Learning Conversation in Mathematics Practice – school-industry partnerships as arena for teacher education

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Abstract

On-going research from the research project Learning Conversation in Mathematics Practice *is reported. The paper gives an overview of issues within this project that relate to the EIMI-study. School-industry partnerships enable the study of pupils and student teachers participating in an educational setting which includes an industrial environment. Two examples are given. The first example illustrates how an assignment made possible by the industrial context influences the intentionality, functionality and empowerment of pupils and student teachers. The second example is concerned with mathematical modelling in this context, especially with regard to the development of critical democratic competence.*

The on-going research project *Learning Conversation in Mathematics Practice* (LCMP)[1] focuses on communication and learning in the field of mathematics. Its goal is to develop the notion of learning conversation as a didactical concept and tool for describing and facilitating learning processes. The project collects research data from schools that have established partnerships with industrial[2] companies. An aim of these partnerships is for pupils[3] to learn mathematics through experiencing and discussing how mathematics is applied and used at work. This paper gives two examples of research areas within the LCMP-project

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[1] LCMP is financed by the Research Council of Norway (NFR) and Bergen University College. LCMP is part of the research consortium *Teaching Better Mathematics*, which also consists of mathematics educators from University of Agder, Bodø University College, Oslo University College and Sør-Trøndelag University College. LCMP is lead by Marit Johnsen-Høines. Webpage (in Norwegian): Læringssamtalen i matematikkfagets praksis (LIMP), http://www.hib.no/fou/limp/.
[2] Industry is in this paper broadly interpreted to include different types of workplaces where mathematics is used. Different types of companies participate, varying from oil related mechanic industry to shops.
[3] In this paper, children in school are referred to as pupils and student teachers as students.

that are made possible or enhanced by the school-industry partnerships. These examples are connected with several of the themes outlined in the Discussion Document of the EIMI-study, including teacher training, examples of practice, modelling and issues related to communication and collaboration. How the school-industry contexts influence students will be a main theme. We want to elaborate on the research context and the questions and discussions that are potential as part of the LCMP-project. We do not aim to give answers to these questions in this paper or at this stage.

A school development initiative "*Real-life Education*"[4] enables the LCMP-project to study industry as part of the learning environment of pupils and students. In this development initiative lower-secondary schools have established school-industry partnership agreements. This agreement entails that the learning and teaching of mathematics is organised sequentially in industrial and school environments. Students from Bergen University College participate in the "Real-life Education"-initiative through their practice teaching[5]. The experiences gained, by both pupils and students, through the "Real-life Education"-initiative are conjectured to impact their attitude towards mathematics and the way mathematics is communicated. The LCMP-project collects and analyses data from three different layers[6] (Johnsen-Høines, in print):

- the school development initiative, where the research focus is on pupils' ability to communicate and learn mathematics
- the professional development of student teachers engaging in the school development initiative, where the research focus is on the students' communication related to their professional development as mathematics teachers
- the collaboration between didacticians, schoolteachers and students, where the research focus is on the communicative learning processes that develop between members of the learning community

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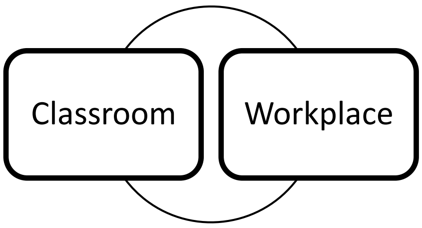
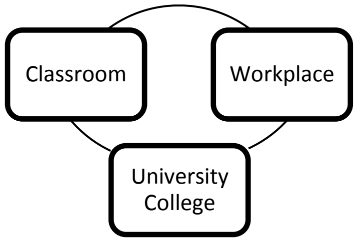
[4] In Norwegian: *praksisnær undervisning*. The initiative is administrated by Gode Sirklar AS (http://www.godesirklar.no/).

[5] I. e. practicum (student teaching), which is an integrated part of their study in mathematics/mathematics education.

[6] Empirical data is collected from teaching and learning sequences in the mathematics classroom and in pre- and post-classroom discussions. Conversations in which mathematical and didactical issues are discussed are recorded and transcribed. The data collected from teaching and learning sequences and from the collaborative communications in which students, teachers and didacticians participate are analyzed. Students and teachers take part in discussing some of these analyses.

Central to the project is the passage between different spaces of learning. This can be illustrated by learning loops that depict different contexts where pupils and students participate (Johnsen-Høines, 2009). Pupils and students participate in the different practices and move between them. The learning this involves is an object of study in the project (cf. Lave (1999) and Dreier (1999), who argue that learning is development through participating in and between different practices).





Learning loop – pupils   Learning loop – students

We investigate what kind of meta-learning the pupils' learning loop facilitates. We envision that pupils and students can develop a meta-reflection where the differences between mathematics at a workplace and in the classroom are problematised and reflected on. For example, the tools used by the company for solving mathematical problems (e.g. different technological tools) can be in tension with the school's intentions of what should be learned and how. In other cases can different use of language and tools be an enriching source for new learning. It is of interest to study how the pupils' knowledge about the company and the company's praxis characterize the conversation on mathematical topics and how the pupils' experiences from school mathematics influence their conversation when visiting the company.

The intentionality inherent in learning and teaching is influenced by the resources of intention available. The workplace context makes resources of intention available that are not necessarily available in the school context. Alrø & Skovsmose (2004, 154-163) considers intention as basic to participation in a dialogue. As such, the workplace context may enable involvement in dialogues for which the school context, for some pupils, does not give the necessary resources of intention. The *intentions-in-learning* and *intentions-in-teaching* of students having their practice teaching connected to a school-industry partnership can also be influenced in a likewise manner. In the first example it is shown how the context influences the intentions-in-teaching of a task given by students to pupils.

The *functionality* of knowledge is essential for its use and application. Our consideration of the "functionality of knowledge" is inspired by Mellin-Olsen (1989) and Skovsmose (1994). The contexts given by the school-industry partnerships enable a widening of pupils and students functional understanding.[7] Experiencing mathematics functioning in the industry context will hopefully develop their understanding and view of specific mathematical topics, as well as of mathematics as a whole.

Example – workplace assignment

The group of four students, a school teacher and a didactician are preparing for the next teaching period. The school had a partnership agreement with a company producing valves for the oil industry. The students decided on statistics to be the mathematical focus for the pupils. As the students anticipated the necessity of the pupils having some rudimentary knowledge of statistics before they met the people at the company, the students developed a short module containing what they considered to be the most fundamental statistical concepts. However, they did not succeed as desired, and commented that "the pupils did not get engaged, they did not show interest in the learning even though they were told that these concepts would be helpful when working in contact with the industry". The discussion that followed made it clear that the students wanted the pupils to "work on issues they saw as important"; they wanted them "to experience knowledge as useful and necessary"; they wanted to organize the activities in a way that "stimulated the pupils' independence and motivation". These discussions are to be seen as a background when the students decided to challenge the company leaders to request the pupils to carry out an assignment. "*The pupils should be requested to do a job that the company really needs done,"* the students said.

The director welcomed the pupils to their first visit at the company by saying: "Statistics is the Alpha and Omega for us, we can just close down if we buy too little metal of the different sorts needed for producing the valves that are ordered or are expected to be ordered. We must have an overview of our production and stock. […] We have expanded so fast and we really have not developed good

[7] De Villiers (1994) defines functional understanding as "the role, function or value of a specific mathematical concept or of a particular process".

enough systems." The manager addressed one group of pupils by saying: "We want you to help us!"[8] He gave them a register of unsorted orders.[9]

The pupils worked on this assignment in the classroom. The register seemed cryptic and chaotic for the pupils as well as for the students (and for the teacher and the didacticians). The pupils needed to understand the codes used for labelling different metals and products (i.e. valves) made, and contacted the company several times in order to get more information. Additionally, tools for sorting were needed. The students were used as experts when the pupils learned to use Excel to sort. The pupils made new registers that gave a better overview of the register.

The student teachers decided that the pupils were to be viewed as a "consultancy firm"[10]. The pupils should ask for information when this was needed, they should present the results when the work was done, and they should challenge the company to discuss consequences if they saw any. The company cooperated on these ideas, as can be seen by them informing the pupils that they would pay for the job – if it was well done. The pupils invited people from the company to a meeting at the school, and presented their result. They told that they had experienced the importance of accuracy, and gave examples of choices they had made in order to obtain an overview they predicted to be sufficient. They discussed the result, and addressed the company by asking critical questions. The presentation and discussion was seen as important in a pre-perspective: The fact that this was part of the task given gave motivation for and direction to the work. However, it also turned out to be evident that the presentation-session became important for the pupils' and the students' subsequent learning. It became a stage to look back at and make reference to, as well as for bringing about reflections for later work. "What have we learnt" became a meaningful utterance to inquire into.

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[8] The director's voice acts here as reference for the pupils on the given tasks. The pupils may interpret the challenge given as referring to statistics as important knowledge and an industrial tool, as referring to the importance of this specific job being done and that the director believes that the pupils are capable to do it, and/or as referring to the importance of being done diligently. The director's approach can be seen as influencing the intentions-in-learning and intentions-in-teaching by the way it puts the tasks into the discussion on necessity and functionality

[9] Different groups of pupils got different challenges. Each student teacher collaborated mainly with one group.

[10] The students defining the consultancy firm role can be seen in the context of note 8, referring to functionality and meaningfulness, and is connected to the students' discussions about ownership and empowerment of pupils using mathematics (intention-in-teaching).

The teaching and learning sequences referred to above illustrate the context in which the LCMP research is situated, and it gives the background to briefly consider some themes of research interest connected with this example. In this paper we restrict ourselves to pointing out a few themes that we have found significant in the chosen example: intentionality, functionality, and empowerment (Mündigkeit). The conversations in the initial module on statistics that was given to the pupils appeared to be very different from those in the further continuation. A central issue for the group to inquire into is then: How can the communication be characterized in these situations, and how do the differences emerge? Further discussions deal with investigating the conditions: What influences the conversations and the learning, what are conditions for developing different sorts of communication in the context of learning?

Intentionality. By studying the learning/teaching sequences and the collaborative communications within the LCMP-group the intentions-in-teaching of the students become evident. They want to[11] organize for the pupils to be enthusiastic learners; they want the pupils to work on issues that they see as "real" and important; they want the pupils to experience mathematics as essential knowledge; they want the pupils to be independent and to see the importance of accuracy. The intentions of the students developed during the process. This development can partly be seen as interplay with the intentions of the manager, the pupils, the teacher and the researcher. The way we are analyzing students' intention here, it can be characterized as intentions-in-teaching. But we find that the students are describing their intentions as intentions-in-learning as well. They see themselves as learners, of this being part of their professionalization as mathematics teachers.

Functionality. The students have inquired into "functionality of knowledge" as part of their study in mathematics education. The discussions in practice challenge the concept of functionality from different angles. The participants are questioning why and how statistics (and also tools such as Excel) is vital as a tool for the industry and for the students' and the pupils' learning of mathematics. The functionality of theories and didactical models is also discussed in the context of developing the teaching-and-learning sequences, as part of the students' professionalization as mathematics teachers.

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[11] Our interpretation "they want to" is based on transcripts from conversations where the students, together with other group members, are inquiring into what they want to try out in their teaching practice and their rationality for making their choices.

Empowerment (Mündigkeit). *Communication* underpins the project; it defines the research focus and is seen as a tool for developing the collaboration and the teaching and learning interactions. Referring to "inquiry co-operation", as developed by Alrø & Skovsmose (2004), it is vital that participants see contributions by themselves and others as important for the community. Thus it becomes relevant to organize for and study the students' development as independent, responsible and collaborative partners. The development of the pupils' empowerment as collaborative learners is seen as important as well, and this is articulated as one of the students' main interests. The collaborative inquiries focused on the empowerment of pupils and of students in the light of one another. The data includes such meta-conversations.

Example – mathematical modelling

Another theme we study is how mathematical modelling can be integrated into education, both in primary schools and in teacher education. Of special interest is to study how students and pupils develop *critical democratic competence* [12] in interactions with such models.

Mathematical modelling is a theme for the students in their course work at the university college. Together with students we have tried to include mathematical modelling in the learning loop of the pupils. This also makes mathematical modelling a theme for the students throughout their own learning loop. Questions regarding mathematical modelling are discussed in the LCMP-group consisting of students, school teacher and didacticians.

A group of students have included semi-authentic models[13] as part of their practice teaching (Hansen, 2009). After a study of different mathematical models at the university college, the students decided to let the pupils in the classroom work with trend diagrams and regression to predict company turnover.[14] Two different models were used. These models gave different predictions. This leads to questions about validity and uncertainty; and reflections about how the results given by a particular model may depend on various input-data. We regard students' and pupils' abilities to raise such

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[12] The term 'critical democratic competence' is used here in relation to mathematics and refers to peoples' ability to remain critical, considering and analyzing according to use of and results from mathematics in society (Blomhøj, 1992, 2003; Skovsmose, 1994).

[13] By 'authentic model' we mean a model used in real world applications (i.e. enterprise planning of income, oil recovery, climate forecasts etc.). The word 'semi-authentic model' refers to a simplified model compared to daily life industrial models.

[14] This illustrates how the students move in and between different practices in the learning loop.

questions as important parts of their critical democratic competence. For such questions to arise we believe that some models and pedagogical initiatives could be more appropriate than others. By analysing conversations in the classroom and between didacticians, teachers and students we hope to get further insight into such issues. This is related to the following research questions:

- How can industrial mathematical models be made relevant for pupils' learning?
- How can some models be more appropriate than others for development of critical democratic competence in the field of mathematics?
- How necessary is the use of authentic models to achieve insight into modelling, and thus to the development of critical democratic competence?
- What criteria do we use when we discuss fruitful ways of working with models?
- Assuming that working with mathematical models increases pupils' critical democratic competence in mathematics, how does classroom communication reflect such skill development?

Our belief regarding the first question is that not all models used for industrial purposes are well-suited for classroom use. Authentic mathematical models often hide complex mathematical structures and advanced technology which excludes many models (cf. the notion of "black box"). For use in primary education these authentic models usually need to be simplified, which leads to the use of semi-authentic models. Thus it becomes pertinent to investigate how pupils and students in different learning situations can work with semi-authentic models connected to topics in the school curriculum (e.g. concepts such as functions, equations and linearity). Part of this will focus on how classroom communication may reveal different stages in pupils' development of critical democratic competence.

Final remarks

In this paper we have included examples where students participate, but the focus is also on the pupils' conversations and learning.[15] What characterizes the pupils' mathematical conversations as they move between classroom and

[15] Parts of the LCMP-project are primarily interested in the pupils (this is the first layer described on page 2). A PhD-student, Toril Eskeland Rangnes, is working on pupils mathematical conversations as they participate in the learning loop, with particular emphasis on mathematical literacy. The questions raised in this paragraph will be part of her study.

company? Studying pupils’ mathematical conversations at the workplace and in the classroom linked to pupils' readiness to apply mathematics in new contexts is believed to give new knowledge about pupils’ learning through conversation. We investigate whether the inclusion of outside-school mathematics in mathematics teaching facilitate pupils’ participation in problem solving, communication of ideas and discussions about strategy use and solutions. The pupils’ learning loop makes it possible to mathematize and model real-world problems. Mathematization and modelling require discussion; e.g. simplifications must be done and results must be critically evaluated. Through studying mathematical conversations in and outside the classroom, we will search for insight into the impact mathematical conversations have on the pupils’ development of mathematical literacy. The OECD describes mathematical literacy as a preparedness to employ mathematics when one needs it, a critical strength to influence through mathematics, and critically consider mathematical results (OECD 2003; 2006). Mathematization, functional understanding, empowerment and critical democratic competence are all related to mathematical literacy.

We also wish to look for traces of inquiry – whether pupils and students by their own interests together wonder and seek information (Lindfors, 1999) – and how they initiate and invite into searching conversations with an inquiring stance in and about mathematics. An inquiring stance will impact the intentionality and empowerment of the participants.

We have given two examples from the LCMP-project where we see the influence of the school-industry partnership. This illustrates how the context of the project enables us to give insight into the relationship between school and industry. The first example points toward the school-industry context changing the conditions of learning and teaching, and thus changing the intentions of students and pupils. The context gives the knowledge acquired a different functionality and empowers the students and pupils. In the second example the source of relevant mathematical models in the classroom is enhanced by the partnership with a company. The real-world connection may be helpful in engaging pupils and students in discussions that relate to critical democratic competence.

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