A Case Study of Four Beginning Mathematics Teachers' Formative Assessment Strategies

Eva-Lena Erixon
Stockholm University

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Depending on how it is adopted, there are potential learning gains when teachers use formative assessment. It is difficult, however, for teachers to learn and implement and beginning mathematics teachers are not adequately prepared to use formative assessment. Further studies are needed to support the learning and understanding of how teachers develop their use of formative assessment when teaching mathematics. This qualitative case study addressed this need by characterising four beginning mathematics teachers' formative assessment strategies; that is, focusing on aspects that teachers can use to improve their teaching and learners can use to improve their outcomes. Data were generated from twelve video-recorded lessons. The teachers who participated in the study had graduated from the same teacher programme at a Swedish university and they each had about 18 months of teaching experience after graduation. The findings show that the most notable differences in teacher practices concern the types of questions they ask, how frequently they give feedback, and which feedback types dominate their practice. These differences also affect classroom interactions. The findings are discussed in relation to those aspects of formative assessment that pre-service teachers need to learn about during their studies. The discussion concludes with some implications for teacher education.

Keywords • mathematics teacher education research • beginning mathematics teacher • formative assessment • mathematics teachers • teacher education

Introduction

Formative assessment is difficult for teachers to both learn and implement effectively (Ayalon & Wilkie, 2021), and beginning teachers are not always adequately prepared to use it in practice (Popham, 2009). They often lack both the knowledge and skills required, which highlights the fundamental role teacher education has in preparing teachers to use high-quality formative assessment practices (DeLuca & Klinger, 2010). Also, given the complexity of formative assessment it is important that pre-service teachers get the opportunity to develop assessment strategies during their teacher education to avoid them merely reproducing what they experienced as learners (Shepard, 2000). Although both personal and contextual factors affect the implementation of formative assessment, education has been shown to have the greatest impact (Yan et al., 2021).

There is some agreement among researchers that formative assessment plays a central role in and can have a positive impact on learners' outcomes (Dayal & Chand, 2021; Heitink et al., 2016; Pinger et al., 2018; Shepard, 2000). More specifically, Pinger et al. (2018) found that formative assessment had positive effects on both learners' mathematics achievement and interest. Hattie and Timperley (2007, p. 102) claimed that "[f]eedback is among the most critical influences on student learning", and "[f]ormative assessment is about feedback" (Tillema, 2010, p. 563). Reports, however, on the effects of formative assessment on learners' achievement differ. It is proposed that this may be due to differences in how formative assessment is implemented (Boström & Palm, 2023; Yan et al., 2021).

Researchers have argued that there is a need to explore further and describe more explicitly the characteristics of formative assessment practices (Andersson et al., 2017; Boström & Palm, 2023; DeLuca & Johnson, 2017; Gotwals et al., 2015; Ozan & Kincal, 2018; Yan & Pastore, 2022). Ozan and Kincal (2018) also suggested that teachers' formative assessment practices should be examined further through

qualitative studies. More specifically, DeLuca and Johnson (2017) identified an urgent need to support both teachers' work and their learning of assessment practices, arguing for more research that provides deeper insights into how to support pre-service teachers as well as practicing teachers. This study will contribute to the field by exploring and characterising four beginning teachers' use of formative assessment strategies to better understand how formative assessment can be implemented in practice and how the use of formative assessment during whole-class instruction can be developed to further enhance learners' outcomes. The findings will also be discussed in relation to implications for teacher education.

The research question guiding this study was:

> *What is characteristic of the formative assessment strategies of four beginning mathematics teachers during whole-class instruction?*

Background

Defining Formative Assessment

Formative assessment has been on the education agenda globally for decades (Birenbaum et al., 2015). In educational assessment a distinction is made between the assessment of learning for grading and reporting, and assessment for learning with the purpose of enabling learners to improve their learning (Elwood & Klenowski, 2002). Formative assessment emphasises ongoing monitoring and collecting evidence of students' progress throughout the learning process, while summative assessment primarily concentrates on measuring and reporting students' learning achievements at the end of a learning period (Yan et al., 2021). Drawing on three key processes in learning and teaching—establishing where the learners are in their learning, where they are going, and what needs to be done to get them there (Black & Wiliam, 2009), Wiliam and Thompson (2008) developed a framework to guide researchers studying formative assessment. In the framework, formative assessment, or assessment for learning, is conceptualised by one overarching "big idea" and five key strategies (KS) that can be seen as indicators of formative assessment practices:

1) Clarify and share learning objectives and success criteria.
2) Create opportunities where the learners can show evidence of their learning, for example, through classroom discussions and questioning.
3) Provide feedback to support learners' achievement.
4) Support learners to act as instructional sources for one another, for example, through peer assessment.
5) Enable learners to own their learning, for example, through assessment.

The "big idea" is that the teacher uses information about learners' achievement to adjust teaching to better meet their needs (Wiliam & Thompson, 2008).

Although formative assessment is acknowledged as good classroom practice, it is often described as a practical and conceptual "work-in-progress" and researchers suggest that more work needs to be done to develop both the classroom practice (Bennett, 2011) and its conceptualisation (Bennett, 2011; Torrance, 2012; Van der Kleij et al., 2015).

Teachers' Use of Formative Assessment

It is important to be aware of how formative assessment is used by teachers, because its potential to enhance learning depends on both the learning context and the manner in which it is implemented (Black & Wiliam, 1998). However, research indicates that this is a challenging practice for teachers to adopt (Furtak, 2012). Both teachers' content knowledge and pedagogical content knowledge affect teachers' formative assessment practices (Furtak, 2012), and teachers need substantial knowledge to implement high-quality formative assessment (Bennett, 2011). Bennet concluded further that teachers,

in general, do not possess that knowledge, and that they needed both time and targeted support to develop it.

Without sufficient pedagogical content knowledge, teachers may struggle to identify student misconceptions and to provide effective feedback (Schildkamp et al., 2020). It is often the case that beginning teachers may be underprepared to utilise assessment strategies that enhance learners' outcomes (Mitchell, 2006) and find themselves needing additional support to assess learners' achievement and to address gaps when instructional goals are not realised (Wenzel et al., 2023). They also need time to reflect on their experiences of formative assessment through engagement in cycles of use, reflection, and adaptation. Of importance is teachers exploring and reflecting on their own teaching, especially how they ask questions and give feedback, to develop their formative assessment practices (Torrance & Pryor, 2011). For feedback to be effective, the teacher needs to analyse the learner's response in order to understand the thinking behind it (Black & Wiliam, 2009), identify specific actions for learner improvement, and adapt instruction to better support learning (Gamlem, 2015).

Guiaya and Bueno (2019) explored how questioning in mathematics education affects learners and found that the use of questioning as a formative assessment strategy enhances learning. It is crucial that teachers' questioning is framed to explore key features of learning and to promote a classroom climate where learners can share their ideas even if they are not confident that they have the right answers. The learners need to be an active part of their own learning and for this to take place the teacher has to create the right classroom environment (Black et al., 2006). When mathematics teachers ask follow-up questions it is vital that they listen to and interpret the learners' answers. They must allow enough wait time for learners to prepare answers, revoice learners' contributions, encourage discussion, and ask questions that give their learners the opportunity to elaborate on their initial responses and provide alternative answers (Lim et al., 2020). Research indicates that learners who encounter teachers who listen and interpret carefully are given the opportunity to take part in more mathematically productive discussions and their role shifts from being a respondent to being an active participant (Lim et al., 2020). Classroom activities in which learners are active participants provide them with a platform to make their mathematical ideas visible in discussions. These activities are valuable because they offer rich opportunities for learners to develop conceptual understanding of mathematics (Kazemi & Stipek, 2001).

Teachers knowledgeable about formative assessment may still face challenges when implementing it in the classroom (Govender, 2019). It seems they struggle to create a balance between their beliefs about and experiences of teaching and use of formative assessment. and tend to maintain classroom practice that mirrors those beliefs. Unfortunately, beliefs about conventional approaches to effective learning and teaching tend to emphasise testing and demonstrate limited awareness of assessment for learning (Dayal & Chand, 2021). Implementation of formative assessment is also affected by contextual factors such as school environment, internal school support, and working conditions (Yan et al., 2021).

Teacher Education and Formative Assessment

Teacher education has a critical role to play in preparing competent beginning teachers and when it comes to assessment education an approach is needed "that integrates practice, theory and philosophy across concepts of assessment of learning and assessment for learning" (DeLuca & Klinger, 2010, p. 424). The first aspect relates to what a teacher does in the classroom, the second to knowledge of assessment and evaluation, and the third to broader philosophies of teaching and pedagogies (DeLuca & Klinger, 2010).

Sleep and Boerst (2012) argued that there should be a focus on formative assessment in teacher education because of its challenging nature and its importance in teaching. DeLuca and Klinger (2010) found that pre-service teachers benefit from assessment instruction in courses. Teachers and especially beginning teachers lack knowledge and skills about assessment. The authors concluded that if teacher education does not provide compulsory courses in assessment (both summative and formative), then the pre-service teachers rely on developing assessment competence during their practicum where they become dependent on the knowledge and skills of their colleague teachers (DeLuca & Klinger, 2010).

According to Akkoç et al. (2016) teacher students' beliefs about the importance of assessment can be reinforced by observing mathematics teachers' use of formative assessment during practicum.

Teacher education, with the fragmented structure of campus and practicum, and instructors with different approaches to assessment, poses a challenge for education about assessment (DeLuca & Volante, 2016). "Instructors' own levels of assessment capability might also, in some cases, be lacking" (DeLuca & Johnson, 2017, p. 121). Hamodi et al. (2017) explored the influence of pre-service teachers experiences of formative assessment during their teacher education, on practicum. The pre-service teachers highlighted two difficulties when trying to implement formative assessment in their teaching—their working environment and the students' families. The findings show that "rigid environments, where few work colleagues are innovative, interfere the implementation of these types of assessment systems" (Hamodi et al., 2017, p. 184); that is, the teachers need to fit into the general work environment. Problems about assessment expressed by learners' families relate to their traditional perceptions of assessment as examination (Hamodi et al., 2017).

Teachers' understanding of educational assessment and the skills needed to practise it would develop if teacher education prepared pre-service teachers adequately. There are some implications relating to the content and structure of assessment education; lecturers in teacher education need to be up to date about assessment research and provide opportunities for the teacher students to connect theory and practice. Additionally, teacher students need to be given opportunities to reflect on their concepts and practice in relation to assessment (Xu & Brown, 2016). Teachers' implementation of formative assessment is also partly based on their own definition of the concept, so it is important for teacher education to be cognisant of the fact that teachers do not have a shared understanding of the concept (Harris, 2016). To enhance pre-service teacher opportunities to develop high-quality formative assessment practices, Buck et al. (2010) suggested including field experiences that involved with cycles of planning, teaching, and reflection in relation to assessment practices.

Methodology

This study employed a qualitative case study research approach, as this methodology "provides tools for researchers to study complex phenomena within their contexts." (Baxter & Jack, 2008, p. 544). This multiple-case study (Thomas, 2011) comprises four cases and was designed to explore the characteristics of four beginning teachers' formative assessment strategies during whole-class instruction.

Context of the Study

This study was part of a larger study called TRACE (Tracing Mathematics Teacher Education in Practice), where one of the aims were associated with identifying the influences of teacher education on teachers' learning. The teachers in this study were chosen because they had graduated as Grade 7–9 mathematics teachers from the same teacher education programme at the same university and they had all had about 18 months of teaching experience since graduation. The teacher education programme was designed for students who had already completed the required mathematics studies. Over three semesters, pre-service teachers studied pedagogy and mathematics education and participated in practical training. One semester focused on mathematics education where perspectives on teaching and learning in mathematics were deepened. For example, the pre-service teachers studied the relationships among teaching, learning, and assessment of learners' knowledge and skill development. A particular emphasis was placed on the formative and summative functions of assessment, as well as creating a learning environment conducive with implementing assessment and grading practices in a way that would promote equity and improve students' learning.

Participants

For this study, the requirement was that the students had graduated as teachers for Grades 7–9 and were beginning teachers who had been observed in the classroom as part of the larger study, were

selected. Gabriella, Ethan, Talia and Alexander (pseudonyms) gave informed consent to be involved in the study. Gabriella and Ethan graduated in January 2017 and were observed in October 2018. Talia and Alexander graduated in February 2018. Talia was observed in September 2019 and Alexander in October the same year.

Data Collection and Analysis

The data for this qualitative case study were collected from 12 video-recorded mathematics lessons taught by the four beginning mathematics teachers (i.e., three mathematics lessons per teacher taught in sequence). To characterise the formative assessment strategies of the four beginning mathematics teachers', the video recordings were transcribed verbatim before being coded. To ensure dependability, the data were coded on two different occasions to reduce inconsistency in the coding. Further, the transcripts from two video recorded lessons were coded individually by two scholars, who also went over the coding jointly to resolve discrepancies until complete agreement was reached.

The characteristics of the formative assessment strategies of the four beginning mathematics teachers utilised during whole-class instruction were described in terms of the formative assessment activities the teachers used in their mathematics teaching. The coding was structured according to the framework proposed by Wiliam and Thompson (2008), where formative assessment is conceptualised as consisting of five key strategies. The main codes in the coding manual according to the key strategies were as follows: transparency of the learning goals and success criteria (KS1); elicitation of information about learner learning (KS2); teacher feedback (KS3); peer feedback (KS4); and learners' regulation of their own learning (KS5). Indicators of KS1 are activities related to the teachers' clarifications of the learning goals and criteria of success to the learners; KS2 are activities focused on eliciting information about learner learning; and KS3 are activities corresponding to the way the teachers respond to learners' comments. Indicators of KS4 and KS5 are activities during whole-class instruction that concern how the teachers provide the learners with opportunities and encouragement to give peer feedback and regulate their own learning.

Activities based on the data were given subcodes (see Table 1). Although the initial subcodes for the five key strategies were based on previous research (Andersson et al., 2017; Andersson & Erixon, 2021), they were refined and expanded as needed. To make the coding procedure transparent, Table 1 presents the data, which includes quotations from the transcripts.

Table 1
Subcodes and Examples from Data for each Key Strategy

Main code	Subcodes	Examples from data
Transparency of the learning goals and success criteria (KS1)	Explicit formulated learning goal (ELG)	Gabriella: Today we will start with something new, namely polynomials.
	Explicit formulated learning sub-goal (ELSG)	Talia: We will learn how to calculate the perimeter of a circle.
	Implicit formulated learning goal (ILG)	Alexander: Why is it useful to know about angles?
	Goal of doing (DG)	Ethan: We begin by doing the tasks in Chapter 2:3.
	Criteria of success (CS)	Gabriella: The highest level is when you can use this in a different context.
Elicitation of information about learner learning (KS2)	Learner engagement which provides opportunities to elicit evidence of learning (EE)	The teacher engages learners by asking them to contribute to whole-class discussion and by writing their solutions to mathematical tasks on the whiteboard.
	Questioning The teacher asks a 'how, why, what' question that requires more developed answers (QD) and questions that require short answers like, "Yes" or "No" (QS)	Gabriella: What about the first one, a plus b raised to two, what happens if you expand that? Alexander: If you know the first one, can you calculate the other one?
	Using assessment material (AM)	Ethan: Yes, we will do one [exit ticket] today and one tomorrow, to follow up on what you have learned.
Teacher feedback (KS3)	Answering a question from a learner (FA)	Learner: Yes, but I don't understand how to factorise, what does it mean? Ethan: You take a number and rewrite it with several factors. In this case, two factors.
	Repeating what the learner said (FR)	Learner: Something with 3,14. Talia: It is something with 3,14.
	Confirming the answer as correct or acceptable (FC)	Learner: It [the prime number] is only divisible by itself and one. Ethan: Right.
	Explaining (often by simplifying or deepening) (FE)	Alexander: You subtract with 180, so you can say that the angle u plus the angle v will be 180 because that is the straight angle.
	Initiating mathematical reflection on the solution process (FQ)	Talia: And explain your solution.
	Dismissing the answer as incorrect/not acceptable (FW)	Learner: A right [angle]. Alexander: No, that one was right.
	Inviting the other learners to give a response (FI)	Ethan: (refers to a solution to a mathematical task provided by a learner) Good, then divide by 12 and get 26 years …. Comments on this, anyone?
Peer feedback (KS4)	Providing opportunities to act as peer resources (PO)	Talia: Try to solve it [the task] on your own in your books. Then you will get time to discuss the solution [with your group]. Then we'll do it on the whiteboard.
Learners' regulation of their own learning (KS5)	Providing opportunities for learners to take ownership of their learning (SO)	Encouraging the learners to complete exit tickets, tests and examples of tasks from national tests for diagnostic purposes.
Use of more than one code	This is an example of a part of the dialogue containing more than one code, confirming the answer as correct (FC) and initiating mathematical reflection on the solution process (FC)	Yes, you can round to 51, but there's something else missing in the solution.

Findings

The analysis of the video transcripts showed that activities concerning eliciting information about learner achievement (KS2) and activities related to the way teachers responded to learners' comments (KS3) differ greatly among the four participants' classroom practices. Differences were observed in

classroom interactions, how the learners are involved in the formative assessment processes, and the teachers' opportunities for acquiring information about the learners' needs. To better understand the cases of the beginning teachers' formative assessment strategies, the findings are introduced with an overview of the formative assessment strategies. The characteristics of the four different practices are depicted as four different cases and each case is introduced with a short description of the mathematical content of the lessons in the next section.

Overview of the Characteristics of the Formative Assessment Strategies of Four Teachers

The teachers shared and clarified learning goals (KS1) differently, thereby offering different degrees of transparency. The learning goals were presented mainly in three ways: as an explicit formulated learning goal, as a sub-goal, or as a goal of doing (Table 2). The teachers also asked questions in different ways, with questions that required short answers, such as "Yes" or "No" (QS), dominated in three of the four classroom practices. Questions about "how, why, and what" that required more developed answers (QD), only dominated in Ethan's practice. The occurrence of these two types of questions in 60 minutes of teaching is presented in Table 2 to provide an overview of questioning related to KS 2. Table 2 also highlights the total number of feedback occasions per hour of class time and Figure 1 shows the five most used feedback types (KS3). Although the purpose is not to focus on quantitative aspects in relation to KS2 and KS3, this overview is important to better understand the qualitative differences and the presentation of how these practices are characterised.

Table 2
Overview of the Four Teachers' use of Formative Assessment Strategies

	Alexander	Gabriella	Ethan	Talia
The goal is presented mostly as …(KS1)	a goal of doing	an explicit formulated learning goal or subgoal	a goal of doing	a goal of doing and as an explicit formulated sub-goal
Number of questions (QD+QS) used per 60 minutes (KS2)	109 (34% QD, 66% QS)	53 (47% QD, 53% QS)	15 (67% QD, 33% QS)	157 (30% QD, 70% QS)
Number of feedback occasions per 60 minutes (KS3)	102	85	145	96
Providing opportunities to act as peer resources (KS4)	Invites to whole-class discussions	Invites to whole-class discussions, encourages learners to help each other	Invites to whole-class discussions and to write solutions on the white-board	Invites to whole-class discussions and to discussions in smaller groups
Providing opportunities for learners to take ownership of their learning (KS5)	Provides opportunity to take part in whole-class discussions	Provides opportunity to take part in whole-class discussions	Provides opportunity to take part in whole-class discussions, uses exit tickets, uses national tests as diagnostic tools	Provides opportunity to take part in whole-class discussions, uses exit tickets, uses tests as diagnostic tools

Note. QS = questions that require short answers, such as "Yes" or "No," QD = Questions about "how, why, and what" that require more developed answers.

The five most common feedback types used by the teachers are presented in Figure 1:

- FA: The teacher answers a question from a learner.
- FC: The teacher confirms the answer as correct or acceptable.
- FE: The teacher explains (often by simplifying or deepening).
- FI: The teacher invites the other learners to give a response.
- FR: The teacher repeats or reformulates what the learner said.
- FW: The teacher dismisses the answer as incorrect/not acceptable.
- FQ: The teacher initiates mathematical reflection on the solution process.

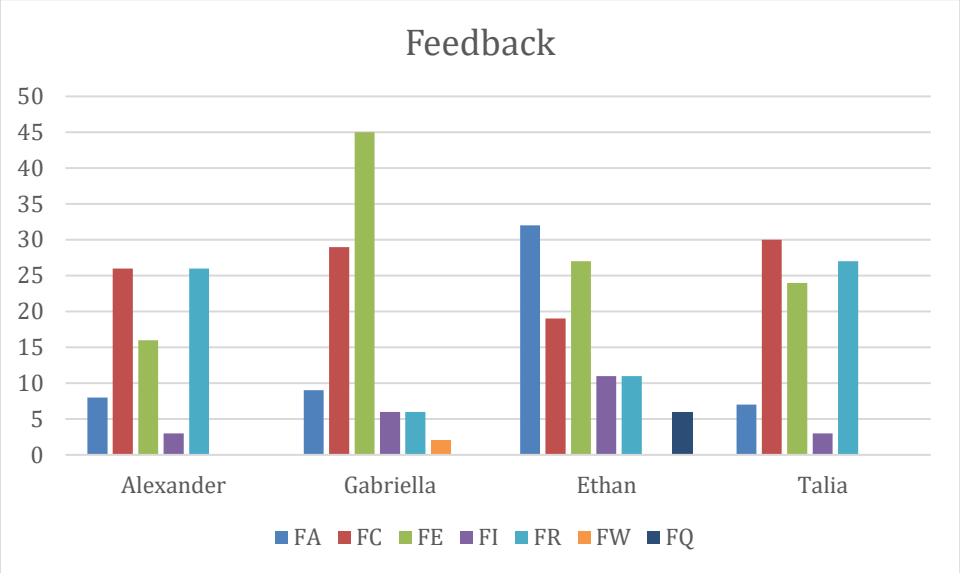

Figure 1. Percentages for the five most common feedback types used by each teacher.

In relation to KS4, there were some occasions where the teachers provided opportunities for their learners to act as resources for one another. For example, learners were asked to share their solutions to mathematical tasks on the whiteboard or to discuss them with each other in smaller groups or in whole-class discussions. The teachers sometimes provided opportunities for their learners to take ownership of their learning (KS5). For example, learners were expected to complete exit tickets, the teachers used tests and tasks from national tests as diagnostic tools and encouraged active participation in discussions about mathematical tasks and examples.

Four Cases of Beginning Mathematics Teachers' Formative Assessment Strategies

The four practices are outlined below to illustrate their key characteristics. Teachers typically began their lessons by discussing mathematical tasks or examples with the whole class, followed by a period of individual work during which the teachers moved around the classroom, observing learners (KS2) and providing individual support.

The case of Alexander

Alexander started lessons with whole-class instruction and a discussion about mathematical examples of geometry (with a focus on angles). The goal of the lesson (KS1) was presented predominantly as a goal of doing, but on some occasions, Alexander wrote examples on the whiteboard and the learners were asked to guess the goal:

Alexander: *How much have you done in this chapter? You were going to do [Chapter] 15:7.*
Teacher: *Can someone guess what we are going to talk about?*

Alexander asked many questions (KS2) compared to the other teachers and about two thirds were questions that required short answers, such as "Yes" or "No" (QS). About a third of the questions Alexander asked were about 'how, why, and what' questions that required more developed answers. An example is when Alexander and the class discussed angles and the discussion ended with a question that encouraged the learners to tell all they know about angles:

Alexander: *Aha! What more do you know about angles?*

This question led to increased interaction and participation of several learners in the discussion.

Alexander used different types of feedback (KS3) on 102 occasions per 60 minutes (see Table 2 and Figure 1). The least used feedback type in their whole-class instruction is the teacher answers a question from a learner (FA, 8%) and the most commonly used feedback type is the teacher repeats or reformulates what the learner said (FR). Alexander asks the learners which of the angles written on the whiteboard is an acute angle and repeats the answer:

Learner: *Bottom left.*
Alexander: *Bottom left, mmm.*

By repeating the answer, the teacher confirmed the learner's contribution. Later, Alexander asked questions about the definition of an acute angle. The first question, which required a more developed answer, was followed immediately by a question that only required short answers but the learners were not given the opportunity to answer the first one. The second question was answered by a learner and the teacher confirmed the answer as correct (the second most commonly used feedback type, FC) and explained FE:

Alexander: *If we call this one v, how would we write it mathematically? That is, less than 90 degrees; what does it have to be greater than?*
Learner: *0 degrees.*
Alexander: *Yes, it should be greater than 0, because otherwise it doesn't exist.*

By inviting the learners to participate in whole-class discussions, Alexander provided opportunities for them to take part in each other's explanations and answers and thereby acted as resources for each other (KS4). By actively participating in these discussions, the learners became aware of what they needed to improve based on the discussions, which created opportunities for them to take ownership of their own learning (KS5).

The case of Gabriella

The lessons started with whole-class instruction where Gabriella led discussions about algebra, which were focused on polynomial. This was followed by individual work with tasks in the digital textbook. Gabriella described the learning goal (KS1) as an explicit formulated learning goal or an explicit learning sub-goal:

Gabriella: *Today we will start with something new, namely polynomials*.
Gabriella: *Now we will soon start with second-degree polynomials.*

Success criteria (KS1) were rarely discussed in Gabriella's whole-class teaching, but there were some instances where she emphasised the importance of understanding:

Gabriella: … understand why they [perfect square trinomial formulas] look the way they do.

Gabriella asked fewer questions (KS2) than Alexander and Talia and slightly more than half of them required short answers such as "yes or no" (53%). When Gabriella asked questions, the learners were often not given an opportunity to answer, which affected the opportunities to elicit evidence of learning. The following example illustrates how Gabriella asked questions when multiplying polynomials with brackets:

Gabriella: *We start by multiplying 2x, and then we take x multiplied by 2x. We can change places on these factors because it's multiplication, then it's the same as 2x multiplied by x, but x multiplied with x? Do you remember? [turns to the learners but continues to answer the question herself, even though a learner answers the question]. That is x raised to the power of two.*

Gabriella also used questions about how, why, what that required more developed answers. On this occasion the class worked with the perfect square trinomial formula:

Gabriella: *But you know the bracket is preceded by a negative sign, and when we take away the brackets, what will happen then?*

Gabriella used different types of feedback (KS3) on 85 occasions per 60 minutes (see Table 2 and Figure 1). The teacher explained was the most used feedback type:

Gabriella: *If we are going to simplify 2x+3x+4*
Learner: *5x-4*

Gabriella: *Exactly, then we will find the terms of the same degree to add, or the same variable. In this case, these two, then it will be 5x-4'. You already knew this, right?*

Gabriella invited the learners to participate in discussions about mathematical tasks but did not always give them opportunities to answer the questions. Also, her responses to the learners when they did answer lacked feedback. This limited the learners' opportunities to engage in each other's explanations and answers and act as resources for each other (KS4) during whole-class discussions. or become aware of what they needed to improve based on the discussions; and thus their possibilities for taking ownership of their own learning (KS5). There were times, however, when Gabriella encouraged the learners to help each other solve mathematical tasks and act as resources for each other.

The case of Ethan

The lessons started with whole-class instruction where Ethan led discussions about mathematical examples of divisibility. In most cases, he presented the goals of the lessons (KS 1) in terms of what tasks to complete, as a goal of doing:

Ethan: *Solve the tasks on page 32.*

Ethan asked fewer questions (KS2) than the other three teachers and two thirds of the questions were about how, why, what that required more developed answers. He often asked the learners to explain or develop solutions to mathematical problems or to explain concepts:

Ethan: *28·1. Yes, and can you factorise this to prime factors in some way? Can you develop?*

Ethan also encouraged the learners to contribute to whole-class discussion, which provided an opportunity to elicit evidence of learning (KS2), by asking them to write solutions to mathematical tasks on the whiteboard. Ethan also used exit tickets (KS2) to follow up on what the learners acknowledged as learning:

Ethan: *Yes, we will do one today and one tomorrow, one exit [note], just to follow up on what you have learned.*

Ethan used feedback (KS3) more often than the other teachers—on average 145 feedback occasions per 60 minutes (see Table 2 and Figure 1). The frequent use of the feedback type, the teacher answers a question from a learner (FA) implies that the learners asked a lot of questions:

Learner: *What do you mean by factorise?*

Ethan: *Factorise means, if you have, for example, the number six, then you can factorise and then you can think, then you write 3·2. And then you can try to factorise as far as possible. If you think that we factorise as far as possible. Then you can take 12, 4·3 and 4 can be written as 2·2.*

By encouraging the learners to contribute to whole-class discussions about mathematical tasks and to write solutions of mathematical tasks on the white board, Ethan provided opportunities for the learners to act as resources for each other (KS4). Ethan also provided opportunities for them to take ownership of their own learning (KS5) by encouraging them to complete exit tickets, to use mathematical tasks from national tests as diagnostic tools, and to participate in whole-class discussions.

The case of Talia

Talia's lessons started with whole-class instruction and discussion of mathematical examples about geometry and problem solving. The discussions were followed by individual work from the textbook. During this time, Talia walked around the classroom, observing (KS2) and helping learners individually. In one of the lessons, Talia alternated whole-class instruction with individual work in short sessions, presenting the goal of learning (KS1) in two ways—as a goal of doing, and referring to problem solving:

Talia: *Today we are going to do problem solving.*

Problem solving was set as an explicit learning sub-goal, when the goal was to learn about the perimeter of some specific shapes.

Talia asked more questions (KS2) than the other teachers and about 70 percent were questions that required short answers such as "yes or no" (QS). Talia invited the learners to answer the questions, but did not always give them opportunities to respond, sometimes asking questions in quick succession

with a mix of questions that required short answers and questions that required more developed answers. Some of the questions had the potential to elicit evidence of learning; however, this required the learners being given opportunity to respond and interact. The following quotation shows how Talia asked questions when the class was discussing the perimeter of some specific shapes:

Talia: *What did you say? Do you have any questions? Do you want to add something? Did I forget something?*

In addition to these activities, Talia used exit tickets (KS2) to assess learning during the lesson and better understand where the learners needed further development. Talia introduced the exit-ticket to the learners as follows:

Talia: *I want to see what you have learned and what you need to learn more about after this lesson.*

Talia used different types of feedback (KS3) 96 times every 60 minutes (see Table 2 and Figure 1). The most used feedback type was the teacher confirmed the answer as correct or acceptable (FC). The following quotation is an example of how Talia confirmed an answer as correct when the class discussed scale:

Learner: *1 centimetre represents 200 centimetres.*
Talia: *Exactly.*

In Talia's classroom, there were activities that challenged the learners to discuss tasks and solutions with each other:

Talia: *Good. Then, I thought you should have time to work it out by yourselves first. Then you'll discuss in groups, and then we'll do it on the board. How does that sound?*

Several times, Talia provided opportunities for the learners to act as resources for each other (KS4) by encouraging them to discuss mathematical tasks with each other and to take part in whole-class discussions about tasks. She also provided opportunities for learners to take ownership of their learning (KS5) by encouraging the use of exit tickets, the use of tests as diagnostic tools, and participation in whole-class discussions.

Discussion and Conclusion

The aim of this study was to characterise the formative assessment strategies in whole-class instruction. Questioning as a formative assessment strategy in mathematics teaching can support learning (Guiaya & Bueno, 2019). The findings from this study showed that the types of questions the teachers used, and how they used them, differed across classrooms. Using different questionings made it possible for the teachers to elicit information about learners' mathematical thinking and learning to various extents. Although the teachers employed similar types of feedback, they used them to different degrees, and both questioning and feedback influenced patterns of classroom interaction. Whole-class discussions created opportunities for learners to act as peer resources, for example, when the learners wrote solutions to mathematical tasks on the whiteboard and when they discussed mathematical tasks in small groups. The learners were encouraged to take ownership of their learning through the use of exit tickets, diagnostic tests, and participation in whole-class discussions.

Gabriella most often used explicitly formulated learning goals or sub-goals, whereas the other three teachers mostly used goals of doing. Although learning goals are not formative assessment strategies *per se,* they are crucial for the effective implementation of other key strategies (Black & Wiliam, 2006), as formative assessment aims to enable learners to understand their learning and the goals they are working towards (Elwood & Klenowski, 2002). Clearly articulated learning goals also provide teachers with stronger opportunities to evaluate whether learners have achieved the intended outcomes and whether teaching needs to be adjusted.

Alexander and Talia asked more questions than the other teachers, the majority of which were questions that required short answers like, "Yes" or "No", and did not give the learners opportunity to elaborate on their initial responses or provide alternative answers (Lim et al., 2020). These questions were limited in their capacity l to make the learners' mathematical thinking visible (Sleep & Boerst, 2012). Talia also asked one question after another without giving the learners an opportunity to answer. It is

important that teachers interpret learners' answers carefully and let them take part in mathematical discussions to enable them to shift from being a respondent to being an active participant (Lim et al., 2020); active participation is essential for making mathematical ideas visible in classroom discussions. When mathematical ideas become visible, they can offer rich opportunities for learners to develop conceptual understanding of mathematics (Kazemi & Stipek, 2001). Teachers also need to be able to construct questions to elicit information about learner needs (Gottheiner & Siegel, 2012). However, most of the questions the teachers asked did not elicit much information about learner achievement and did not promote the development of understanding of mathematics.

Gabriella and Talia both used questions that required more developed answers about the mathematical solution processes applied. These questions invited the learners to share their thoughts about how to solve mathematical tasks. In Talia's teaching, however, the learners were often not given an opportunity to prepare answers and elaborate on their responses, representing lost opportunities for formative assessment (Lim et al., 2020). This was also the case when Gabriella asked questions and did not confirm the answers or give the learners an opportunity to respond. This highlights how important it is for teachers to reflect on how they pose questions and give feedback (Torrance & Pryor, 2001), as well as how they listen to and interpret learners' contributions in mathematical discussions (Lim et al., 2020).

Across the four cases, feedback was most commonly used to repeat learners' responses, confirm answers as correct, explain content, or answer learners' questions. Alexander and Talia primarily used two feedback types: *confirming the answer as correct or acceptable* and *repeating what the learners said*. These feedback types do not focus on learners' reasoning or understanding of mathematical content. The feedback type *answering a question from a learner* was used infrequently, which suggests that the learners rarely had opportunities to make their mathematical thinking visible through questioning. Gabriella differed from Talia and Alexander in her more frequent use of explanatory feedback. Although such explanations support the visibility of mathematical content, the limited use of learner-initiated questions and the restricted opportunities for learners to respond suggest constrained opportunities for learners to contribute their own mathematical thinking.

Ethan's feedback practices differed from those of the other teachers as he frequently responded to learners' questions. This meant that much of his feedback, created opportunities to make mathematical thinking visible. When learners actively formulated questions, they expressed what they understood or needed support with, allowing Ethan to adapt his teaching accordingly. His practice aligns more closely with effective formative assessment, including analysing learners' responses to understand their thinking (Black & Wiliam, 2009), identifying actions for learner improvement, and adapting instruction to support learning (Gamlem, 2015). In contrast, the feedback practices of the other teachers had more limited potential for informing instructional decisions.

Although the four beginning teachers had graduated as Grade 7–9 mathematics teachers from the same teacher programme, had similar teaching experience, and worked within the same curriculum context, their formative assessment strategies differed markedly, especially in relation to questioning, feedback, and the interaction. These differences raise questions about opportunities provided in teacher education for learning about formative assessment. Research suggests that using formative assessment is challenging for teachers and especially for beginning teachers (Bennett, 2011; Furtak, 2012; Popham, 2009), and that both content knowledge and pedagogical content knowledge influence its implementation (Furtak, 2012).

Teacher education is therefore fundamental for development of formative assessment competence (DeLuca & Klinger, 2010; Xu & Brown, 2016). Previous research highlights the importance of providing opportunities for the teacher students to connect theory and practice (Xu & Brown, 2016), and providing opportunities for reflection. Some pre-service teachers, however, reported having limited experience in connecting theory and practice (Christiansen & Erixon, 2024). Another aspect is opportunity for pre-service teachers to reflect on practice in relation to formative assessment (Xu & Brown, 2016). During their teacher education, they need to be part of a parallel process of practice and reflection (Andersson & Erixon, 2021) and reflection should be integrated into cycles of planning and teaching (Buck et al., (2010).

The study highlights the need for teacher education to focus more explicitly on developing teachers' skills in asking questions that elicit information about learners' understanding and in using feedback to make learners' thinking visible. Pre-service teachers need structured opportunities to reflect on how their questions and feedback influence classroom interaction and learning. Given the influence of pedagogical content knowledge on effective feedback (Schildkamp et al., 2020), beginning teachers may be underprepared to utilise formative assessment strategies that support learning (Mitchell, 2006) and often need additional support to assess learners' achievement and to address gaps in their learning (Wenzel et al., 2023). Overall, the findings suggest that more research is needed to better understand how teacher education affects teachers' formative assessment practices, particularly how theory and practice are connected during teacher preparation.

Limitations

Using only video-recordings of whole-class instruction, it was not possible to identify all types of activities related to formative assessment, only directly observable activities. These activities, however, add important information about the use of formative assessment in beginning mathematics teachers' teaching and contribute to the understanding of how teachers develop their use of formative assessment. This study did not focus on teachers' reflections on their practice or on learners' experiences of it. A forthcoming study that includes these aspects would represent an interesting development of this research.

Corresponding author

Eva-Lena Erixon
Stockholm University
Stockholm, Sweden
eva-lena.erixon@su.se

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Ethical approval

This study is part of the Trace project supported by the Swedish Research Council. The participants in the project signed up voluntarily to participate in the project. Before data were collected, the participants received information about the study and ethical concerns before signing written consent forms. They also agreed for their data to be reported using fictitious names. The work reported in the manuscript submitted, which is based on data acquired within the project TRACE, did not fall under the scope of the requirements of the law. The Office for Research, Engagement and Innovation Services at Stockholm University concluded that the research was exempt from the requirement of ethical review approval in accordance with the abovementioned Swedish regulation.

Competing interests

The author declares there are no competing interests.

References

Akkoç, H., Balkanlioglu, M. A., & Yesildere-Imre, S. (2016). Exploring preservice mathematics teachers' perception of the mathematics teacher through communities of Practice. *Mathematics Teacher Education and Development, 18*(1), 37–51.

Andersson, C., Boström, E., & Palm, T. (2017). Formative assessment in Swedish mathematics classroom practice. *Nordic Studies in Mathematics Education, 22*(1), 5–20.

Andersson, C., & Erixon, E. (2021). Changes in the use of and reflections on formative assessment: From student teacher to beginning mathematics teacher: A case study. *Assessment Matters, 15*, 4-30. https://doi.org/10.18296/am.0049

Ayalon, M., & Wilkie, K. J. (2021). Investigating peer-assessment strategies for mathematics pre-service teacher learning on formative assessment. *Journal of Mathematics Teacher Education, 24*(4), 399–426. https://doi.org/10.1007/s10857-020-09465-1

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report, 13*(4), 544–556.

Bennett, R. E. (2011). Formative assessment: A critical review. *Assessment in Education: Principles, Policy & Practice, 18*(1), 5–25. https://doi.org/10.1080/0969594X.2010.513678

Birenbaum, M., DeLuca, C., Earl, L., Heritage, M., Klenowski, V., Looney, A., Smith, K., Timperley, H., Volante, L., & Wyatt-Smith, C. (2015). International trends in the implementation of assessment for learning: Implications for policy and practice. *Policy Futures in Education, 13*(1), 117–140. https://doi.org.ezp.sub.su.se/10.1177/1478210314566733

Black, P., McCormick, R., James, M., & Pedder, D. (2006). Learning how to learn and assessment for learning: A theoretical inquiry. *Research Papers in Education, 21*(2), 119–132. https://doi.org/10.1080/02671520600615612

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice, 5*(1), 7–74. https://doi.org/10.1080/0969595980050102

Black, P., & Wiliam, D. (2006). Assessment for learning in the classroom. In J. Gardner (Ed.), *Assessment and learning*. (pp. 9–25). SAGE Publications.

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability, 21*(1), 5–31. https://doi.org/10.1007/s11092-008-9068-5

Boström, E., & Palm, T. (2023). The effect of a formative assessment practice on student achievement in mathematics. *Frontiers in Education, 8*, 1101192 https://doi.org/10.3389/feduc.2023.1101192

Buck, G. A., Trauth-Nare, A., & Kaftan, J. (2010). Making formative assessment discernable to pre-service teachers of science. *Journal of Research in Science Teaching, 47*(4), 402–421. https://doi.org/10.1002/tea.20344

Christiansen, I. M., & Erixon, E.-L. (2024). Opportunities to learn mathematics pedagogy and learning to teach mathematics in Swedish mathematics teacher education: A survey of student experiences. *European Journal of Teacher Education, 47*(1), 159–177. https://doi.org/10.1080/02619768.2021.2019216

Dayal, H., & Chand. (2021). How teachers use formative assessment strategies during teaching: Evidence from the classroom. *Australian Journal of Teacher Education, 46*(7), 1–21. https://doi.org/10.14221/ajte.2021v46n7.1

DeLuca, C., & Johnson, S. (2017). Developing assessment capable teachers in this age of accountability. *Assessment in Education: Principles, Policy & Practice, 24*(2), 121–126. https://doi.org/10.1080/0969594X.2017.1297010

DeLuca, C., & Klinger, D. A. (2010). Assessment literacy development: Identifying gaps in teacher candidates' learning. *Assessment in Education: Principles, Policy & Practice, 17*(4), 419–438. https://doi.org/10.1080/0969594X.2010.516643

DeLuca, C., & Volante, L. (2016). Assessment for learning in teacher education programs: Navigating the juxtaposition of theory and praxis. *Journal of the International Society for Teacher Education, 20*(1), 19–31.

Elwood, J., & Klenowski, V. (2002). Creating communities of shared practice: The challenges of assessment use in learning and teaching. *Assessment & Evaluation in Higher Education, 27*(3), 243–256. https://doi.org/10.1080/02602930220138606

Furtak, E. M. (2012). Linking a learning progression for natural selection to teachers' enactment of formative assessment. *Journal of Research in Science Teaching, 49*(9), 1181–1210. https://doi.org/10.1002/tea.21054

Gamlem, S. M. (2015) Feedback to support learning: changes in teachers' practice and beliefs. *Teacher Development, 19*(4), 461–482. https://doi.org/ 10.1080/13664530.2015.1060254

Gottheiner, D. M., & Siegel, M. A. (2012). Experienced middle school science teachers' assessment literacy: Investigating knowledge of students' conceptions in genetics and ways to shape instruction. *Journal of Science Teacher Education, 23*(5), 531–557. https://doi.org/10.1007/s10972-012-9278-z

Govender, P. (2019). Formative assessment as 'formative pedagogy' in Grade 3 mathematics. *South African Journal of Childhood Education, 9*(1), Article 739. https://doi.org/10.4102/sajce.v9i1.739

Guiaya, M. T., & Bueno, D. C. (2019). Strategic questioning as formative assessment in teaching mathematics Grade 9 Learners. *Institutional Multidisciplinary Research and Development Journal, 2*, 149–152. https://doi.org/10.13140/RG.2.2.21743.89769

Hamodi, C., López-Pastor, V. M., & López-Pastor, A. T. (2017). If I experience formative assessment whilst studying at university, will I put it into practice later as a teacher? Formative and shared assessment in Initial Teacher Education (ITE). *European Journal of Teacher Education, 40*(2), 171–190. https://doi.org/10.1080/02619768.2017.1281909

Harris, S. E. (2016). *Teachers' understanding and use of formative assessments in the elementary mathematics classroom*. [Doctoral dissertation, Harvard Graduate School of Education]. http://nrs.harvard.edu/urn-3:HUL.InstRepos:27112699

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81–112. https://doi.org/10.3102/003465430298487

Heitink, M. C., Van der Kleij, F. M., Veldkamp, B. P., Schildkamp, K., & Kippers, W. B. (2016). A systematic review of prerequisites for implementing assessment for learning in classroom practice. *Educational Research Review, 17*, 50–62. https://doi.org/10.1016/j.edurev.2015.12.002

Kazemi, E., & Stipek, D. (2001). Promoting conceptual thinking in four upper-elementary mathematics classrooms. *The Elementary School Journal, 102*(1), 59–80.

Lim, W., Lee, J.-E., Tyson, K., Kim, H.-J., & Kim, J. (2020). An integral part of facilitating mathematical discussions: Follow-up questioning. International *Journal of Science and Mathematics Education, 18*(2), 377–398. https://doi.org/10.1007/s10763-019-09966-3

Mitchell, J. (2006). Formative assessment and beginning teachers: Ready or not? *Scottish Educational Review, 38*(2), 186–200.

Ozan, C., & Kincal, R. Y. (2018). The effects of formative assessment on academic achievement, attitudes toward the lesson, and self-regulation skills. *Educational Sciences: Theory and Practice, 18*(1), 85–118. [EJ1179831]

Pinger, P., Rakoczy, K., Besser, M., & Klieme, E. (2018). Implementation of formative assessment: Effects of quality of programme delivery on students' mathematics achievement and interest. *Assessment in Education: Principles, Policy & Practice, 25*(2), 160–182. https://doi.org/10.1080/0969594X.2016.1170665

Popham, W. J. (2009). Assessment literacy for teachers: Faddish or fundamental? *Theory Into Practice, 48*(1), 4–11. https://doi.org/10.1080/00405840802577536

Schildkamp, K., van der Kleij, F. M., Heitink, M. C., Kippers, W. B., & Veldkamp, B. P. (2020). Formative assessment: A systematic review of critical teacher prerequisites for classroom practice. *International Journal of Educational Research, 103,* 101602. https://doi. org/10.1016/j.ijer.2020.101602.

Shepard, L. A. (2000). The role of assessment in a learning culture. *Educational Researcher, 29*(7), 4–14. https://doi.org/10.2307/1176145

Sleep, L., & Boerst, T. A. (2012). Preparing beginning teachers to elicit and interpret students' mathematical thinking. *Teaching and Teacher Education, 28*(7), 1038–1048. https://doi.org/10.1016/j.tate.2012.04.005

Thomas, G. (2011). A typology for the case study in social science following a review of definition, discourse, and structure. *Qualitative Inquiry, 17*(6), 511–521. https://doi.org/10.1177/1077800411409884

Tillema, H. (2010). Formative assessment in teacher education and teacher professional development. In *International Encyclopedia of Education* (pp. 563–571). Elsevier. https://doi.org/10.1016/B978-0-08-044894-7.01639-0

Torrance, H. (2012). Formative assessment at the crossroads: Conformative, deformative and transformative assessment. *Oxford Review of Education, 38*(3), 323–342. https://doi.org/10.1080/03054985.2012.689693

Torrance, H., & Pryor, J. (2001). Developing formative assessment in the classroom: Using action research to explore and modify theory. *British Educational Research Journal, 27*(5), 615–631. https://doi.org/10.1080/01411920120095780

Van der Kleij, F. M., Feskens, R. C. W., & Eggen, T. J. H. M. (2015). Effects of feedback in a computer-based learning environment on students' learning outcomes: A meta-analysis. *Review of Educational Research, 85*(4), 475–511. https://doi.org/10.3102/0034654314564881

Wenzel, A., Hovey, K. A., & Ittner, A. (2023). Examining early career teachers' formative practices to inform and support continuous improvement in educator preparation programs. *Athens Journal of Education 10*(1), 85–100. https://doi.org/10.30958/aje.10-1-5

Wiliam, D., & Thompson, M. (2008). Integrating assessment with instruction: What will it take to make it work? In C. A. Dwyer (Ed.), *The future of assessment: shaping teaching and learning*, (pp. 53–82). Lawrence Erlbaum Associates.

Xu, Y., & Brown, G. T. L. (2016). Teacher assessment literacy in practice: A reconceptualization. *Teaching and Teacher Education, 58*, 149–162. https://doi.org/10.1016/j.tate.2016.05.010

Yan, Z., & Pastore, S. (2022). Are teachers literate in formative assessment? The development and validation of the teacher formative assessment literacy scale. *Studies in Educational Evaluation, 74*, Article 101183. https://doi.org/10.1016/j.stueduc.2022.101183

Yan, Z., Li, Z., Panadero, E., Yang, M., Yang, L., & Lao, H. (2021). A systematic review on factors influencing teachers' intentions and implementations regarding formative assessment. *Assessment in Education: Principles, Policy & Practice, 28*(3), 228–260. https://doi.org/10.1080/0969594X.2021.1884042