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The professional identities of prospective mathematics teachers who teach through programming

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Abstract

As has been the case in many countries around the world, the new Norwegian curriculum from 2020 included programming as part of mathematics education. However, little is known about how prospective teachers perceive this addition in regard to their developing professional identities. When the results from an electronic survey of 394 prospective teachers showed unexpected findings, five of the subjects were asked to participate in a focus group interview in order to explore some of these results. The focus group interview was conducted to understand how prospective teachers considered the past, present and future aspects of their professional identities as teachers of mathematics through programming. The results reveal that, although the prospective teachers had little experience of programming, they were positive regarding its implementation in mathematics lessons because they identified themselves as digital natives; they therefore believed that learning to program would be easy. They aligned themselves with their students, as masters of technology, in contrast to their future colleagues, whom they implicitly described as digital immigrants. The findings of this study have implications for teacher education. Even if the prospective teachers have a positive attitude toward programming and consider themselves digitally competent, a limited understanding of how programming can be integrated into their mathematics teaching will affect the identities that they see for themselves as teachers who teach mathematics through programming.

Keywords Prospective teachers · Professional identity · Programming · Mathematics

Introduction

Since 2020, computational thinking, of which programming is part, has been integrated into mathematics education in the Norwegian curriculum (Ministry of Education and Research, 2020). The rationale for this addition, in Norway and many other countries, is that there is a strong link between programming and mathematics through problem solving (Bocconi et al., 2018). In the Norwegian mathematics curriculum (Ministry of Education

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and Research, 2020), computational thinking is emphasized as important for developing strategies and approaches to solve problems, and to break a problem down into smaller problems that can be solved systematically. Further, it also includes evaluating whether these smaller problems can be solved more easily with or without digital tools. Programming, as a digital tool, means producing instructions, usually for a computer or another electronic device, to perform certain tasks or to solve given issues. Computational thinking refers to the thought processes involved formulating problems so their solutions can be represented as computational steps and algorithms. However, the addition of computational thinking through programming into mathematics education has raised concerns about how to develop teachers' competency to utilize this link (Kaufmann & Stenseth, 2020). This is partly because teachers' professional digital competence "must be closely linked to situations and concrete uses, and it is thus no longer possible to speak of just one type of digital competence but rather of several inter-connected digital competencies" (Engen, 2019, p. 18).

Kilhamn et al. (2021) studied teachers at a Swedish compulsory school who were early adopters of programming in mathematics classes, and who described programming as being generally engaging for students. Nevertheless, the teachers had difficulties connecting mathematics and programming, despite recognizing the potential to do so. In a web-based survey, 91 Finnish primary school teachers were asked how they viewed programming as part of their new mathematics curriculum (Pörn et al., 2021). As was the case with Kilhamn et al.'s (2021) interviews, Pörn et al. (2021) found that the teachers made few connections to specific mathematical topics. When they did make connections, it was to spatial thinking and geometric shapes, or to processes such as logical thinking and problem solving. In a review of relevant literature, Eckert and Hjelte (2021) found that several research articles reported cases in which students engaged in programming without making connections to mathematics or, in some cases, without being aware that they were using mathematics.

Similarly, in teacher education, concerns have been raised concerning the complexity of programming (Grover & Pea, 2013). For prospective teachers to choose appropriate programming tools for teaching specific mathematical topics, they need an awareness of their own skills in computational thinking (Herheim & Severina, 2020). However, the concrete situations in which digital tools as programming are to be integrated are also likely to have an impact on the choices that prospective teachers make about linking programming to specific mathematical topics (Engen, 2019). Ndlovu et al. (2020) found that prospective teachers took a range of factors into consideration when making decisions about integrating digital tools into their mathematics teaching. These considerations included the specific classroom context, the mathematical topics, their skills with the digital tool and their willingness to trust the usefulness of the digital tool as being effective for teaching and learning mathematics. Kaufmann and Maugesten (2022) analyzed the results from an electronic questionnaire that had been answered by 394 Norwegian prospective teachers. Although the majority of prospective teachers had very little experience of programming, many were positive about incorporating it into their mathematics teaching. This contrasted with Ndlovu et al.'s (2020) findings, which showed that knowledge and skills regarding digital tools were needed for prospective teachers to be able to feel comfortable with integrating it into their mathematics teaching. Further, in contrast to Pörn et al. (2021), the respondents in Kaufmann and Maugesten's (2022) study evaluated programming as being significantly less useful for geometry than other topics, such as numbers, algebra and functions, and problem solving. They also evaluated programming as being more useful for differentiated teaching and multilingual classrooms than for the teaching of specific mathematical topics. The responses from the Norwegian prospective teachers seemed to be quite different to those in other studies. This makes them an interesting group to find out more about in relationship to how they considered programming could be integrated into mathematics education.

As integrating programming into mathematics education was a new requirement, we chose to consider how this new curriculum requirement contributed to the development of prospective teachers' professional identities. More than twenty years ago, da Ponte et al. (2002) stated that "ICT may actually play an important role in teacher education, thus contributing to the professional and personal development of prospective teachers" (p. 97). More recently, Bobis et al. (2020) found that teachers' identities contributed to the establishment of a supportive learning environment, which could include different digital tools to match students' learning needs. However, prospective teachers' professional identities are likely to still be forming as they move from their roles as students to that of being teachers (Beijaard et al., 2004). The building of these professional identities will be affected when they encounter new demands, such as the integration of programming, which they themselves had not experienced while at school.

In this article, we explore prospective teachers' developing professional identities as they describe programming and how they considered that it relates to the learning and teaching of mathematics. In particular, we were interested in what experiences were likely to have shaped their professional identities, as prospective teachers' professional identities can be considered as neither fixed nor imposed, but are instead negotiated through experience (Sachs, 2005). Our research question is: How do prospective teachers describe past, present, and future aspects of their professional identities as teachers of mathematics through programming?

Mathematics teachers' professional identity

In previous research on teacher identity in mathematics education, and especially in mathematics teacher education, there is a general acceptance that professional identity formation occurs as a result of individual experiences and social interactions (Anderson, 2007; Bobis et al., 2020) and that identities are continually reforming as new experiences and social interactions occur (Lamote & Engels, 2010). Therefore, we have adopted Losano et al.'s (2018) definition of mathematics teachers' professional identity as:

> A set of self-understandings related to ways of being, living, and projecting into the teaching profession, facing the voices, demands, and social and political conditions of the teaching practice. It is important to highlight that these self-understandings are not only personally or subjectively constructed by the teacher. They are mainly socially and historically constructed with other participants of the world of teaching (colleagues, students, educators, school principals, etc.). (p. 291)

This definition takes into consideration many of the aspects raised by others in defining a teacher's professional identity. For example, Bjuland et al., (2012, p. 408) stated that "identity is represented and shaped through the social and discursive practices available to individuals and groups at particular moments." Teachers' professional identity can be considered an ongoing process of interpretation and re-interpretation of their experiences (Lamote & Engels, 2010).

Prospective teachers' experiences include those at institutions, such as teacher education and at the schools where they participate in practicums, as well as their previous experiences of being a student in school. For example, today's prospective teachers are often labelled digital natives (see Orlando & Attard, 2016), because they were raised using various digital tools (Prensky, 2001). Digital natives are contrasted with digital immigrants, who must learn about digital tools as adults. Therefore, identities are collectively shaped and constructed between individuals and societies (Sfard & Prusak, 2005) and are continually changing as the prospective teachers meet new experiences and reflect in new ways on previous ones.

Following Darragh and Radovic (2020) and Sfard and Prusak (2005), we consider teachers' professional identity to be the stories that individuals use to justify, explain and understand themselves in relation to their work as a teacher. These stories are constructed from social discourses and provide insights into how those individuals currently view their identities in relation to the past, present and future (Lutovac & Kaasila, 2018; Sfard & Prusak, 2005). This is in alignment with Wenger (1999), who described identity formation as a learning trajectory that connects the past, present and future. However, it is important to consider prospective teachers' personal as well as professional identities, especially in relation to educational changes. If these changes produce conflict with what teachers personally desire and experience as being good, then "conflict can lead to friction in teachers' professional identity in cases in which the 'personal' and the 'professional' are too far removed from each other" (Beijaard et al., 2004, p. 109).

Research on prospective teachers' identities has focused on past and present dimensions of identity (Kaasila, 2007). For example, Lutovac and Kaasila (2018) described how prospective teachers' experiences of their own years at school contributed to their views of mathematics and their mathematical identity. There is also some research on how prospective teachers verbalize their reflective, future-oriented thoughts (Urzúa & Vásquez, 2008). This is important because teachers' professional identity includes not only perceptions of who they are as a prospective teacher, but also the kind of teacher they want to be (Beijaard et al., 2004).

Therefore, our aim is to analyze how prospective teachers described their past, present and future identities as mathematics teachers who teach through programming. The stories that the prospective teachers told provide insights into how they interpret and reinterpret what Losano et al. (2018) described as their ways of being, living and projecting into the teaching profession. Professional identities provide a means to understand prospective teachers' considerations of how they should or could integrate programming into their mathematics teaching.

Methodology

To answer our research question, we interviewed a focus group of five prospective teachers, in 2019, about the introduction of programming in mathematics education. At that time, it was known that programming would be part of the new curriculum to be implemented from August 2020, but the final version of the curriculum had not been released. This study was part of a wider study, which included the questionnaire reported on in Kaufmann and Maugesten (2022).

After Kaufmann and Maugesten's (2022) analysis of the survey produced unexpected results, we conducted a focus group interview to obtain additional information. A focus group interview was used because, as others had noted (Bjuland et al., 2012; Ponte & Chapman, 2008), a crucial aspect of a teacher's professional identity is expressed in their participation in the processes of interacting and collaborating with other teachers, and when they are reflecting on their own activity and about themselves as teachers. A focus group interview provided the possibility to explore how a group of prospective teachers reflected on their professional identities in relation to the introduction of a new educational change—the introduction of programming into mathematics teaching.

Convenience sampling (Lewis-Beck et al., 2003) was used, with volunteers being requested, from one class of 19 prospective teachers in their third year of teacher education for teaching Grades 1–7. Five prospective teachers agreed to participate. The first author was their lecturer in the first year of their teacher education. However, none of the authors had a relationship with these prospective teachers when the interview occurred. The prospective teachers were informed that participation was voluntary and that they could withdraw at any time. The participants were five women aged 21–23 years. These were typical demographics for prospective teachers in Norway, with the majority of prospective teachers for Grades 1–7 being women aged between 20 and 25 years. These were also the most common group in our survey results. The focus group participants had programming experience as part of someone else's Bachelor project, but had not engaged in programming in their spare time. None of them have had experience in teaching programming in mathematics or in school, but had observed a mathematics lesson when a teacher used programming.

The first and second authors of this article conducted the interview, which lasted 47 minutes. The interview comprised questions on digital tools and programming. Although the focus of the questions was on programming, the prospective teachers often compared their experiences with using other digital tools.

Analyzing the focus group interview

Once the interview had been transcribed, the first and second authors read through the text independently. Initially, all statements concerning programming and digital tools were identified. The informants often used programming and digital tools as synonyms; thus, isolating specific points related to programming was sometimes difficult.

Once the relevant terms had been found in the transcript, two stages were undertaken to understand how the prospective teachers viewed the relationship between programming and their professional identity. The first step involved identifying when prospective teachers were talking about their professional identity in relation to programming. The second stage was to determine whether their statements were connected to their past experiences prior to teacher education, their present experiences as prospective teachers, and their expectations of being a teacher in the future.

In the first stage, we identified stories about their experiences with digital tools that they related to programming in mathematics. We determined whether the stories were interpreted or re-interpreted by the prospective teachers in relation to their professional identity. In the stories, the prospective teachers used the subject pronouns "we" and the generic "you." We considered that the use of such pronouns indicated that by sharing these stories the prospective students situated themselves as having the same or similar experiences, and so had similar self-understandings about their professional identity. An example of one such story is from one of the participants.

> I think there is much we take for granted. It is kind of like, like mobile phones, we have always grown up with mobile phones. But my dad, he did not have a mobile

phone until much later. So that is new to him. And harder for him to handle than for me, who has always had one. It will be the opposite for me as a teacher. I think it will be more difficult to move away from digital devices, and teach without any technological devices.

In this extract, the prospective teacher tells a story about their own experience and how it relates to their professional identity as a teacher, although she uses "we" at the beginning to indicate that the story was likely to be shared and interpreted in similar ways by the other prospective teachers. As such, it illustrates the social construction of her self-understanding, in which this prospective teacher reflected and re-interpreted her past experiences in relation to her future role as a teacher.

The second stage involved identifying the stories that the prospective teachers told about the past, such as their experience with programming in school and the use of digital tools in their leisure time. They also described their current experiences in their teacher education and how programming could be included in the mathematics curriculum, and their future expectations about being mathematics teachers. Their stories gave insights into their professional identities as they provided an understanding of how they saw their ways of being, living and projecting into the teaching profession (Losano et al., 2018). This was important in understanding how educational change, through the incorporation of programming into mathematics teaching, was integrated into the prospective teachers' professional identities.

The development and refinement of the collective stories that the prospective teachers told was an ongoing iterative process. Reading them repeatedly led to them being evaluated several times by the first and second authors, working as part of the data analysis. Any cases of disagreement about the analysis were discussed with the third author, in the process of establishing trustworthiness.

Results

During the focus group interview, the prospective teachers related their experiences of digital tools and programming in their previous education, current prospective teacher education, which involved both learning on practicum and on campus, and their future role as teachers. In so doing, they provided insights into their professional identity through their self-understanding about how aspects of their lives related to the teaching profession, and what they needed to learn to fulfil the professional requirements (da Ponte et al., 2002).

The past: their previous education

Although the five prospective teachers had not had experience of programming when they were at school, they had had experience of other digital tools, which provided them with the confidence to consider how they could teach mathematics in the context of programming:

PT3: I remember that, as a student, we used the Smartboard from 5th grade, I think. It was at that time that Smartboard became popular. We also used GeoGebra in the classroom. I have learned Excel too. It has been such a big part of my life, my whole life, so it is easier for me to learn programming and use it in teaching, as I have a relationship with digital tools.

PT2: I think we take too much for granted. It's a bit like, like phones. We have always grown up with phones… For us, it will be more difficult not to use Smartboard… So I think we have an advantage that we have grown up with it.

In these quotes, the prospective teachers related the requirement for the integration of programming in mathematics education to their previous experiences of mastering other digital tools. Their self-understanding about the ease of mastering other digital tools suggested that they could master programming for mathematics education fairly easily. In fact, they considered that not using the latest digital tools would actually be likely to impede their possibilities for teaching. It seemed that these self-understandings led the prospective teachers to align themselves with what Prensky (2001) called digital natives, who, having been born at a particular point in time and living in a digital world, expected to keep having access to newer and better technology as part of their everyday experiences.

The use of the pronoun "we" by PT3 suggests that this prospective teacher considered that the others in the group would have similar experiences and self-understanding about being digital natives (Prensky, 2001), highlighting that the social construction of their stories was related to their shared experiences. Although the prospective teachers did not discuss this explicitly, their self-understanding (Losano et al., 2018) as digital natives would most likely have been constructed from wider discussions in society, in which they were positioned as being able to master technology easily.

The present: teacher education on campus and on practicum

When the interview was conducted, at the end of 2019, the prospective teachers knew that programming, as part of computational thinking, would become part of the mathematics subject curriculum from August 2020. Although they had no experience of programming in relation to mathematics from their on-campus experiences of teacher education, they had encountered it being used in schools during their practicum periods. For example, two of the prospective teachers referred to a practicum episode in which high-performing mathematics students were able to program after they had finished the set classroom tasks. The prospective teachers used these experiences and expectations to reflect on what they needed to learn and why programming was crucial.

I: What do you think about adding programming to the mathematics curriculum?
PT1: It is quite cool.
PT2: I think programming will be fun as there are a few more challenges. I do not know; I do not know enough about it, that is, all aspects of programming. How to take advantage of what you learned about programming in real life, in a way. But the idea of implementing programming, I have experienced that it is positive for the students, at least. So… it certainly gives them motivation, even if it does not result in learning.
PT3: It could be difficult to link programming to all the mathematics subjects. And it could be a challenge to teach programming to the youngest children. But it could also be easy; it depends on what you are teaching.
PT4: Then you have robots that you can program to walk around. And then they see the robot move. This could be fun for the students. We have to put some effort into that. How to do it, and yes, with a positive attitude.

As was evident with the survey results from the Norwegian prospective teachers (Kaufmann & Maugesten, 2022), the participants in the focus group interview had positive perceptions of programming being included as part of the competence goals in mathematics. They described programming as being fun and motivating for the students. This had similarities with what Piedra (submitted) found from examining prospective teachers' written reports from their practicum experiences of implementing ICT into their mathematics teaching. However, as was also the case with Piedra (submitted), there was no discussion about how programming could be connected to mathematics. Their focus on motivation instead of content could provide an explanation for the results from the survey, in which 39 per cent of the prospective teachers identified programming as being valuable for teaching mathematics in multicultural classrooms and differentiated teaching (Kaufmann & Maugesten, 2022).

With regard to the demands presented by the government-initiated requirement to integrate programming into mathematics education, the prospective teachers felt that programming would provide challenges. Implicitly, they emphasized the students' enjoyment of being challenged and considered that this factor would motivate students, even if no actual learning occurred. Using their experiences from practicum, they reflected on how being a teacher included motivating students, indicating it was enough to have fun when programming in mathematics. Although they recognized a need to consider how programming could be connected to the mathematics that students needed to learn, they focused on the importance of motivating students if learning was to occur.

I: What strengths do you have that will help you to use digital tools in mathematics teaching?
PT1: We have a positive attitude toward digitization and programming. I find that many teachers perhaps don't have such an attitude. They are more like "Oh, that wretched PC, it never works." Or such things. But we like to have a very positive attitude. We are very fond of digital stuff. So, maybe the fact that we have a positive attitude will rub off on the children. So, it is very important that the teacher should find it interesting and useful. If not, then the students won't see it as being important, or they will find it tiring and difficult.
PT2: Yes, I believe that we have an advantage, as we have grown up with digital tools, as have the children who are also now growing up with them.

Following the need to motivate students through the use of digital tools, the prospective teachers' self-understanding (Losano et al., 2018) led them to emphasize that they needed a positive attitude toward digitization and programming. They considered this to be in contrast to many teachers who did not have this attitude. A negative attitude would result in students becoming unmotivated to engage with "digital stuff". In projecting forwards into their future teaching, they felt that being a mathematics teacher would require them to have a positive attitude toward programming. Having the appropriate attitude would enable them to motivate their students, which is not something they would find challenging because, like the students, they were digital natives who would share an interest in and enjoy programming in the mathematics classroom. This self-understanding about having the necessary attitude could explain why so many of the prospective teachers (78%) in the survey (Kaufmann & Maugesten, 2022) had a positive attitude toward the introduction of programming in the new curriculum, even though only seven of the 394 survey respondents had regular programming experience from their leisure time.

The consistent use of the pronouns "we" and "them" indicated that the prospective teachers seemed to identify the school teachers and themselves as two groups, in terms of experience with digital devices and programming, attitude toward the subject, and learning something new, such as programming. Because these prospective teachers were in their third year of study, we were surprised that they did not identify with their future colleagues. Meaney and Lange (2012) found that their first-year prospective teachers had a sense of identity as students, which had been instilled in them from their time at school. Perhaps even in their third year of study, they had difficulty aligning themselves with the shared identity of being a school teacher, when the differences in skills and knowledge related to digital tools seemed large. What seemed more important to them was their willingness to learn about a new digital tool, and this quality aligned them more with school students than with school teachers. From the perspective of the government requirement to integrate programming into mathematics education, there appears to be few concerns about how the prospective teachers think they will project into the teaching profession. Their self-understanding (Losano et al., 2018) are socially constructed within the group of prospective teachers, since they have grown up with digital tools and a share a positive attitude, but this may be different if they had been socially constructing their self-understandings about their professional identities with school teachers.

The future: their role as teachers

The interviewees were aware that, in the future, their role of being a mathematics teacher would include the teaching of programming in mathematics education. However, at this point in their career, they focused more on knowing how to program than on how to teach programming to students or on making students aware of the relationship between mathematics and programming.

When imagining their work in schools, the prospective teachers perceived themselves as different to experienced teachers. As digital natives, their experience with digital tools provided them with a better basis for learning programming than teachers who had first used technology in adulthood, and who, according to Prensky (2001), were digital immigrants:

I: What will be your task as a future teacher?
PT1: I imagine that we will be the ones beginning our jobs in the schools who are going to get questions from the older generations of teachers – "You have learned programming at school. Can you show me?" And then it has to be the case that we have learned it so well that we can also teach other teachers how to use it.
PT4: Even if I and a fifty-year-old teacher get equal training in something new, such as programming, we already have a lot of knowledge, so that things become much more logical for us and maybe we understand why things are as they are.

In these quotes, the interviewees projected themselves as future teachers who will be competent and successful users of digital tools, and who would learn to program easily. They also compared themselves to older teachers, to whom they attributed an identity of not being so competent with the use of digital tools, which would impede the older teachers' ability to learn programming. As teachers, they saw themselves not only teaching programming to their students, but also to their future teacher colleagues. They would take on the position of being the experts, whose expertise would be valued in the schools in which they would work. Their self-understanding (Losano et al., 2018) as digital native is constructed from their previous knowledge and use of digital devices, from the past and present as students in school and in teacher education.

The focus group interview was completed a few days before the publication of the new Norwegian curriculum. The interviewees knew that programming would be part of the mathematics curriculum but were unaware of its implementation. This may have limited their possibilities for considering their roles as teachers of programming, or as teachers of mathematics through programming.

In the survey, a surprising result was that the respondents considered programming to be useful for differentiated teaching and multicultural classrooms, but less useful for geometry (Kaufmann & Maugesten, 2022). This result was surprising because the origins of the inclusion of programming with mathematics had been concerned with strengthening students' understanding of geometry (Papert, 1980). When asked why survey respondents might highlight that programming could be valuable in multicultural classrooms, the prospective teachers reflected on it as being a new type of language:

> *PT2: It might be a different language then, if there are linguistic difficulties. The idea that maths is … another type of language that might be a little more understandable, perhaps? And I guess programming is something that… You don't need to know Norwegian well …*
> *PT1: Programming is a separate language.*
> *PT2: Yes, that's what I was trying to say.*
> *PT4: But as there are for instance people from England or Norway, different use of words. So I think it's easier, maybe? With programming, because it is so specific.*
> *PT2: Yes, and then, maybe most students will be at the same level, in programming. Not everyone has so much experience. So, you're kind of on an equal level. It's just as unknown or just as familiar to everyone. And then you're not an outsider.*
> *PT4: I think maths is what is most relevant to learn [speak over the top of each other].*
> *PT3: And then there is differentiated teaching. We have not learned that yet.*

In this extract, the prospective teachers address the demands of working with programming in multilingual classrooms. Although they did not consider this to be a difficult challenge, they did seem more uncertain about what the implications would be for their teaching. Programming is no longer discussed as being motivational. Instead, the interviewees had two main arguments for the importance of programming in multicultural classrooms. One argument was that programming was a separate language, although exactly what was meant by this was unclear. One interpretation is that they thought that programming had its own syntax, or that many programs used English as a programming language. There also seemed to be a suggestion that the programming language was precise, which made it more understandable. Another argument was that the prospective teachers assumed that the students had little experience of programming and would therefore be at the same level, which meant that multilingual students would not be restricted in their learning because they did not have the same knowledge of the Norwegian language as the students with a Norwegian background. However, they noted that they had not been taught about differentiating their mathematics teaching for specific students, and so it was difficult to comment on the impact of programming.

Unlike in the discussions, where they had aligned themselves as sharing a background as digital natives with their future students, the prospective teachers seemed to consider themselves to be different from students with a multilingual background or students in need of differentiated teaching. This suggests that the prospective teachers considered this group of students as needing to see themselves as being on the same level as other students in the class—"So you're kind of on an equal level."

Although the importance of connecting programming to mathematics was raised, at this stage the point was unclear. Later, the interviewer asked specifically how they viewed programming as being connected to mathematics.

I: But why is it related to mathematics?
PT2: Will there be competence goals in mathematics?
I: It should be integrated in the curriculum yes, in mathematics.
PT2: Yes, in mathematics. Then it's… That is, it makes sense since it belongs to competence goals.

In these quotes, the prospective teachers did not question the government requirement that programming should be integrated into mathematics education. Rather, they implied that, if something was in the curriculum, then they, as teachers, would be required to teach it. Therefore, their responses to the question illustrated that they did not see a mathematical reason for teaching programming, just a legal one.

The survey results and the absence of any mention of mathematical topics in the focus group interview suggest that the prospective teachers were more concerned about their own ability to program and pedagogical concerns, such as motivation, than about teaching specific mathematical topics through programming. This finding is consistent with Pörn et al. (2021), whose study indicated that only a few teachers were able to connect programming to central computer science concepts, such as algorithms and abstractions, and to mathematical content. It may be that, in time, broader discussions about what the introduction of programming means for the teaching of mathematics could contribute to the prospective teachers increasing their understandings about possible connections. However, at this point in their teacher education, it seems that their self-understandings (Losano et al., 2018) about what role they could have as a school teacher affected what they saw as the possibilities for including programming in their mathematics teaching.

Discussion

Current curricula in Norway (Ministry of Education and Research, 2020) and elsewhere require that programming is integrated into mathematics education. For programming to not just become another tool that teachers resist or have difficulty integrating (e.g., Kaufmann & Stenseth, 2020), there is a need to understand how prospective teachers' identities affect their own perceived possibilities as teachers of mathematics through programming. Our research question was: How do prospective teachers describe past, present, and future aspects of their professional identities as teachers of mathematics through programming? Our findings contribute insights to the limited research on prospective teachers' views on the integration of programming into mathematics education by considering how its introduction affects their self-understandings about their professional identities.

Our survey of 394 Norwegian prospective teachers found that they considered programming to be useful in mathematical topics such as numbers, algebra and functions, and problem solving, but they were more sceptical about the usefulness of programming in geometry (Kaufmann & Maugesten, 2022). The prospective teachers also perceived programming to be valuable for teaching in multicultural classrooms and differentiated teaching. These results were surprising because they were different to those in previous research (e.g., Ndlovu et al., 2020). The focus group interviewed allowed us to explore those results in more depth and relate them to prospective teachers' self-understandings about the role of mathematics teachers.

The focus group interview reinforced the findings that the prospective teachers had a positive attitude toward programming. None of the prospective teachers questioned the introduction of programming in mathematics education, seemingly because, as part of the curriculum, they were obligated to incorporate it into their mathematics teaching. Their current knowledge about programming meant that they could discuss programming in relation to its advantages in multilingual mathematics classrooms, but not in relation to different mathematical topics. Instead, they seemed to see their professional identity as a teacher as being one of motivating the students. When they compared themselves with already employed or 'old' teachers, whom they seemed to see as digital immigrants, they considered that having grown up with digital tools made it easier for them to embrace new digital tools such as programming. This meant that their teacher professional identities were not so far removed from their personal identities and did not cause the potential conflict that Beijaard et al. (2004) suggested could occur when education changes forced a chasm between these identities.

At this point in their career, their professional identities seemed to be strongly connected to their understanding of themselves as being digital natives (Prensky, 2001). This valuing of easily being able to master digital tools seemed to have been adopted from their past and present experiences, and then projected onto their professional identity as teachers. It is perhaps not surprising that the prospective teachers highlighted such a connection to their role of being a teacher, as it allowed them to position themselves as being able to make a positive contribution to the schools in which they would work in the future.

By sharing a positive attitude toward digitalization and programming with their students, they considered that it would be easy for both themselves as teachers and their students to learn programming. This would allow them to make connections with the students that they implicitly seemed to assume were part of the role of being a teacher. This implicit assumption could also reinforce the idea that programming, similar to other digital innovations, was primarily to be used to engage and motivate students to learn (Kaufmann & Ryve, 2022). We find similar indications in our results, as the prospective students emphasize the teacher's motivational role, focusing on having fun with a positive attitude, and do not emphasize creating instructional contexts.

Even though the prospective teachers were required to teach mathematics through programming, they were uncertain that students would be able to learn mathematics this way; instead, the students could be motivated to learn incidental mathematics when using programming. Given that, as documented in earlier research (Eckert & Hjelte, 2021), many teachers reported that students who engaged in programming did not engage with mathematical ideas or were not aware that they were using mathematics, it is perhaps not surprising that the prospective teachers were also not able to articulate how to teach mathematics through programming, or how to make students aware of this possibility. However, until they are taught how to integrate programming into their mathematics teaching in their teacher education program, they are unlikely to be able to socially construct understandings about how this can be achieved. As a result, their professional identity will only be connected to motivating the students with programming to perhaps learn mathematics alongside.

Although the prospective teachers understood that they would be responsible for teaching programming, they only mentioned this explicitly regarding the need to teach their future older colleagues. They did not seem to consider that they would soon share the professional identity of these teachers already employed in the school. Instead, they regarded these teachers as having different identities, that of being digital immigrants (Prensky, 2001). The students would not need to be "taught" programming in the same way because, as digital natives (like the prospective teachers), it would be easy for them to learn.

In describing past, present, and future experiences, the prospective teachers indicate how they envisioned their professional identity as a teacher of mathematics through programming. Their lack of discussion of mathematical topics suggests that they did not see mathematics as something that could be taught through programming. It was, therefore, not part of the professional identity that they already considered that they had (such as being good with digital tools) or something that they would need to learn before they went out into the classroom (such as differentiated teaching or how to program). We had expected that prospective teachers would focus more on what they needed to learn about the relationship between mathematics and programming. However, given previous research with teachers, it is perhaps not surprising that this connection was not a feature of their awareness, perhaps because such discussions were not available to be included in the social constructions of their self-understandings.

Conclusion and implications

The research question focused on how prospective teachers described past, present, and future aspects of their professional identities as teachers of mathematics through programming. They referred to themselves as being able to easily master digital tools, which would contribute to them mastering programming, equally as easily. They ascribed a similar identity to their future students, but not to their future colleagues, whom they seemed to consider as being digital immigrants (Prensky, 2001), who would need to be taught programming in a more explicit way than their future students. The prospective teachers emphasized their role as future teachers as being resource people for their colleagues. However, as part of their self-understanding, they admitted having a lack of knowledge of programming, although they seemed confident that their general knowledge of digital tools would provide them with the appropriate background to be teachers who would teach programming alongside mathematics. They did not seem to recognize that teaching mathematics through programming would require an understanding of how different mathematical topics could be related to different aspects of programming, such as abstraction and debugging.

The findings of this study have implications for teacher education. The focus group interview revealed that the prospective teachers' self-understanding concerned the use of programming primarily to motivate and engage students. If they were to develop a professional identity as teachers who teach mathematics through programming, then their teacher education courses need to develop an understanding of how programming can develop students' understanding of mathematical concepts.

As professional identity is constantly reconstructed in response to experience (Lai & Jin, 2021), the prospective teachers need understandings about how programming relates to mathematics to become successful teachers of mathematics through programming. An implication for further research would be to conduct a longitudinal study of how professional identity is affected across prospective teachers' experiences in teacher education and into their first years of being a classroom teacher. This research would show how new experiences for prospective teachers in their teacher education courses and in schools influence their self-understanding of their role as teachers of mathematics teaching programming as part of their professional identity.

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Declarations

Conflict of interest The authors declare that there are no competing interests.

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