Teachers' perspectives on programming through emerging technologies in mathematics education

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This article explores the perspectives of pre- and in-service teachers on the integration of programming in mathematics at the Norwegian primary and lower secondary schools. The study focuses on teachers' perceived programming level and how it affects their ability to teach programming effectively. We discuss two different educational frameworks that emphasize on the teachers´ training workshops through block-based programming techniques (like Edublocks and Miro:bits). The data were collected from 64 pre- and in-service teachers who participated in workshops. The findings indicate that many teachers have little to no prior programming experience, which impacts their confidence in teaching the subject. These workshops on professional development were found to be helpful in increasing their confidence and perceived skill level.

Keywords: Teachers´ professional development, block-based programming, mathematics education.

Introduction

Information technology has rapidly emerged and changed our society dramatically in recent years. The present school-going generation is meeting and interacting with information technology almost everywhere. Computer programming have been implemented in national school curricula in many countries with different approaches, either as a separate subject (e.g., in Great Britain and Poland) or particularly as an integrate part in science or mathematics education (e.g., France and Spain) (Grover & Pea, 2013; Kaufmann & Stenseth, 2021) in view of the increasing and futuristic importance of information technology. Consequently, the Norwegian Ministry of Education has introduced programming (coding) in different courses, especially in mathematical courses, i.e., according to the latter approach, at primary and lower secondary (PLS) school levels. The school year 2020-2021 was the first year with this revised curriculum including programming (coding) in Norway (The Norwegian Directorate for Education and Training, 2019).

It is important to highlight here that the implementation of a successful programming curriculum in mathematics in the schools is difficult and requires adequate resources and teacher (pre- and in-service) trainings. The challenges associated with this inclusion in the revised curriculum in Norwegian schools and in the teacher education institutions are manifold. It is natural for the schools and teacher-education institutions to reflect this reality on a high priority basis. The national PLS level teacher education program has not traditionally contained any programming courses until recently, and there are currently no compulsory professional development programs in programming for pre- and in-service teachers. Based on this, and on our background knowledge about Norwegian teachers, we suspect that their programming level is low, which was the case in neighbouring countries, e.g., in Sweden, before their curriculum renewal in 2018 (Misfeldt et al., 2019). Faced with the new programming curriculum, the teachers feel insecure on both the technical (Kaufmann &

Stenseth, 2021) and pedagogical content knowledge aspects on programming (Sentance & Csizmadia, 2017), and how to integrate it in the mathematics education (Vinnervik, 2022). In this study, we draw on the work of Finger and Houguet (2009), who describe intrinsic and extrinsic challenges that teachers face when implementing technology into the curriculum, which is also relevant in the case of curriculum change related to programming (Sentance & Csizmadia, 2017). Some of the most relevant challenges are, for example, intrinsic: *professional knowledge and understanding*, *professional adequacy* and *professional attitudes and values*; extrinsic: *lack of resources*, *practicality of implementation* and *time management*. The former are challenges that teachers may face on a personal level, while the latter are challenges due to external factors.

The first two authors of this article have given courses and conducted workshops on technical and pedagogical aspects of programming to pre- and in-service teachers in PLS mathematics with two different approaches/education programs. One approach was to use the students' and teachers' knowledge of geometrical figures to learn basic programming aspects with Turtle Geometry (Papert, 1980) through the block-based editor Edublocks. The other approach was related to blocked-based programming by using the tool Micro:bit. In the present pilot study, we report on the education programs used and present data from surveys answered by the course participants (n=64) on their perception of own programming skills, attitude towards programming in an educational context and confidence to incorporate programming in their own present and future mathematics classrooms. Our guiding research question is: what are teachers' perspectives on using programming in mathematics at PLS level through workshops/teacher training programs to enhance their professional development?

Methods

In this section, we describe two different education programs and settings they were taught, as well as the data acquisition used in the various workshops. The objectives of the workshops were to enhance the pre- and in-service teachers' technical and pedagogical competence in programming by presenting them to an education program they could apply in their own classrooms. In the following, pre- and in-service teachers will be commonly referred to as teachers. The research model (see Figure 1) presents our research implementation strategy which shows two working environments: in-service teachers from Bodø municipality, Norway, who were offered training using Edublocks led by the first author of this paper (Education program 1 (EP1)), and pre-service groups from the teacher education program of Nord University, Norway, who were given workshops on block-based programming using the Micro:bit tool led by the second author of this paper (Education program 2 (EP2)).

Education program 1 (Turtle geometry)

The first education program was given in two workshops: one for lower secondary in-service mathematics teachers from local schools in Bodø municipality, and the other for PLS teacher students with mathematics as elective subject at Nord University. Both workshops consisted of coursing and individual/group work including problem solving with a total duration of approximately four hours. There were 14 in-service teachers and 6 teacher students participating in two workshops, which were organized in August 2022 and January 2023, respectively. The education program had been tested by three in-service teachers in their respective lower secondary classes (grade 8-10) prior to the workshops (see Løken (2022) for details), and one of them was present in the first workshop to share his classroom experiences with the other participants.

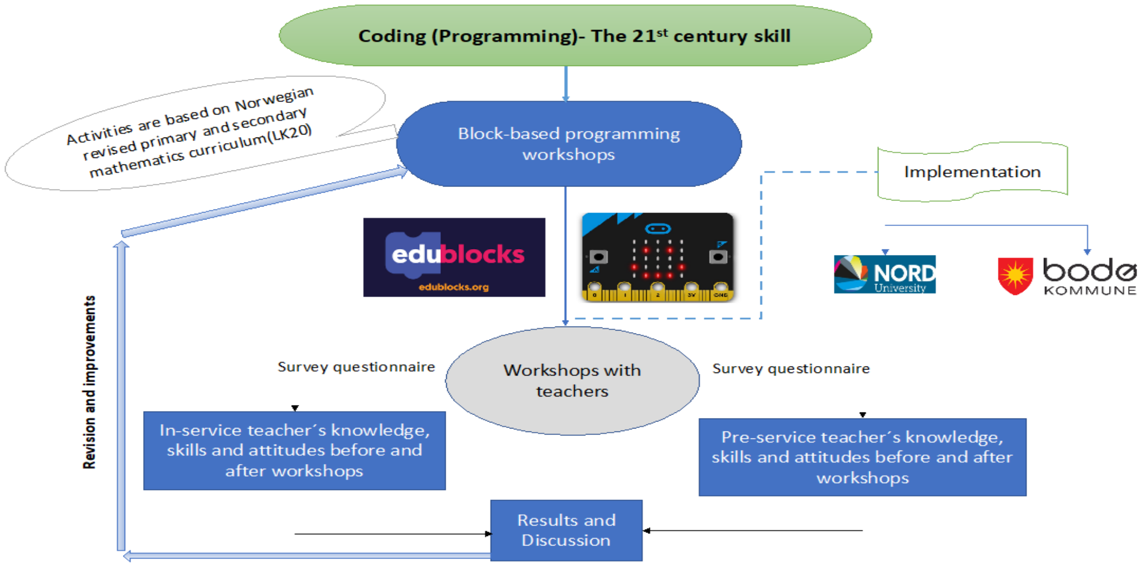

Figure 1: A schematic representation of the research plan and implementation

In this education program, we applied a teaching strategy for programming linked to geometric understanding and drawing of geometric figures via block-based coding performed in Edublocks.org, inspired by Turtle Geometry, although it has a somewhat inversed approach. Instead of using programming to explore advanced geometry, we propose to use construction of familiar geometric figures as an entry to basic programming.

Education program 2 (Block-based programming with Micro:bit)

For this module, we have conducted three workshops for pre-service teachers, 44 in total, in different time intervals during the last two years (2021-2023) on block-based programming by using Micro:bit in different campuses of Nord University. Appropriate activities and tasks in programming teaching are important aspect of improving learning skills of the learners (Popat & Starkey, 2019). Therefore, we designed and presented activities on Micro:bit for the workshops which target one of the learning goals related to programming in the Norwegian revised 7th-grade mathematics curriculum in schools.

Data acquisition

After the workshops, the participants in both educational program modules were given questionnaires designed by the authors of this paper, which consisted of statements to be graded (Likert-scales) and open-ended questions. The statements/questions varied a bit between the workshops, but they all mainly represented the categories: 1) Teachers' conceptions of their own programming competence; 2) Teachers' attitudes toward the implementation of programming in mathematics education; 3) Teachers' perceived learning outcome from and opinion about the workshop (an example of one questionnaire can be found here: https://github.com/asifmq/workshop-questionnaire.git). The Likert-scale statements were related to categories 1)-2), which were inspired by previous studies (Misfeldt et al., 2019; Sentance & Csizmadia, 2017). The Likert-scale had six alternatives, meaning that the participants were to grade every statement on a scale of 0 (meaning "not at all/very unlikely") to 5 (meaning "to a great extent/very likely"), which is within the bounds of the optimal number of alternatives (4-7) for survey scales in social sciences (Lozano et al., 2008). The open-ended questions were related to category 3) and were included to shed light on the needs and challenges of the teachers in the process of implementing programming in their classes.

The participants were recruited at two local lower secondary schools, where all the mathematics teachers were invited and encouraged by the leadership to participate in the workshop, and in various mathematics courses taught by the two first authors, as compulsory part of the 5-year integrated master's program of the PLS school teacher education. It was voluntary to join the study by submitting the questionnaire and all the participants chose to do so. The 14 in-service teachers participating were distributed as following: gender: 30% female; age (in years): 24% in range 30-39, 38% in range 40-49 and 38% > 50; teaching experience (in years): 15% in range 0-9, 54% in range 10-19 and 31% >20. The 50 pre-service teachers participating were distributed as following: gender: 70% female; age (in years): 72% < 25, 28% in range 25-34; study progression: 24% in second year, 40% in third year and 36% in fourth year. The number of participants was rather low (64 teachers across all groups combined), so we cannot, in general, expect our results to be statistically significant.

Results and discussions

In this section, we present our findings from the questionnaires and analyze the data in light of the conceptual framework of Finger and Houguet (2009) around intrinsic and extrinsic challenges related to the implementation of programming in the mathematics curriculum. Although the questions did not explicitly ask about challenges, we argue that this framework is still applicable for categorization of our results because the background of the study and the workshops is related to the syllabus renewal and the challenges consequently faced by the teachers.

Graded questions

In this subsection, we perform a simple descriptive analysis of the Likert-scale answers from the questionnaires. We emphasize that the data presented here are preliminary results, thus, we do not present or confirm any hypothesis. For a clearer representation of the data, the scales have been converted into three graded categories: "low" (0-1), "intermediate" (2-3) and "high" (4-5). Figure 2 presents the teachers' perceived programming level before and after the workshops, which are related to intrinsic challenges such as professional knowledge, understanding and adequacy. Note that both these two questions were answered after receiving training, meaning that their answers represent the perceived relative difference in programming level pre- and post-workshop. In one of the workshops in EP2, this question was omitted from the survey. Hence, the number of respondents is 55 here.

The majority of the teachers deemed their own programming level low prior to the workshops, which is consistent with our experiences and the literature. For example, subject knowledge in programming is identified as the top intrinsic challenge faced by teachers in the UK (Sentance & Csizmadia, 2017), and Swedish teachers do not feel prepared to take on the task of lecturing programming due to lack of training (Misfeldt et al., 2019). In this study, 86% of the respondents considered their programming level to be low prior to the workshop, 13% considered it to be intermediate and none considered it to be high (combining the results of EP1 and EP2). After the workshop, most of the participants considered their programming level to be intermediate (62%), although 31% still were in the lower category. Only 7% found their programming level to be high after the workshops, which suggests that longer training is necessary to reach this perceived competence level. There are no substantial differences in the responses from the participants in EP1 and EP2.

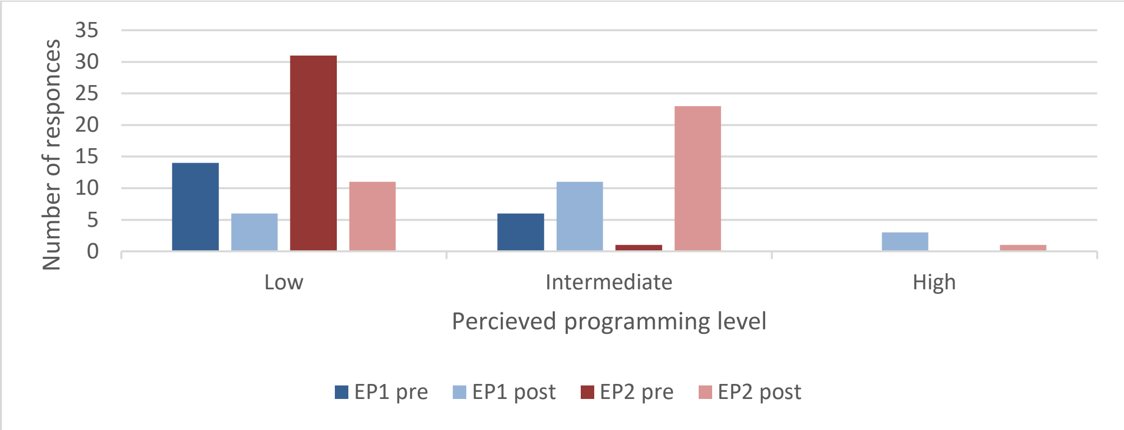

Figure 2: Teachers perceived programming level pre- and post-workshop in EP1 and EP2

Figure 3 summarizes the teachers' interests in, attitudes towards, and confidence in teaching programming in a mathematics education context, upon the questions: "To what extent are you interested in programming?", "How important is it to teach programming in PLS schools?" and "How comfortable are you in teaching programming?", respectively. The in-service teachers who received EP1 were not asked these questions, meaning that n=50 in these representations.

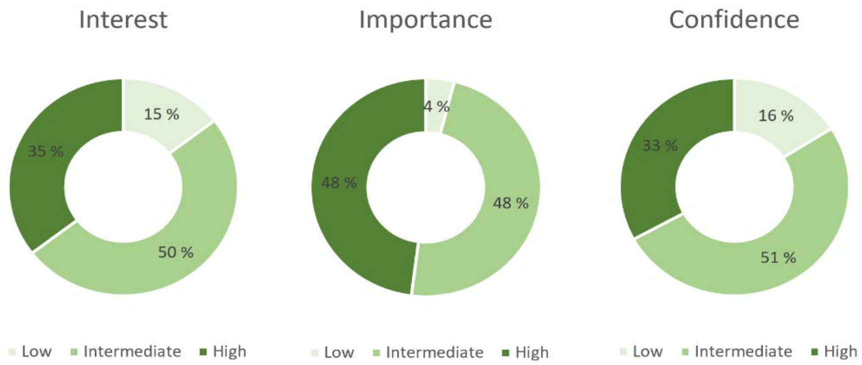

Figure 3: Pre-service teachers' conceptions about programming in a mathematics education context

The left diagram in Figure 3 shows to which degree the teachers were interested in programming. Interestingly, 35% of the teachers had a high interest in programming, even though only 7% of them thought they had a high programming level. Almost half of the asked teachers found it highly important to include programming in the teacher education program, which is shown in the middle diagram. Interest in and view on importance of programming are clearly within the category *professional attitudes and values*, identified as an intrinsic teacher challenge when implementing programming (Finger & Houguet, 2009), and the current results are in line with recent findings from Sweden, where teachers consider programming in school as highly relevant (Vinnervik, 2022). The fact that approximately 1/3-1/2 of the teachers find programming highly interesting and important to include in the teacher education program, i.e., *professional attitudes and values* according to the framework, may motivate them to increase their programming level on their own initiative, i.e., *professional adequacy*, as the intrinsic challenges are reported to be correlated (Vinnervik, 2022). The right diagram shows that 33% of the teachers are highly confident in teaching programming in PLS mathematics education. Thus, it seems like a high perceived programming level is not a necessity for high confidence in teaching programming, i.e., when comparing Figures 2-3.

Open-ended questions

In this subsection, we perform a qualitative analysis of the responses to the open-ended questions, which were only asked in the survey related to EP1 (n=20). The teachers' text answers have been coded, categorized and analysed with the lens of intrinsic and extrinsic classification of challenges related to the inclusion of programming in the curriculum (Finger & Houguet, 2009). The coding scheme was decided individually for each question after reading the free-text answers and discussion among the authors, i.e., in an inductive manner. We did not limit the answers to one theme per participant per question (a maximum of three themes per answer occurred during the coding). The themes and their occurrences related to each question are summarised in Table 1.

Question:	Coding scheme:	Number of mentions:
1. What did you learn during the programming workshop?	Fundamentals of programming	3
	Online editor (Edublocks)	7
	Tips for own lecturing	2
	Code specific	8
	Confidence related	3
2. Which part of the presented education program will you use in your own mathematics teaching?	Geometry related	3
	Introduction to programming	4
3. What did you like about the workshop?	Time to explore/probe	8
	Collaboration	3
	Classroom experience	1
	Slow/thorough progression	5
4. What did you dislike or miss about the workshop (is there anything you would like to learn more about within programming)?	Eager to learn more	4
	Text-based programming	2
	More tasks	3

Table 1: Coding scheme with occurrence frequency for open-ended questions

The analysis of teachers' responses indicates that about half of them appreciated that they were made aware of and introduced to an online editor that is freely available (question 1). Since most of the teachers had to a small degree or not at all included programming in their teaching, it is probable that they were not familiar with a suitable editor or program for lecturing, and thus did not know how to get started. This is clearly related to the extrinsic challenge *lack of resources,* according to the framework. Half of the teachers also said that they had learned about code-specific principles like loops, statements, lists and variables, which are related to the intrinsic category *professional knowledge and understanding*. Several responses were confidence-related, i.e., related to the intrinsic category *professional adequacy*, such as: "It is easier than I feared" and "Now I dare and want to explore programming", which suggests that even just four hours of training has a positive impact on the teachers' view on their competence.

When asked about which part of the education program the teachers will use in their own classrooms in the future (question 2), several answered that they will use part of the content as an entry to programming or as fundamental training in Python. Others were a bit more specific and used phrases related to exploration of geometrical figures. For example, one answered: "Programming geometrical figures such as the square and the rectangle", which indicates how it makes it easier for them to integrate programming in mathematics education, and which topic in the syllabus they may relate it to. Many teachers liked to be presented with a complete education program with assignments that they could use in their own class. These replies are sorted under the extrinsic *practicality of implementation* category of the framework.

Upon question 3, many teachers expressed appreciation that they were given time to test and probe different blocks and features in Edublocks and to explore its concept on their own, e.g.: "The possibility to work practically on my own". Also, they liked that the instructions were thorough, stepwise and slow enough. Both these type of answers are related to the extrinsic *time management* category of the framework. Several also liked to have the possibility to collaborate with colleagues or ask the course instructors for help, i.e., to learn in a social setting. Some also pointed out that the education program was already tested by some of their teacher colleagues and found it useful that the experiences (challenges and tips) from the classrooms were shared, which can be categorized as *practicality of implementation*.

Regarding question 4, most teachers emphasized what they would like to learn more about and did not mention anything they disliked about the workshop, although some would have liked to have more time allocated for the workshop. One in-service teacher stated that the workshop provided "New input in a mathematical topic which was hardly given any attention during my education". This mathematical topic could be, e.g., algorithmic thinking or programming. On the one hand, many seemed to thirst for better programming skills and were eager to learn more to solidify their knowledge in order to feel confident about lecturing on their own, which sort under the intrinsic categories *professional knowledge and understanding* and *professional adequacies*. Some of them would have liked to receive and work with more tasks/examples, which supports this. Others, on the other hand, said that the content of the course was enough to begin with.

Concluding remarks

This paper presents two education programs (EPs) for the implementation of programming in mathematics education at the primary and lower secondary school level. The two EPs have been introduced to pre- and in-service teachers, 64 in total, through several workshops organized by the authors. We emphasise that the project is ongoing and that more data is needed to enhance the confidence level of the study. From surveys conducted in the workshops, it was found that the teachers' perceived programming level was, on average, low prior to the workshop and intermediate afterwards, which means that just four hours of training makes a substantial improvement on their belief about teachers' own programming experience. This observation is also reflected in the fact that most of the teachers (84% of the respondents) had medium-to-high confidence in teaching programming in their mathematics classes after the workshop, and several teachers gave positive confidence-related free-text answers.

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