Instructors' views on the developmental needs of peer tutoring in the non-formal learning environment

Jenni Räsänen, Juha Oikkonen and Maija Aksela

University of Helsinki

Abstract: There is a need to organize non-formal learning activities in mathematics for children and youth. In Finland, we are developing a new non-formal learning environment called Pulmaario where we use peer tutors as instructors. This study is the empirical problem analysis of the design-based research. The aim was to find out what kind of support the instructors of the Pulmaario learning environment felt they need. The research material (N=51) was collected with questionnaires. The analysis of the questionnaires was based on the method of inductive content analysis. The results shows the needs for developing the non-formal learning environment further.

Keywords: design-based research, peer tutoring, cross-age tutoring, non-formal learning environment, science education in mathematics

Contact: jenni.j.rasanen@helsinki.fi

1 Introduction

In Finland, the Ministry of Education and Culture has the aim that Finland becomes one of the leading countries in science education. By science education, the ministry means strengthening the science competences. (OKM, 2014) At the University of Helsinki, science education in mathematics has been developed systematically at least fifteen years and the goal is to develop new solutions and pedagogical innovations to support meaningful learning in mathematics. (Aksela, Oikkonen & Halonen, 2018). Usually the math activities are organized by teachers or university students but there would be need for bigger amount of instructors. The ministry of Education and Culture pointed out that there are not enough science clubs for all those willing to participate and they suggested to involve upper secondary school students to work as instructors (OKM, 2014). So, there is a demand to design new ways to organize math activities.

In our development and research project, the aim is to develop new solutions for meaningful learning in mathematics in a non-formal learning environment. To develop a new learning environment, the *design-based research* (Edelson, 2002) is used as a research methodology. Design-based research is chosen because it provides

research products, which can be directly put into practice (Edelson, 2002). The aim of the wider project is to 1) increase children's and youth's interest in mathematics, 2) to spread the math activities to municipalities further away from universities and 3) to prevent exclusion.

Firstly, to increase children's and youth's interest in mathematics, we are using peer tutoring. The recent studies have shown that student's situational interest can be awakened by organizing an interesting teaching situation (Krapp & Prenzel, 2011) and by working with others (Isaac, Sansone & Smith, 1999). Secondly, the upper secondary school students will be trained to guide children in the learning environment to spread the activities all over Finland. Thirdly, public libraries are used as a new non-formal learning environment to influence those children who won't participate in the math activities organized at schools or universities.

In this current study, we are developing training and support system for instructors to carry out the second aim of the project, which is to spread the science education activities all over Finland. To be precise, we are trying to find out the developmental needs for training and supporting instructors when they are guiding children in the new non-formal learning environment called *Pulmaario*. The name Pulmaario is a wordplay, which comes from Finnish words "pulma" (in English: problem or puzzle) and "laboratorio" (in English: laboratory).

Organizing training for the instructors of the Pulmaario learning environment is in key position for success because the instructors of the new learning environment might not have completed any pedagogical studies. Before the upper secondary school students start to work as instructors, we need to start with an empirical problem analysis of the workshops, which were already organized in the Pulmaario learning environment by university students and librarians. The current study presents the results from the first empirical problem analysis before the first cycle of the research (figure 1).

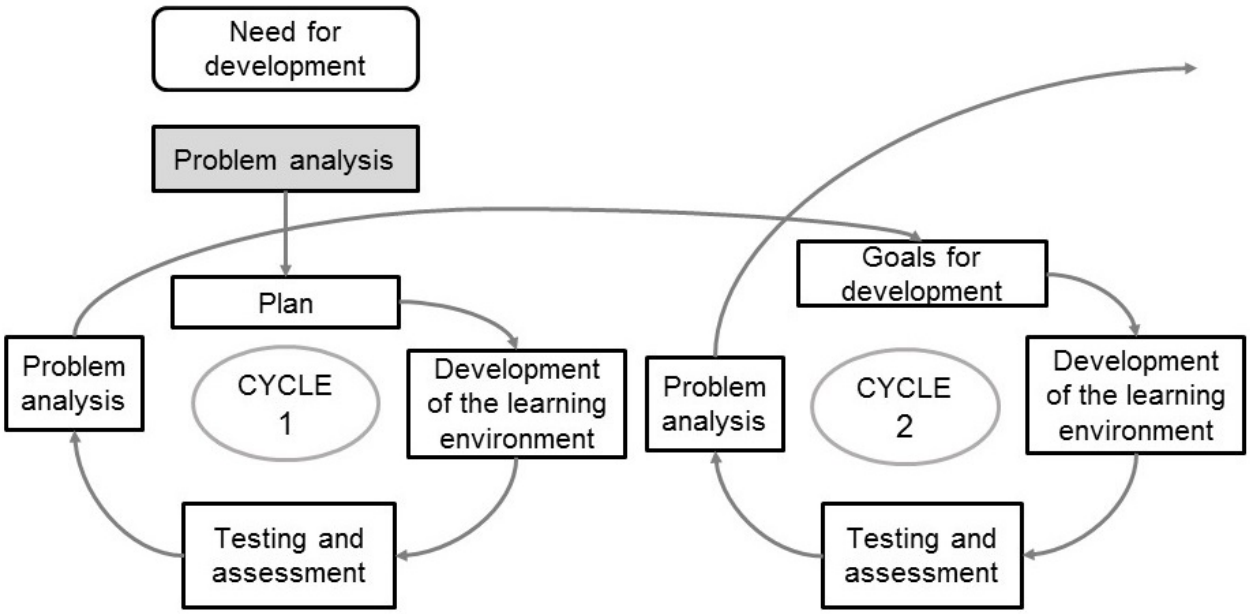

Figure 1. This paper describes the results from the first empirical problem analysis of the wider development and research project through design-based research.

2 Theoretical framework

Design-based research uses and produces different kind of theories for example frameworks for action. The purpose of the frameworks for action is practical and these frameworks provide the guidelines for designing the new learning environment. (diSessa & Cobb, 2004) In this study, we use theories about non-formal learning environments and peer tutoring as the frameworks for action.

2.1 Non-formal learning environment

Learning can happen in-school and out-of-school environments. The learning in schools is defined as formal learning whereas the learning out of schools is divided into informal and non-formal learning. The difference between informal and non-formal learning is that informal learning occurs in real life situations without any authority while non-formal learning is planned and guided but happens in out-of-school situations. (Eshach, 2007) Eshach (2007) characterizes non-formal learning as structured, usually prearranged, supportive and voluntary. It can be guide or teacher-led but learning is not evaluated in general.

Non-formal learning occurs at institutions out of school (Eshach, 2007), for example in universities, museums or, like in this study, public libraries. Usually non-formal learning environment takes place outside school activities but it can also be part of it e.g. the clubs organized by schools. Common examples of the non-formal learning environments are science clubs and camps, museums, science centers and companies. Instead, learning that happens while watching TV, reading magazines or books or talking with others, is classified to be informal learning. (Vartiainen, 2016) The previous study has shown that participation in a math club was related to better performance in high school mathematics (Gottfried & Williams, 2013). In addition, out-of-school learning environments can have a positive impact on students' attitudes towards a science course (Yildirim, 2018).

Skillful instructors are in key position for the successful non-formal learning environments. Kenttälä (2009) argues that pedagogically thinking club instructor enables good-quality clubs, which engages and motivates participants to join the club. The instructor doesn't have the same authority to the children as the teacher have and the relationship between instructor and the children can be quite even although the instructor is always responsible for the children. (Kenttälä, 2009)

2.2 Peer tutoring

Concepts for learning with the help of peers vary in research literature. The notion of peer learning is used as an umbrella concept for describing the learning with others. De Lisi and Golbeck (1999) characterize peer learning as 'an educational practice in which students interact with other students to attain educational goals' (p. 3). The forms of peer learning include for example cooperative learning and peer tutoring (Koho, Leppälä, Mustonen & Niemelä, 2014).

In peer tutoring, someone else than a professional teacher is used to guide one student or a bigger student group (Koho et al, 2014; Topping & Ehly, 2001). Those who guide are assigned the role of tutor and those who are guided are assigned the role of tutee (Roscoe & Chi, 2007). The roles of tutors and tutees can be fixed or reciprocal and tutoring can be among same-age students or cross-age students with large or small age gaps (Koho et al, 2014; Roscoe & Chi, 2007). Usually the tutor has more knowledge and expertise than the tutee (Roscoe & Chi, 2007) but this isn't necessary for example if the roles are changing. In this study, we define peer tutoring as older and more experienced students guiding group of younger and less-

experienced students. The participants are accompanied into fixed roles where older students work as tutors and the younger ones as tutees.

The recent research literature presents the benefits of peer tutoring e.g. its positive impact on academic achievement (Leung, 2015). Teaching others improves person's own learning and teaching is even more effective for the one who teaches than for them who are teached (Allen & Feldman, 1973). Besides, approaches in which a student studies along with others and is also responsible for the learning of someone else, encourage students to stay near the subject matter studied (Juuti & Lavonen, 2018). In addition, cross-age peer tutoring combined with mathematical games has been shown to enhance the self-esteem for both tutors and tutees and to increase the quantity and quality of discussion about mathematics (Topping, Campbell, Douglas & Smith, 2003).

To get the best results of peer tutoring, training the tutors is important because trained peer-tutors use more effective teaching strategies than tutors who are not been trained (Chapman, 1998). The training should include demonstration, practice, and coaching about the learning method, which was chosen (Topping & Ehly, 2001).

2.3 Aim and research question

The research literature about peer tutoring concerns, for example the learning outcomes for tutors and tutees. Still, there are missing the instructions how to train or support peer tutors, especially in the non-formal-learning environments. In this current study, we are trying to find out the peer tutors experiences about their work in the non-formal learning environment.

In this study, the research question is: What kind of support the university students and the librarians felt they need when they were working as instructors in the non-formal learning environment Pulmaario?

3 Method

Design-based research proceeds in cycles. It often starts with a perceived problem and an analysis of how to solve the problem. The problem analysis can be either theoretical or empirical or it can consist of both of these two forms of analysis. The analysis helps to find out the needs, possibilities and challenges for the design. (Edelson, 2002) The current study presents the results from the first empirical problem analysis before the

first cycle of the research. This study defines the operations for the development based on the problem analysis.

3.1 Context

The current study was conducted in the non-formal learning environment Pulmaario. In this learning environment, mathematics and programming are studied through playful learning. The math activities include playing, games, crafts and problem solving games. The Scratch program is used for programming own games.

The workshops for 9 to 13 year-old children are organized in the Pulmaario learning environment. One workshop includes meetings once a week for five weeks. Each meeting lasts two hours and the meetings are held in public libraries. The workshops also include different themes (nature, space and detectives) and stories related to these themes.

Before the workshops, the instructors had a change to attend to a 2-hours training session. In this session, there was a short introduction to the Pulmaario learning environment and some examples of the math activities were given. In addition, the instructors got an introduction to programming in Scratch.

In this study, the Pulmaario workshops were organized in fifteen public libraries in 2015-2016. Nineteen workshops were held in total. In the workshops, university students and librarians were working as instructors. There were one math student and one computer science student guiding children with the help of librarians in each workshop.

3.2 Participants

The participants of this study were university students and librarians who guided children in the non-formal learning environment Pulmaario. Fifty-three of them answered to the questionnaires. Two of the participants didn't answer to the open-ended questions in the questionnaires so they were left out in the data analysis.

The research material (N=51) contained two groups: (1.) university students (N=30) and (2.) librarians (N=21). The university students were mainly studying mathematics or computer science as their major subject. Besides, many of them had already some experience about the non-formal learning in mathematics and/or

programming. Instead, for some of the librarians mathematics and programming were new contents.

The division of labor between these two groups was that the university students were responsible for the content of the workshops and guiding children. In turn, the librarians were assisting them. Most of the respondents (N=42) participated in 4-5 meeting. In addition, some of the participants worked in several workshops and may have answered to the questionnaires more than once. Even so, their answers where about experiences from different workshops.

3.3 Data collection and data analysis

The data collection of this case study (Syrjälä & Numminen, 1988) was used to survey the instructors' views on their needs for peer tutoring. The data was collected with electronic questionnaires, which were prepared based on the previous research literature. The open-ended questions of the questionnaires were analyzed in this study. The questions were about the instructors' experiences about guiding the workshops, the new things what they had learned and ideas how to develop the learning environment.

The analysis of the questionnaires was based on the method of inductive content analysis (Elo & Kyngäs, 2008). Each whole answer was chosen to use as an analysis unit. The analysis was started by removing the inessential answers like "boo!" or "I don't know". After this the analysis units were simplified e.g. the answer "I think that informing about the workshops worked really well" was defined to describe the simplified expression *successful informing*. Also simplifying was done by splitting the analysis units to smaller pieces.

After simplifying the answers, the reduced expressions were categorized into 27 sub-categories. These sub-categories were named to describe their content. For example, the reduced expressions like *the skill differences of participants in programming* and *too complicated for younger participants* formed a sub-category, which was named as *participants' different skills*. By combining the sub-categories, eight generic categories were formed and these further formed the four main categories. Classifying the categories was continued until the main categories were formed. The first author of this paper conducted the data analysis. Because it wasn't possible to use another independent coder to improve the validity of this paper, the codings were reread many times to make sure that the categorization was consistent.

4 Findings

In this study, it turned out that the instructors need help in four fields as they are working in the non-formal learning environment Pulmaario. These fields are: 1) Knowledge and skills, 2) Organization, 3) Affective support and 4) Communication. The categorization of the data is presented in table 1.

Table 1. The categorization of the data.

Main category	Generic category	Sub-category
Knowledge and skills	Content	Mathematics
		Programming
	Pedagogy	Participants' different skills
		Group management skills
		Working with children
		Motivating and encouraging participants
		New learning method
Organization	Content structure	Activities
		Theme and narrative
	Practicalities	Availability of materials and equipment
		Scheduling and breaks
		Number of participants
		Organization of the registration and participation
		Organization of the space
Affective support	Participants' experience	Positive experience for participants
		Commitment of participants
		Different interests of participants
	Instructors' own experience	Positive experience for instructor
		Commitment of instructor
		Atmosphere
		Importance of the workshops
		Instructor's feeling about own knowledge
Communication	External	Informing participants and their parents
		Informing schools
		Marketing
	Internal	Co-operation between the instructors and the division of labor
		Co-operation in the project

Next, the results are presented in more detail.

Knowledge and skills

The instructors felt that they need help with content and pedagogy. Some of the instructors had already some knowledge about the contents of mathematics and programming. Still, the instructors needed help in both mathematics and programming.

> ”I learned more about programming although it was still difficult to guide the process of making the more complicated programs.” (University student 9)

The teaching method of the learning environment Pulmaario was new for some of the instructors. Also some of the instructors didn’t have any experience working with children. However, it was felt important to have some experience with children when working in the non-formal learning environment. Also the group management skills were mentioned to be important for the instructors. Motivating and encouraging the children was experienced to be hard occasionally. As well, the children’s different skills were found to be challenging.

> ”-- The students were not that used to guiding child groups, using voice, calming down the situation etc.” (Librarian 15)

> ”-- Perhaps the challenge was that the children had different skill levels in programming again. The more advanced programmers are hard to take into account when the materials are for beginners. --” (University student 15)

Organization

Needs for support in organization were related to the content structure and to the practicalities. The structure of the content included well-developed activities and strong theme and stories, which were seen to be important for the learning environment. Besides the stories were hoped to be developed further.

> ”-- based on the workshop we did, the story could be developed further.” (University student 11)

Organizing the practicalities seemed to cause many challenges although some positive things were also pointed out. The challenges were related to the availability

of materials and equipment and organization of the working space. Addition to, some participants felt that the organization of the registration and participation were challenging, because those made it possible to join the workshops during the activities. Also the number of participants was sometimes too big and instructors had hard to guide everyone. On the other hand, scheduling the workshops divided the participants' opinions. Some of them wanted longer workshops meetings while others thought that two hours was already too long time for both children and the instructors. However, both agreed on the importance of breaks.

> "-- In addition, when the crafts and coding were done around the same table, it wasted some time for the workshops because we had to clean the table and fetch and share the computers" (Librarian 8)

> "Math puzzles and coding could be separated or held at different times. If it was too draining for an adult, maybe it was for the children too." (Librarian 2)

Affective support

Both instructors' and children's experiences influenced to the participant's affective experiences. The answers showed that children's experiences about the workshops were very positive. They were committed and enjoyed participating the workshops. Still, the different interests of children caused challenges for the instructors.

> "-- the children were mostly interested in programming and although the other part made it easier to program, the children couldn't necessarily see that. --" (Librarian 19)

Participating to the Pulmaario workshops was mainly positive experience for all the participants. However, there were lot of variation in the participants' feelings about their own experience. Especially, the librarians felt themselves insecure while the students seemed to be quite confident. The participants felt that organizing this kind of workshops is significant and these diversifies the offerings of the libraries. Also the atmosphere were experienced to be good although there were also too much noise and restlessness. Some of the participants mentioned that the commitment of the instructors should be improved. This was seen to be important for successful workshops.

> "I'm bad at math, so yeah, I learned." (Librarian 2)

> "-- Enthusiastic librarians are key for successful workshops." (University student 28)

Communication

Regarding communication, the support was needed for the external and the internal communication. For the external part, informing schools, participants and their parents is important and there should be more communication with them. The participants felt that marketing should be started early enough. As well more communicational channels should be used.

> ”-- keeping the parents informed should be increased a lot.” (University student 6)

The participants were mainly satisfied with the co-operation between other instructors and other organizers but some improvements where mentioned. Especially, the division of labor should be discussed in good time.

> ”Before the workshops start, it would be good to arrange a meeting between the librarian and the students. In the meeting, the program and the materials needed could be checked and the division of labor, roles etc. could be settled. --” (Librarian 15)

5 Discussion

This empirical problem analysis give us information to develop the training and the workshops and it defines the goals for the development of the new non-formal learning environment. Firstly, the training for the instructors should include information about both content and pedagogy. Often the instructors of the non-formal learning environments have their own interest in the content. However, in the Pulmaario learning environment, there are also people working as instructors (e.g. librarians), who might not be interest in mathematics and programming and who don’t know that much about these contents. Besides, the instructors might not have studied any pedagogical studies so they should be trained to guide children, for example encourage them to generate their own explanations and examples, not only to follow the given materials (Roscoe & Chi, 2007).

Secondly, the organization of the non-formal learning environment should be structured, as well as Eshach (2007) defines it (e.g. structured, prearranged, supportive and voluntary). The content structure, which includes activities, theme and stories, should be designed ready for the instructors. Also the practicalities should be developed to be clear. Still, the flexibility is essential in peer tutoring and the

decisions should be fit together with local needs (Topping & Ehly, 2001). For example, the time and the length of the workshops could be decided to fit in with the activities of each libraries.

Thirdly, the instructors' affective experiences are important to take into account when developing new learning environments and the positive experiences of instructors should be supported. The participants pointed out the importance of instructors' commitment and enthusiasm. Roscoe & Chi (2007) also argues that tutors, who enjoy tutoring or the domain, can find it rewarding to think more deeply about the content than those tutors who are not that interested. Another aspect in the affective support of instructors is connected to their feelings about own knowledge. The training of instructors should include exercises, which improve their feelings about own competence because it is common that novice peer tutors are feeling not that capable to explain challenging contents or being in charge of someone other's learning (Roscoe & Chi, 2007).

Finally, we need to make a good marketing plan to contact schools and participants and their parents. Besides, although the instructors were quite happy with working together, there should be still more time for the co-operation of the instructors. To support their co-operation, there should be also designed structures that enables all the instructors to meet each other before the workshops are starting.

This study gives a good basis to start to develop the training and support system for instructors who guide children in the Pulmaario learning environment. The learning environment should include the four fields of support and needs mentioned earlier. Next, we are going to train upper secondary school students to work as instructors. Because the upper secondary school students are much younger and have different knowledge and skills than the university students and the librarians, the research about the needs of instructors should be continued. On the other hand, this study didn't examine the experiences of the children who participated in the Pulmaario learning environment. Their experiences should also be taken account because their views on the action of instructors could also give good ideas for developing the training.

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