of these innovations’ (Brown 1992, p. 141). She maintains that several interdependent aspects characterize classroom settings, such as teacher training, curriculum selection and testing, and that these must be considered as a whole operating system. How has this interpretation been employed in studies of students’ knowledge constructions and other educational issues in the years since Brown’s article was published?

While much has been written about design experiments as a methodological approach, there are surprisingly few examples in which design experiments are used analytically, with some exceptions (see e.g. Roth et al. 1999; Barab et al. 2002; Barron et al. 2002). Below, we first summarize contributions that have focused on design experiments as a methodological approach.

Design experiments as a methodological approach are discussed in three special issues of different highly esteemed journals: the Journal of the Learning Sciences (see e.g. Barab & Squire 2004; Collins et al. 2004), Educational Psychologist (see e.g. Hoadley 2004; Sandoval & Bell 2004; Tabak 2004) and Educational Researcher (see e.g. Cobb et al. 2003; Shavelson et al. 2003). All of these contributions share in slightly different ways Brown’s (1992) interpretation of design experiments, which we call a ‘mainstream interpretation’. This means that they take the individual as the unit of analysis when analysing learning processes and outcomes. We argue that this line of interpretation is similar to laboratory-orientated experiments, in that take, the context is taken into account without actually being included as part of the unit of analysis. The influential and strong tradition of laboratory experiments is thus replaced with one of design experiments.

These contributions are nonetheless important to the field, and have inspired our interpretation to a certain extent as well. We similarly argue for including a number of the same aspects endorsed by Brown, including classroom ethos, curriculum and technology. At the same time, when we consider these aspects more thoroughly, the differences between our interpretations become more evident. Specifically, while Brown
conceptualizes contextual features in terms of external inputs to the interaction, we regard them as relevant when, and if, they become visible in the students’ and their teachers’ interactions. In this sense, we consider them as an intrinsic part of the interactions. Some may argue that this description of the design experiment tradition is unfair because the aim of the research is to produce models and theories of innovation-based studies of artefacts and relevant contextual factors. However, we maintain that this methodological interpretation of design experiments has some obvious limitations, which are linked to two different conceptual orientations to the understanding of knowledge construction. While researchers in the mainstream tradition prioritize the individual as the unit of analysis based on a socio-cognitive analytical frame, we build on a socio-cultural unit of analysis. In the next paragraphs we elaborate on our methodological interpretation to design experiments as historical and situated.

According to our socio-cultural analytical frame, the unit of analysis is mediated action developed over time (Wertsch 1991; Säljö 2000; Valsiner & van der Veer 2000). This entails a different analysis of data than approaches used in studies of cognition in design experiments. While they attempt(s) to situate a research agenda in a classroom setting (Brown 1992, p. 152), we aim to situate our studies of students’ knowledge constructions into larger institutional settings. This means that, if necessary, we go beyond the borders of the design experiment, and include the longer historical lines of which this is a part. Moreover, in our study of students’ knowledge construction, the question of how and which part of the context should be included becomes, in a sense, irrelevant, in that we have built context into the premises of our unit of analysis. As we discuss further below, the contextual aspects – or mediational means – that are significant are those that become relevant in the students’ interactions. It is in these interactions that the interrelation between the different mediational means, and how these might change over time, becomes evident.

Importantly, what becomes relevant may not correspond with the aims of the particular design experiment. In other words, the learning design may be quite good, but if the larger institutional aspects mediate the students’ knowledge constructions, for example, in ways that are not productive, the students will unlikely manage to construct conceptual knowledge related to parts of a larger system. As a result, students’ knowledge will remain fragmented. Finally, although design experiment researchers are aware of context issues, and even discuss how to include these in the analysis, they have not, according to their own reports, figured out how to solve this: ‘Unfortunately, little is known about how to coordinate across these various levels [read contextual issues] or even how to specify the key variables interacting within and across levels’ (Sandoval & Bell 2004, p. 221).

Some adherents of Ann Brown’s interpretation of design experiments tend towards a rather idealistic view about what can be accomplished: ‘This approach of progressive refinement in design involves putting the first version of a design into the world to see how it works. Then, the design is constantly revised based on experience, until all the bugs are worked out’ (Collins et al. 2004, p. 18). This statement builds on an assumption about a final, controlled and complete version of a design, which can be controlled independently of the situation of which it becomes a part. As such, the longer historical lines of which the design experiment must be considered part are ignored. In line with Engeström (2007), we find these kinds of isolated, arranged design experiments rather problematic. Engeström (2007) claims that design experiments are far too intervention-oriented, with a focus on the intervention as such and excluding analysis of how these unfold in the situation and larger setting. He maintains that the design experiment ‘ignores what sociologists teach us about interventions as contested terrains, full of resistance, reinterpretation and surprise from the actors’ (p. 369).

The interventions in a design experiment, thus, should be seen as a set of mediational means, not as stimuli that fit a certain pre-defined outcome or criteria. As Engeström (2007) points out, this requires a new focus on how we understand agency in intervention.

Part two: a situated interpretation of interaction analysis

In line with most other design experiment researchers, we use interaction analysis as an analytical tool. However, our conviction in employing this kind of analysis is linked to our socio-cultural perspective, in which interactions are the primary source of data. This means that different mediational means are relevant to the extent of their presence in the students’ and their
teacher’s interactions. It is according to this mediational orientation that we differ from most other design experiment research. Interaction analysis has been characterized as an empirical investigation of the interaction of human beings with each other and with objects in their environment. It investigates human activities such as talk, non-verbal interaction, and the use of artifacts and technologies, identifying routine practices and problems and the resources for their solution (Jordan & Henderson 1995, p. 39).

This analytical approach encourages a focus on both verbal and non-verbal interactions, considering ‘action turns’ as a possible response to ‘verbal turns,’ and vice versa. Accordingly, both tools and signs are considered in terms of how they mediate students’ interactions in different, and sometimes intersecting, manners. Signs are here understood in line with Bakthin (1986), including social language and speech genres. In our studies of students’ knowledge constructions, then, highlighting how different means mediate interactions over time are of vital importance. The means include tools and this extended version of signs, which encompasses micro-genetic but also socio-genetic aspects. Interaction analysis also gives us the possibility of studying the intersection between these means, which are sometimes difficult to separate because they represent two sides of the same coin. The codon table (see Fig 1), based on deep conceptual knowledge (sign) and manifests in a concrete table (tool), is a useful illustration of this.

Interaction analysis as an interpretation tool is also characterized by another quality. Theories about knowledge constructions and actions must be founded in empirical data. Jordan and Henderson (1995, p. 65) argue that it is in ‘the temporal organization of the moment-to-moment, real-time interaction’ that this kind of data can be located. This is interesting because it opens up the study of both what happens in situ and how this is related to longer historical lines. In other words, it gives us the opportunity to consider the data collected in design experiments in relation to the situation of which they are part, and in which ways the technology comes into play (Rabardel 2003; Rabardel & Bourmaud 2003; Ruthven et al. 2008) when institutional aspects are taken into consideration. In the empirical illustration presented below, this is addressed through a focus on the school as a curriculum deliverer.

We follow students’ and teacher’s interactions moment to moment, in the sense of how these unfold in situ. In line with interaction analysis, we will argue that the best foundation for understanding the students’ knowledge constructions is provided by observation. This is a viewpoint that we share with other interaction analysts (Jordan & Henderson 1995; Säljö 2000), and which gives video recordings special status in interpretation processes.

Part three: an empirical example of a situated interpretation of design experiments – implications for analysis and further designs

In this section, we present an empirical example analysed and discussed in a previous article (Krane & Ludvigsen 2008) to illustrate our methodological interpretation of design experiments as situated. In this example, we look at how a particular CSCL technology designed to support science education came into play during students’ and their teacher’s interactions within the institutional setting of a secondary school. When starting to look into the data, it became obvious that the students, together with their teacher, had problems in constructing conceptual knowledge, that is, understanding how concepts are related and together constitute a
larger conceptual system, what Vygotsky calls a scientific concept (Vygotsky 1986). As a result, the students’ knowledge remains fragmented, although they worked out all the problems they were asked to solve in the design experiment. In the following, we present a selection of this data to exemplify the decisive role a situative interpretation had in our efforts to explain the limitations in the students’ and their teacher’s knowledge constructions. Furthermore, we describe how the analysis informs our suggestions to enhance the design of the particular learning resources under consideration. Before going into the data and the analysis, we briefly present the design experiment and the problems the students were asked to solve.

Design experiment

The empirical illustration is taken from a 4-week gene technology project at a Norwegian secondary school arranged at the beginning of 2002. Three groups of four ninth-grade students (14 years old) were asked to solve several biology problems, and each group was provided with a number of computer-based 3D models to use in their problem solving. These models were organized for distributed settings, and the students, together with their teacher, all represented by avatars, were connected in a local area network supplied with a telecommunication system that allowed them to verbally communicate during the entire session. The computer-based 3D models are used in conjunction with a website containing educational inscriptions to scaffold progress and support students in completing the problems. These inscriptions are specifically related to the knowledge domain, for example, presentations and explanations of the codon table (see Fig 1).

Solving problems with computer-based 3D models

In total, the students were asked to solve three main problems: sequencing an insulin gene, boiling an insulin-protein and performing a DNA analysis (Fig 2). We focus on the second of these to illustrate the decisive role that our situative interpretation to design experiments had in our effort to explain students’ knowledge constructions and why they had problems in developing these in a conceptual direction. Moreover, we employ these findings to identify some design issues for further elaboration of these particular computer-supported learning resources.

The problem, ‘build an insulin protein’, consisted of two main phases and was a follow-up to a problem that the students had solved the day before, ‘sequence the insulin gene.’ During the first period of building the insulin protein, the students constructed knowledge about how to use a codon table to read the DNA sequence of a gene (the insulin gene), find the corresponding amino acids and combine these into an insulin-protein. During the second stage, they used this knowledge to build a computer-based 3D model of the protein. This implies that the students, and their teacher, at least on a theoretical level, should have been capable of considering conceptual aspects of sequencing a DNA molecule and of building a protein in relation to that concept. To help the reader understand this rather complex subject matter, we need to explain the problem a bit further in order to make the data extract meaningful. We first explain more about the knowledge domain, and how it is presented on the website. We then describe the computer-based 3D model that the students employed in solving the last part of the problem.

The knowledge domain presented on the website

The students start by solving a problem given on the website. The problem was to find out whether a particular part of a DNA sequence, arranged in codons (see for example ATG, GTA, CCC), corresponded with a chain of amino acids below it (see for example Met, Val, Pro) (see Fig 1). These amino acids were parts of a specific protein, namely the insulin protein.
To be able to control this DNA sequence so that it can generate a chain of amino acids, the students needed to find out how to use a codon table (see Fig 1).

This knowledge was available on the website, which was particularly designed to support students' disciplinary problem solving. The actual procedure that the students were meant to follow was to start by identifying the first letter in the codon GTA. They would have found the letter G, which in the example was marked green in the middle of the circle, and then they could have traced the next letter T, which in the example was marked yellow in the next inmost circle, and an A, which in the example was marked pink in the third circle. This would imply that they could identify the amino acid Val, which in the example was marked blue. The identification of all other amino acids follows the same procedure.

The computer-based 3D models – the storyline and building of a protein
The activities in the computer-based 3D learning environment were linked together by a storyline. The students and their teacher met in a 3D model of a research laboratory (see Fig 3).

Immediately, they found a professor lying on the floor in a state of hypoglycaemia. A medicine shelf was open, and all the potions of insulin-protein were destroyed. The teacher told the students that they were going to help the professor recover, but before they could do so, they had to solve some problems related to making insulin. Figure 3 shows the laboratory just after the students had made the insulin. The hypodermic image means that the standing student can now give the professor an injection.

When the students made insulin, they entered a different part of the computer-based 3D learning environment, at the molecular level of the cells (see Fig 4). Here, the students picked up fluid amino acids (for example ‘Gly’, or ‘Ser’) and placed these like pearls in a chain. A flickering ball marked where they were to put the acids. On the website, a long sequence of codons was presented, and in order to identify the corresponding amino acids, the students had to use the codon table. They then had to enter the computer-based 3D model, use their avatars to pick up these acids (e.g. the figure in the middle of the picture) and place them at the end of the chain.

It is important to note that both of the computer-based 3D models were objects that the students and their teacher shared. They could see each other while moving their avatars around and when manipulating the amino acids. They could hear each other while talking through a telecommunication system about what they were doing, and partly, what it meant. This was also the case with the website.

Data presentation
The problems the students were asked to work out were all solved through the combined use of website and

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computer-based 3D models. We have recorded video data of all the interactions that took place during this problem solving. In addition, we have video data from a face-to-face debriefing session arranged immediately after the problems were solved. It is this latter set of data that have been used in this article. The debriefing sessions were arranged as part of the educational setting and were used to study what problems the students and their teacher saw as relevant during the problem solving, in contrast to post-problem-solving phases.

We have chosen to focus on the debriefing session because the interactions that took place made an obvious change in terms of what the students in one of the groups were allowed to talk about during and after their problem-solving trajectory. During the problem solving, which lasted 53 min, one of the students asked 12 times what their activities actually meant conceptually. This question was never really acknowledged or answered, neither by the other students nor by the teacher. This points to the importance of including institutional aspects into analyses of data collected in design experiments both in order to understand the phenomenon under investigation, and to construct principles for designs of computer-supported learning environments.

The level of detail in the transcripts aims to suit the depth of the analyses, and to create a high level of transparency so readers can easily follow the talk and the interactions (Mercer 1991). The students interacted in Norwegian, and the transcripts have been translated into English by the authors. All the names are pseudonyms.

Analysis of the debriefing session – discussing conceptual issues

Researchers have focused on the distinction between procedural and conceptual problem solving in science and mathematics from different theoretical positions on knowledge construction (Lemke 1990; Roschelle 1992; Vosniadou 1999, 2007; De Jong & van Joolingen 1998; Kumpulainen & Wray 2004; Linn 2004; Moss & Beatty 2006; Mason 2007; Krange & Ludvigsen 2008; Krange 2008). One of the most robust findings across these different perspectives is that the articulation of conceptual issues is demanding for students (Jiménez-Aleixandre et al. 2000; De Jong 2006; Lehrer & Schauble 2006; Anderson 2007). There are different explanations for this finding, but it provides a basis for claiming that one of the most central challenges for the design of learning environments in science is to make scaffolds that support students’ conceptual knowledge constructions. In our study, it was evident that students’ knowledge constructions in science had the potential to expand procedurally oriented knowledge and become conceptually oriented only after the students had worked out the problems they were asked to solve. Students who were procedurally oriented dealt with a range of concepts, but they did not consider how these were related to larger conceptual systems. Interestingly, they could often ‘solve the problem’ even though they had a limited conceptual understanding of the actual biological process. This meant that only those students who, over time, could combine procedural and conceptual knowledge, and connect concepts to systematic relationships, would appropriate the scientific discourse in a knowledge domain.

Language is considered the tool of tools within the socio-cultural perspective on learning (Vygotsky 1978; Säljö 2000), and forms the basis of our study on how students approach curriculum-based problems as a cultural phenomenon. In addition, different kinds of tools emerge to play a central role in the analysis. These are institutional features, the knowledge domain and aspects of the CSCL environments. The interconnection between these tools can be characterized as tensions or interdependent reinforced tendencies, in the sense that these lead the interactions in certain directions. The students need to perform gap-closing (Lave 1988), in the sense of carrying out actions that aim to maintain a minimum of social order. This means that they need to find a shared focus, and the relationship between tools becomes tensional, an interconnected reinforced tendency. Moreover, the different tools have what we could call meaning potential. The linguistic meaning is an open potential, and there are non-fixed codes of meaning. Words and sentences are essentially characterized by ‘vagueness, ambiguity and incompleteness’ (Rommetveit 1984, p. 335). The meaning is only partly in the mind because it is always created in interaction with the cultural and historical settings as backgrounds. The meaning potential must be realized through actions (Rommetveit 1984; Linell 1998), and the potential is thus not necessarily identical to the meaning making taking place in situ.

The analysis aims to illustrate how a situated interpretation of design experiments opens up the analysis and explanation of students’ knowledge constructions.
in science, beyond the computer-based 3D models, the website designed to support knowledge construction, and the knowledge domain. ‘Beyond’ includes institutional aspects, and, in particular, what we have called ‘the school as curriculum deliverer’. As we discuss below, this means that the school seems to have a particular responsibility to ensure that students actually solve problems that are pre-defined in the syllabus, while the quality of their knowledge constructions seems to be of less importance. In this empirical example, gathered from the debriefing session, we study how the students for the very first time, if not answered, at least acknowledged the question that one of the students repeatedly raised during the problem-solving activity, namely, the question of what their activities actually meant conceptually. We enter the data at the very beginning of the face-to-face debriefing session, and the teacher had just asked Cornelia if she understood the use of the ‘ring’ [codon table].

**Extract 1: partly listening to Cornelia’s question**

1. Cornelia: I understood that we were going to build bricks and so on or build upwards. *Cornelia is referring to the computer-based 3D model.* I understood that and looking for all of these [amino acids]. I did not understand what insulin is or a protein is . . . what a, why should we find these GTA and then it becomes Met and so on? That . . . I understood why we did that, but not why or what it means and so on.
2. Pat: No, neither did I.
3. Cornelia: And then I didn’t think that there was any point to build that thing when one doesn’t understand anything. *Cornelia is referring to the computer-based 3D model.*
4. Mark: I don’t understand anything.
5. Fredric: Understand what?
6. Mark: Well, what, what, what is it supposed to be good for?
7. Fredric: What it is good for? You should help that guy! Because he *Fredric is referring to the storyline.*
8. Mark: Why is it like that? Yes, why is it like that, exactly? I will never understand that. Why is it like that?
9. Pat: There should have been some links where it stood, you know, what you should do or what the different things meant.
10. Teacher: Mmm
11. Pat: So that you understood it better.
12. Fredric: Isn’t it just like that, you know.

There is only one main theme in Extract 1. The students have already solved the problem as it was formulated on the website, and the knowledge domain is therefore the only issue in question. Instead, the students put forth a more conceptually oriented focus. We claim that they step out of what they have learned to identify as relevant framing for curriculum-based problem solving in schools (Mäkitalo *et al.*, in press). This means that they are not as restricted by the resources (how to handle a curriculum-based disciplinary problem) they have brought from one educational setting over to this situation. Rather, it finally gives them the space to listen to what Cornelia has questioned throughout the whole problem-solving process in the CSCL environment (utterances 1–8). This means that at least Pat and Mark are willing to follow Cornelia’s effort to step out of the situation, by trying to understand what these concepts represent, and what these mean in relation to each other. All three acknowledge that they have not really understood how different knowledge elements are related, and how these are part of a larger whole, while Fredric never admits this lack of insight. The teacher’s knowledge at this deeper level looks more uncertain. In sum, this means that the gap-closing concerning what they find relevant to talk about is renegotiated and has expanded compared with the interactions the students and their teacher had during problem solving (Lave 1988). The knowledge domain mediates the students’ and the teacher’s interactions in this debriefing situation. Different scientific concepts like the protein, GTA and so on are used as common reference points, and the students take positions on whether they have understood what Cornelia has questioned or not (utterances 2, 4, 6, 8). Now that the problem has been solved, Pat and Mark seem to recognize and comprehend what Cornelia has struggled to understand. However, they do not manage to clarify the relationship between the scientific concepts, and the teacher does not intervene to address this problem either. What we do see is a change in their gap-closing concerning what they find relevant in relation to the knowledge domain (Lave 1988). They are about to understand Cornelia’s curiosity about the relationship between the scientific concepts. Although they finally make a shared understanding of the problem area, they do not formulate an answer to it. This shows that the
students, in some sense, realize that there is more unused meaning potential inscribed both in the computer tools and in the knowledge domain than they managed to realize in action (Rommetveit 1984; Linell 1998).

Furthermore, the computer tools are mediating the students’ interactions even though they have stepped out of the particular CSCL setting and are located face to face. This is partly made evident by how Cornelia refers to the ‘building bricks’ and ‘build upwards’ while trying to explain what she has found confusing (utterance 1), but it is most obvious in the way Fredric refers to the storyline while giving an explanation for why they built the insulin: ‘You should help the guy!’ (utterance 7). Moreover, when Mark follows up his own question, ‘Why is it like that, exactly?’, Fredric does not seem to bother about the underlying scientific issues of what they have done. His actions have been at a procedural and storyline level throughout the whole problem-solving process, and he says, ‘Isn’t it just like that, you know?’ (utterance 12). We claim that this narrative element, which is so characteristic for these kinds of computer-based 3D models, actually, at least to some degree, brings with it certain taxations (Wertsch 1998) by de-emphasizing the students’ focus on conceptual issues and on how scientific concepts relate into larger systems (Vygotsky 1986).

To sum up, while the students are solving the problem, this activity is the main problem to pursue, but when leaving the problem-solving mode, they spend time discussing the knowledge at a deeper level. In our data, the school as curriculum deliverer partly hindered rather than stimulated the students’ knowledge constructions in science, at least in relation to the meaning potential that was inscribed in the knowledge domain, and which could have unfolded in action (Rommetveit 1984; Linell 1998). Note how the narrative takes Fredric’s attention away from the knowledge domain, and the problem he pursues becomes how to help the professor. There is a clear tension between the knowledge domain and the storyline. In this case, this tension is represented through different voices in the students’ interactions (Ludvigsen, in press).

We argue that further designs of this CSCL tools, and especially the educational inscriptions on the website, need to reduce tensions between how schools deal with curriculum-based problems and students’ possibilities of knowledge constructions of scientific concepts. At the same time, it is vitally important that the teacher follows up on these inscriptions and the school’s dealing with curriculum-based problems. First, then, there is a potential to raise the students’ knowledge from a procedural to a conceptual-orientation when working with disciplinary problems.

Conclusion

In this article, we have argued and empirically illustrated the importance of considering design experiments, at least on some occasions, as historical and situated. The implication is that this approach allows insights into both how students can work under certain conditions, and into the historical and institutional tensions involved in transforming schools. These conditions are crucial and vital for students’ orientations to learning difficult concepts and conceptual systems in science as a knowledge domain (Furberg & Ludvigsen 2008; Krange & Ludvigsen 2008). These orientations are part of a long-term trajectory for the students and the teachers. When de-emphasizing how learning is socially organized, there is a problem in developing an understanding of how cognitive and social aspects of learning scientific concepts are interwoven.

The theoretical and methodological critique of how we conceptualize and interpret design experiments emphasizes that we must pay attention to the resources that students can draw on and use, as well as the immediate interventions implemented by the researchers or teachers. Our perspective is that a socio-cultural perspective is vital to improve both the design of knowledge-oriented CSCL environments, and the practical arrangements of their use in educational settings. We have illustrated that it is necessary not only to improve CSCL environments but also to advance and change students’ and teachers’ historical understanding of curriculum-based problems, so that students might make the best possible use of the meaning potential inscribed in the computer tools. This could, for example, include ground rules for communication (see e.g. Mercer & Wegerif 1999).

This entails looking beyond interventions in terms of design experiments to inquire, for example, into how schools deal with curriculum-based problems. The finding presented in this article is unique in that it is explicitly formulated, but similar arguments have been made more generally. As already mentioned, De Jong (2006), for example, claims that students quite often

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have problems dealing with abstract conceptual problems in science, even if the design is supposed to scaffold a conceptual orientation. Therefore, the question is how far we can take this design argument because social and cognitive aspects will always play a major role. Since both the knowledge domain and the computer-based 3D model tend to be procedurally oriented in the 3D environment discussed in this article, it is important that the future design of tasks and scaffolding devices can promote a more conceptual orientation with regard to the educational inscriptions on the website, and a more systematic orientation with regard to how the teacher triggers this kind of curriculum-based knowledge. As an example, this could be as simple as interventions where the teacher actually explains the relationship between the concepts and, in this sense, helps students to develop their own use of scientific concepts (Engle & Conant 2002; Krange 2007). Our view is that we can design environments in the direction described, but that without an advanced social design, the tools’ meaning potential will not be realized. This means that the design of learning environments can be considered in terms of optimizing opportunities for productive knowledge construction, through the careful design of tasks and their sequencing, scaffolds, teachers’ interventions, and by cultivating norms for talk in the classroom. At the same time, we point to problems in designs concerned with predicting learning outcomes based on pre-defined concepts and taking the open-endedness of social interaction out of the ‘equation’.

In order to develop an understanding of the design experiment in classroom settings, or other types of settings, we recommend opening for interpretation how historical aspects are played out in situ, which will contribute to crafting design experiments as a more interesting research tool, and in the long term, as more useful and productive for educational change. The models developed will become more robust and realistic.

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