Co-learning in an IBL-inspired PD session on programming

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In this study we investigated what kind of co-learning and learning gaps could be identified in a professional development session on the topic of programming. We found that both teachers and teacher educators learned about programming and lesson planning for programming. Teacher educators also learned about what kinds of knowledge teachers possessed about programming. Learning gaps identified were teacher educators' knowledge about didactical aspects of programming as well as the use of programming in school. We found that teachers express a need to learn more programming.

Keywords: Mathematical literacy, teacher professional development, inquiry-based learning, co-learning, programming.

Background and theory

Programming

In the new national curriculum in Norway launched in 2020, programming is introduced as an integrated part of mathematics and science. This comes in addition to digital skills as one of the basic skills that are to embrace all subjects. At year 5 the mathematics curriculum specifies that "The pupil is expected to be able to create and programme algorithms with the use of variables, conditions and loops" (Utdanningsdirektoratet, 2020a, bullet 10). The science curriculum for years 5–7 specifies that "The pupil is expected to explore, create and programme technological systems that consist of parts that work together" (Utdanningsdirektoratet, 2020b, bullet 7). Programming is a new theme in the national curriculum in science and mathematics for primary school, which implies that there is an authentic need for professional development. Programming is a new theme for teachers, both because they have not been teaching it but also because they themselves have never studied this theme. At the same time programming is new for teacher educators. Even if they may have studied programming at university, they have to a very limited degree been teaching it as teacher educators. Inquiry-based learning (IBL) is a way to investigate and explore new ideas in the classroom and may be a helpful approach in introducing a new curriculum. This leads us to our research question in this paper: What kind of co-learning and which learning gaps can be identified in an IBL-inspired professional development session on programming?

Inquiry-based learning (IBL)

IBL is seen as a way to organize education so as to make students able to function in a society which is changing and where the ability to think, reason and ask new questions are more important and higher valued than the ability to re-answer questions already asked. Bruder and Prescott (2013) point out that IBL is beneficial for motivation and understanding of mathematics and science, as well as

beliefs about relevance for society. Our understanding of IBL builds on the model developed in the EU Primas project (e.g., Artigue & Blomhøj, 2013; Maaß et al., 2017). In IBL students inquire, pose questions and engage in exploration in collaborative settings. Teachers foster students' reasoning, connect to student experiences and scaffold learning. The classroom culture is dialogic, and questions are open, experienced as real and relevant with multiple solution strategies. It is thus a goal to foster inquiring minds and build understanding of the nature of science and mathematics. Referring to Jaworski (2006) we consider three forms of inquiry practice in an inquiry community of teachers and educators: inquiry in mathematics (pupils engage in inquiry to learn mathematics), inquiry in teaching mathematics (teachers engage in inquiry to develop the teaching of mathematics), inquiry in research on developing teaching of mathematics (teachers and educators engage in inquiry into the research).

Four co-learning dimensions

Jaworski (2003) launched a four-dimensional framework for investigating the development of mathematics teaching and learning. Development is seen as processes of inquiry, involving critical reflection, in a community of inquiry. In the community experiences are shared, this supports individual inquiry and the development of norms. Hence, there are elements of both individual and community relationships that allow the inquiry and reflection to take place, which is seen as the learning and development. Participants can be insiders in the community or outsiders supporting the research and development. This gives rise to four interrelated reflexive pairs: Knowledge and learning, Inquiry and reflection, Insider and outsider, Individual and community. Investigations along these four dimensions are suitable and will provide insights into the inquiries and co-learning taking place in a learning community consisting of teachers, educators and students. Jaworski (2003) suggests guiding questions for each reflexive pair. To answer our research question, it will be helpful to answer questions related to each of the four dimensions:

Knowledge and learning: Who is learning and what knowledge is being developed?

Inquiry and reflection: Who is inquiring and into what? What kind of reflections are taking place?

Insider and outsider: Who are the insiders and who are the outsiders, and in what situations?

Individual and community: How is the community comprised, and how is the dialectical relationship between individuals and community played out?

By searching within each of the four dimensions, a more complete picture may appear of what kind of co-learning is taking place and of which learning gaps can remain.

Methods

The professional development session studied in this paper was carried out as part of a larger, longitudinal research project with focus on mathematical and scientific literacy and IBL. Participants were three mathematics and two science teacher educators from the university, and five teachers from a local school (teaching grade 4, 5 and 6, and one teacher leader). All teachers were generalist teachers. The TEs all had PhDs in mathematics or science, some with teacher education in addition. The lesson study was carried out according to the following plan: a) Teachers suggested a theme and a lesson plan, b) Teacher educators (TEs), including both mathematics teacher educators (MTEs) and science teacher educators (STEs), discussed the suggested theme and plan, c) Teachers and TEs met

in a joint planning meeting, d) Two lesson iterations with reflection and redesign in between. Teaching carried out by one teacher, with other teachers and TEs observing. Final reflection after the second iteration.

The theme suggested by the teachers for this session was programming with micro:bit (https://microbit.org/). Micro:bit is a small computer originally launched by BBC in 2015 with the purpose to be used in schools for pupils to learn programming. To program the micro:bit, pupils use a block-based visual programming language on a computer or tablet, and then transfer the program to the micro:bit using Bluetooth or a USB cable. In the lesson plan suggested by the teachers, pairs of pupils were given the task to make a flashing heart on the micro:bit's LEDs, and then try to make the heart flash with the same rate as their own heart rate. The teachers based this plan on an example found on the Norwegian website Lær Kidsa Koding, which provides resources related to teaching programming to children (Lær Kidsa Koding, n.d.). In the TEs' meeting, the main discussion related to whether the proposed plan opened up for sufficient inquiry or whether it was too focused on following recipes. An alternative task involving using the micro:bit to steer a car was launched. In the joint planning meeting, it was agreed that the lesson plan suggested initially by the teachers would be kept, but some changes were made in the material that the pupils would use.

The following data material was collected: Proposed lesson plan and final lesson plan, field notes from the TEs' meeting, audio recordings of the joint planning meeting and the two reflection and redesign meetings.

The audio recordings from the joint planning meeting and the first reflection and redesign meeting were transcribed. The three authors coded the transcript from the joint planning meeting separately, using the four dimensions from Jaworski's framework as categories (Jaworski, 2003). The three different versions of the coded data were then discussed to come to a joint understanding of each category. To help in guiding the discussion, the lesson plan and field notes were consulted. Subsequently the transcript of the first reflection and redesign meeting was coded separately using the new understanding of the categories. The audio recording of the second reflection and redesign meeting was also analysed using the common understanding of the categories. After this the findings were compiled. The project has been submitted to, and approved by, NSD – Norwegian centre for research data. In this paper, teachers are referred to as T name, where all names are pseudonyms.

Findings

The findings are structured according to the four dimensions suggested by Jaworski (2003).

Knowledge and learning

Our data shows multiple answers to questions related to knowledge and learning. The participants can be divided into three groups according to their prior knowledge of programming, see Table 1.

Table 1. Participants' prior knowledge of programming

Extensive knowledge	Some knowledge	No knowledge

MTE Øystein, STE Arne	MTE Benedikte, MTE Svein	STE Ragnhild, T Fay, T Camilla, T Marie, T Erik, T Jenny

Teachers Fay and Erik had some experience with micro:bit in fourth and sixth grade, respectively. Apart from that, no participants had any prior knowledge of programming in school. Four of the TEs had knowledge of programming from university courses and have used it at some level. Having sufficient programming knowledge at university level is however not sufficient to design tasks that function well at primary school level. The tasks discussed by the TEs in their prior meeting turned out to progress too fast to a too advanced level.

MTE Svein: It can be that, when we talked about it, that it took off and became too advanced.
T Jenny: Is it too advanced?
STE Arne: It is hard for me to say, really, since I have the knowledge.

STE Arne was not able to judge whether the task at hand would be too advanced for the pupils. He had extensive knowledge of programming, so could do the task himself, but did not have experience with programming in primary school, and so needed teachers' inside knowledge of their pupils' abilities and prior knowledge as feedback to judge the appropriability of the task.

Teachers' lack of knowledge about programming is clearly an obstacle for developing good teaching plans that would enhance pupil knowledge.

T Fay: We don't have sufficient knowledge in programming to design good enough tasks.

TEs had knowledge of programming, but not in a school setting. Teachers had knowledge of their pupils, but not of programming. Through the cooperation, both groups had opportunity to enhance their knowledge into new ground. Teachers were given opportunities to develop their knowledge of programming in school:

T Camilla: I ask a lot of questions because I need input on how to continue teaching programming.

We thus see that teachers are learning about teaching programming by cooperating with TEs who have programming knowledge. TEs learn about teachers' knowledge of pupils, and how to integrate knowledge about programming with knowledge of pupils to develop lesson plans. So both teachers and TEs learn how to plan a programming lesson in mathematics or science.

Inquiry and reflection

Several types of inquiry and reflection are evident in the data. During the planning meetings and reflections, ideas were discussed and assessed according to whether they were easy or difficult for the students (mainly with input from teachers) and easy or difficult to program (mainly with input from TEs). Together these constitute inquiry into teaching. Teachers and TEs inquired into pupil knowledge and learning after observing lessons, with reflection on the teaching and how the pupils reacted to the teaching, including how they were able to cooperate and work together in pairs.

As the lessons are to be IBL-inspired, a common quest regards whether the suggested activities offer opportunities for the pupils to inquire and explore. In our case this quest led to a discussion about

whether doing programming would provide opportunities for inquiry or whether the programming had to be embedded in something else.

STE Arne: In this particular task at hand, there is little inquiry involved (…) Because, in terms of programming it is not so much exploring.

T Jenny: I believe, we were satisfied when we came up with this about heart rate, since that may be inquiring.

STE Arne wanted to make the programming itself more explorable, while the teachers had put programming into the context of heart rate to make it into something the pupils could explore. Discussions continued regarding how to make it more IBL-like, and inquire in programming:

T Jenny: Do you think that, it is possible to do inquiry with the programming; and that it will be too difficult to combine it with exploring their own heart-rate in addition?

The question relates to what types of inquiry is possible if you haven't done any programming? Teachers expressed thoughts that when something is new to you, then maybe it does exactly give you opportunities to explore. Since the pupils have not worked with programming or micro:bit before, starting playing is exactly to engage in exploration and inquiry. This was expressed at various points during the planning.

T Fay: We were thinking that it will be some kind of inquiry since they haven't worked with it before.

T Fay: Like this, now, like when I am trying it out, it is inquiry for me; will it not be the same for the pupils?

A teacher asks whether there will be multiple solutions and strategies, relating to an important part of IBL:

T Erik: Will there be many different methods for how they can solve it? Will they come up with more examples of how they have done it?

In order to solve the task, the pupils had to find an appropriate pause (in number of milliseconds) between each heart beat shown on the micro:bit, in order to make it match their own heart-rate. Two possible strategies were mentioned:

T Fay: Some will do as I do now, just trying to make it equal, just moving the numbers around. Or some will try to compute the number of heart beats in a minute.

During the planning meeting, only these two solution strategies were suggested. In the reflection meetings, it became clear that this did not correspond well to what actually happened during teaching. Most of the students did, to a certain extent, follow one of these two strategies, but many of them did so in ways that were not expected. Of those following the strategy of trying out different numbers, many pupils changed the numbers in so small increments that there was no noticeable effect of the change. Those following the strategy of finding the number of heart beats in a minute did not continue in the expected way by computing the correct pause to use in their programs, but rather used the number of heart beats as the length of the pause.

At the reflection after the first lesson, it became apparent that the way the task was designed made it difficult to observe what impact changing the input in the program had. For example, if pupils

changed input from 60 to 70, they were not able to observe any change since those numbers are in milliseconds. In addition, the program block used to display a heart on the LEDs had a built-in pause of 600 ms, meaning that even if pupils put their own correct numbers into the program, the output would be wrong by 0.6 seconds.

MTE Øystein: So that is the biggest problem. That if someone has understood it, and apparently does everything right, they get the wrong result.

As we have seen, the main type of inquiry was inquiry into the teaching, with critical reflection on the lesson and the task.

Insider and outsider

The data reveal several pairs of insider-outsider configurations. An obvious instance is that teachers are insiders in school while TEs are outsiders. Among the teachers, class-teachers are insiders regarding knowledge of the particular group of students, while other teachers and TEs are outsiders. Moving to the classroom, both teachers and TEs are outsiders inquiring into how pupils work during the lesson.

The insider-outsider perspective also relates to programming. Those who know programming are insiders, while those who don't are outsiders. Without pre-knowledge of programming, you don't know what the possibilities and options are, e.g., what is easy to accomplish and what is more difficult. Those who don't know programming are bound by following given recipes. Those who know programming can supply information/knowledge on how to use the recipe, and change it, for their own means. Even so, pupils have to be guided, like STE Arne is guiding the group during the planning:

STE Arne: They either need a recipe, or you have to tell them, like I do now.
T Fay: Yes, if we have a recipe, then it is quite OK.

Part of being an insider in programming is knowing about the terms and concepts and what possibilities these may constitute. Before you reach that level, having a recipe constitutes a safety net.

Individual and community

A prominent example of how the community of teachers, TEs (and pupils) relate to the wider society is the fact that programming as a theme in mathematics and science in the school curriculum was imposed from the government without much support from teachers, and to a degree resistance, from teacher organisations and teacher educators. The competence aims formulated in the national curriculum provided the basis for the session, and were referred to several times during the discussions, to assure that the task designed for the lesson was appropriate for fulfilling the learning goal formulated in the curriculum.

STE Arne: But then it is not that competence aim, then it is another competence aim.
T Marie: Because it says "design and make a program based on user needs".

An interesting aspect is connected to what resources that are available, e.g., the micro:bit technology that was used in this session. Why and how had the micro:bit technology been chosen? Was the

decision made by the teachers or the school or at some higher level? It turns out that the micro:bit technology has been launched at national level:

T Fay: All schools in our commune have been given class-sets of these.
STE Ragnhild: All schools in the whole country have been given such class-sets.

Thus the society at large influenced the lesson both concerning the theme (the curriculum) and the resources (micro:bit). The influence of the national curriculum is obvious and natural. The choice of technology is more surprising, and shows that apparently random choices have big influence on lesson design.

Discussion and conclusion

This lesson study provided ample possibilities for co-learning for teachers and TEs as programming as a theme in school was new to all participants. Misfeldt et al. (2019) point out that even if teachers have a positive attitude towards working with programming, they do not feel prepared to take on the task. Miller (2019) states that the school as a system needs to provide support and opportunities for teachers to gain skills in how to implement computational thinking and coding. Since programming in school was new to all participants in our project, all were learning at some level: a) Teachers learned about teaching in/with programming, b) TEs learned about what teachers know about programming, c) Teachers and TEs learned how to plan a lesson in/about programming, d) Teachers and TEs learned about programming in school.

Learning to teach programming concerns the interplay between teachers' knowledge about teaching and pupils, and TEs' knowledge about programming. How to find or develop a common language? Through the cooperation, teachers provided knowledge about what may work in school so that the two types of knowledge, teacher educators' knowledge of programming and teachers' knowledge of the school setting, resulted in co-learning about programming in primary school.

How easy is it to understand that programming is open to inquiry? Programming involves making algorithms, recipes, which make programming appear "closed". On the other hand, making changes to the code is easy, just do it and see what happens, thus programming is very open to inquiry. Maybe there is an analogy with Lego? You can follow the recipe on the box or play with the pieces freely. We found that teachers with little experience in programming tended to view programming as a closed activity that simply consists of following pre-made recipes. The teachers did, however, also express the view that there is inquiry involved in learning to program.

In the professional development session studied here, both teachers and TEs neglected to work completely through the planned task before the lesson. Everyone simply agreed that the task could be solved, and there was only a very brief discussion about possible solution strategies. It seems clear to us that all teachers and TEs should have attempted to solve the task completely during the planning meeting. This would have made the teachers better prepared for teaching the lesson. But perhaps more importantly, it would mean that the teachers and TEs would sit together actually doing programming (as opposed to just talking about programming), which we believe would have given good opportunities for additional co-learning.

Our findings indicate that teacher educators need to acquire more knowledge about didactical aspects of programming and the use of programming in mathematics and science for primary school. Teachers expressed a need to learn more about programming, learn coding, and thereby gain knowledge that will help them choose or design tasks that are relevant, both in the sense of being relevant for pupils in their learning of programming, and relevant in the sense that they are attainable for the age group.

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