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Formative Assessment and Mathematics Education: the Perspective of In-Service Mathematics Teachers

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ABSTRACT

Background: Although there is consensus on the favourable impact of formative assessment (FA) on learning, it is unclear to what extent general FA strategies are directly applicable to the specific field of mathematics education. **Objective:** Study the relevance of a questionnaire which describes 26 FA practices supported by Wiliam's model in the particular context of mathematics education. **Design:** Mixed, the frequency and feasibility are consulted through a questionnaire and in-depth interviews. **Participants**: Thirty in-service mathematics teachers answered the survey and of ten invited, three agreed to be interviewed. **Data analysis**: We carried out a descriptive analysis for quantitative data and qualitative thematic analysis. **Results**: The strategies of collecting evidence, feedback, collaboration, and self-regulated involvement in learning are viable and frequent in mathematics education, however, the strategy of clarifying and sharing goals requires adaptation to the context. In addition, nine novel FA practices are described. The implementation of formative assessment creates tensions with the summative function, it is laborious to implement and consequently takes time outside the classroom. **Conclusion**: We identified that FA practices are frequent and feasible to implement. Clarifying and sharing goals requires the adequacy of the mathematical context.

Keywords: Formative assessment; Assessment in mathematics education

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Evaluación formativa y educación matemática: la perspectiva de docentes de matemática en servicio

RESUMEN

Contexto: Aunque hay consenso sobre el impacto favorable de la evaluación formativa (EF) en el aprendizaje, no está claro hasta qué punto las estrategias de EF generalistas son aplicables directamente al ámbito específico de la Educación Matemática. **Objetivo:** Estudiar la pertinencia de un cuestionario que describe 26 prácticas de EF apoyadas en el modelo de Wiliam al contexto particular de la Educación Matemática. **Diseño:** mixto, se consulta la frecuencia y viabilidad a través de un cuestionario y se realizan entrevistas en profundidad. **Participantes**: 30 docentes de matemática en servicio respondieron a la encuesta y de 10 convocados, 3 aceptaron ser entrevistados **Análisis de datos**: para los datos cuantitativos se realiza un análisis descriptivo y para los cualitativos análisis temático **Resultados**: Las estrategias de recolección de evidencia, retroalimentación, colaboración e implicación autorregulada en el aprendizaje son viables y frecuentes en Educación Matemática, sin embargo, la estrategia de aclarar y compartir metas requiere adecuación para el contexto. Además, se describen nueve prácticas novedosas de EF. La implementación de la evaluación formativa crea tensiones con la función sumativa, es muy laboriosa de implementar y en consecuencia insume tiempo fuera del aula. **Conclusión**: Se identifica que las prácticas de EF son frecuentes y viables de implementar. Aclarar y compartir metas requiere adecuación el contexto matemático.

Palabras clave: evaluación formativa; evaluación en Educación Matemática

Avaliação Formativa e Educação Matemática: a perspectiva de professores de matemática em serviço

RESUMO

Contexto: Embora haja consenso sobre o impacto favorável da avaliação formativa (AE) na aprendizagem, não está claro até que ponto as estratégias gerais de EF são diretamente aplicáveis ao campo específico da Educação Matemática. **Objetivo**: Estudar a relevância de um questionário que descreve 26 práticas de EF apoiadas no modelo de Wiliam para o contexto particular da Educação Matemática. **Desenho**: misto, consulta-se a periodicidade e viabilidade através de um questionário e são realizadas entrevistas em profundidade. **Participantes**: 30 professores de matemática em serviço responderam à pesquisa e de dez convidados, três concordaram em ser entrevistados **Análise de dados**: uma análise descritiva é realizada para dados quantitativos e uma análise temática para dados qualitativos **Resultados**: Estratégias de coleta de evidências, feedback, colaboração e envolvimentos autorregulados na aprendizagem são viáveis e frequentes na Educação Matemática, no entanto, a estratégia de clarificação e partilha de objetivos requer adaptação ao contexto. Além disso, nove novas práticas de EF são descritas. A implementação da avaliação formativa

gera tensões com a função somativa, é muito trabalhosa de implementar e consequentemente leva tempo fora da sala de aula. **Conclusão**: Identifica-se que as práticas de EF são frequentes e viáveis de serem implementadas. Esclarecer e compartilhar objetivos requer adequação do contexto matemático.
Palavras-chave: avaliação formativa; Avaliação em Educação Matemática

INTRODUCTION

In compulsory secondary education, assessing learning is a daily challenge that requires much time and effort, occupying between 20% and 30% of the teachers' professional time (Stiggins, 1988). In turn, it is an activity that causes anxiety (Ravela, Picaroni, & Loureiro, 2017), and its relationship with improving learning is not always noticeable (Ramos & Casas, 2018).

Although teachers' assessment practices have been investigated in depth, the focus has been placed particularly on the qualification or summative assessment (Jarero, Landa & Sosa, 2013). Summative assessment (SA sums up what students have learned, occurs after instruction has been completed, and serves a certifying purpose. Instead, formative assessment is generally considered part of the instructional process and is intended to provide the information needed to help teachers adjust their instruction and students learn as instruction occurs. In other words, one seeks to measure student achievement, and the other informs how to improve teaching and learning (Vlachou, 2015).

Although there is consensus on the importance of formative assessment to improve learning processes, difficulties persist in operationalising the construct in different learning contexts and disciplines (Taras, 2007). In mathematics education (ME), researchers and policymakers have emphasised the need for in-service teachers to rely on students' characteristics, including the cognitive and metacognitive processes they use to build their mathematical knowledge to guide instruction. Moreover, teachers should understand deeply the content they teach (National Council of Teachers of Mathematics – NCTM, 2014). In particular, they recommend eight principles for mathematics education that reflect points of contact very close to the strategies suggested by general models of formative assessment: 1) Establish mathematical goals to focus learning, 2) Implement tasks that promote reasoning and resolution, 3) Use and connect mathematical representations, 4) Facilitate meaningful mathematical discourse, 5) Ask purposeful questions, 6) Develop procedural fluency from conceptual understanding, 7) Support productive challenges in

mathematical learning and, finally, 8) Obtain and use evidence of students' thinking.

Over the last few years, interesting initiatives promoting formative assessment in mathematics have emerged. Perhaps one of the most ambitious and widely disseminated projects has been the Mathematics Assessment Project (MAP), described in Swan and Foster (2018). This project consists of about 100 units with formative assessments, each one on a specific content in mathematics and with its respective didactic guidelines for teachers. In preparing these materials, the authors echo some general formative assessment techniques (Wiliam & Thompson, 2007).

THEORETICAL FRAMEWORK: FIVE STRATEGIES IN FORMATIVE ASSESSMENT (FA)

In FA, one of the most referenced models is the one proposed by Wiliam and Thompson (2008), which starts from three main processes exercised by three actors in the educational scene, from which nine cells are derived and give rise to the five main strategies to regulate the learning in formative assessment. Table 1 shows a summary of such a model. It is important to point out that although the five strategies are presented separately, they are not independent or sequential; instead, they are interrelated, i.e., one's improvement impacts and benefits the others (Hawe & Parr, 2014).

Table 1.

Free translation of formative assessment strategies (William & Thompson, 2008)

	Where are we headed?	**Where are we?**	**How will we get there?**
Teacher	Clarify and share learning goals and achievement criteria	Provide feedback	Build situations that generate evidence of learning.
Peers		Activate collaboration between students.	

Student	.	Promote self-regulated learning.

Clarify and share learning goals and achievement criteria emerges as one of the most referenced strategies in formative assessment (Heritage 2007, Nicol & Macfarlane-Dick, 2006; Wiliam 2011) and is recommended in the first principle proposed by the NCTM (2014). To define specific learning goals, teachers need to analyse the mathematical content: concepts, reasoning, and procedures that, as Heritage (2006) points out, differ between different domains of mathematics.

Building situations that generate evidence of learning is the second central strategy of FA (Wiliam, 2011; Guskey, 2010), and it is also a practice recommended by the eighth principle of the NCTM (2014). Ask questions and practice interpretive and non-evaluative listening (McMillan, 2010; Stiggins, 2010; Sadler, 1998) to obtain evidence of student learning. Phelan et al. (2011) found academic gains in an intervention group that used brief, short-answer assessment tasks to periodically obtain evidence of learning. However, background indicates that interpreting evidence on students' understanding of complex content is challenging in the context of ME (Clarke, Roche, Cheeseman & van der Schans, 2014; Morgan & Watson, 2002).

Provide feedback that allows students to improve is the third strategy of the FA model. Its prospective and non-retrospective purpose is highlighted. Knowing what you did wrong is important, but much more important is knowing how you are going to solve it, which is why it is said to be "a recipe for future action". It is important that the feedback is located in the student's zone of proximal development. If the teacher returns proper corrections, but the student is unable to process them either because of their quantity or quality, they will tend to drop out and not make an effort to overcome their errors (McMillan, 2010). To know what to do instructionally in response to FA evidence, mathematics teachers must have clear conceptions of how to progress in the subject. A study that aimed to train mathematics teachers in FA reported that as they progressed in their professional development, teachers used more ungraded activities and more comments as feedback (Beessley, 2018).

Activate collaborative learning between peers is a strategy that combines aspects of the previous ones. To implement this strategy, students need to internalise the learning goals with their achievement criteria. Assessing

the work of a peer (co-assess) involves less emotional burden than assessing one's own work (self-assessment), and favours self-regulatory processes (Wiliam, 2009; Black, 2003). The research shows that mathematics teachers have found good results in facilitating small group discussions and peer collaboration (Rowan-Kenyon et al., 2012; Schunk & Pajares, 2001; Zohar et al., 2001). Also, it is an essential element in teaching through problem solving in mathematics since the interaction around a good problem can be an opportunity to assess the students, learn about their difficulties, and adapt the teaching and learning processes (Lester & Cai, 2016).

Involve the student and promote self-regulation (Andrade & Cizek, 2010; Heritage 2007; McMillan, 2010) is the fifth strategy of the FA model. Self-regulation presupposes and promotes a vast repertoire of learning strategies: cognitive, metacognitive, and resource management. The relationship between FA and self-regulated learning (SRL) has begun to be explored. While FA focuses strongly on the pedagogical and instructional, the SRL perspective focuses on the student. Currently, the interaction between both research traditions is promising (Panadero el al., 2019).

Beyond the fact that formative and summative assessment can fulfil synergistic purposes in the classroom, standardised assessment outside the classroom also has a specific objective, facilitating the comparison of performances with greater precision. International studies (OECD-PISA) that evaluate the mathematics learning of students who completed basic secondary education show disparate results. While internationally, 76% of students reach Level 2, categorised as the proficiency threshold in mathematics, only 34.7% reach this level in Latin America (ANEP, 2018).

In this context, FA is presented as an effective strategy to improve mathematics learning (Black & Wiliam, 2009; Sáenz & Lebrija, 2014), which is particularly relevant at the secondary education level. Furthermore, little is known about the effectiveness of the FA in mathematics education (Kingston & Nash, 2011).

Consequently, it is relevant to investigate whether FA strategies with the highest impact reported in the literature are viable in the ME context, according to the expert opinion of in-service teachers. We based this research on the following questions: (1) How often do in-service mathematics teachers use FAs, as proposed by Wiliam (2010)? Why do teachers use them? (2) Which practices are less frequent and why? (3) What FA practices do mathematics teachers report that are not included in the proposed repertoire? (4) What obstacles do teachers meet in implementing these FA practices?

METHODOLOGY

The project was approved by the research ethics committee of the Catholic University of Uruguay.

The research used a mixed design with a quantitative and a qualitative phase.

In the first phase, we applied a self-report questionnaire to ask teachers about the frequency of use of the 26 practices built from the five FA strategies proposed by Dylan Wiliam in mathematics classrooms (see Table 1). The answer format of the questionnaire assumes the use of a Likert-type scale ranging from 1 to 7. At the end of each strategy, we included an open question, inviting teachers to describe frequent practices that had not been considered in the pre-established repertoire.

In the second phase, we conducted semi-directed interviews with a subsample of teachers who completed the questionnaire in the initial quantitative phase (see the script in Appendix B).

Participants

We worked with an intentional sample of 30 secondary education mathematics teachers that completed the quantitative phase. While 36.6% of the sample (N=11) work exclusively in public institutions, 33.3% (N=10) work exclusively in private institutions and 30% (N=9) work in both public and private institutions. Regarding gender, 30% (N=9) declared to be male and 70% (N=21) female. Regarding age distribution, three groups were established: 53.4% (N=16) are between 24-34 years old, 36.6% (N=11) are 35-45 years old, and 10% (N=3) are over 46 years old. Regarding professional qualification, 86.7% (N=26) of the participants have a mathematics teaching degree, whereas 13.3% (N=4) did not. Of the teachers surveyed, 76.7% (N=23) teach in the department of Montevideo (the capital of Uruguay), and 23.3% (N=7) teach in other departments in the Uruguayan countryside. Regarding the teachers' professional experience, 40% (N=12) of the sample had between 3-9 years of experience, 53.3% (N=16) had between 10-19 years of experience and 6.6% (N=2) had 20 or more years of experience.

In the second phase, three qualified mathematics teachers from Montevideo participated. Two gave classes exclusively in private high schools,

and one in private and public schools. Regarding gender, two were women, and one was a man.

Procedure

Within the framework of a broader research project on formative assessment (Balbi, Curione, von Hagen & del Arca, 2019), we designed a questionnaire with 26 items that describe FA practices carried out in the classroom context, according to the five strategies of Wiliam's model. We conducted three pilot studies of the questionnaire with students who answered about the frequency of implementation of these practices in Physics, Spanish language, and Mathematics subjects. Given the objectives of this study, the relevance of these practices for mathematics education was explored from the perspective of expert judges, so the content of the items was adapted to be completed by teachers, instead of students.

Mathematics teachers were invited to collaborate with the research through email, Whatsapp, or Twitter. We asked the teachers to extend the invitation to their contacts using a chain sampling method (Matthews & Ross, 2010). The questionnaire was to be completed online. The call remained active for 39 days, and on the closing day, it has been completed by 30 mathematics teachers.

For the second stage, we selected ten teachers considering gender diversity, professional experience, and geographical area. Three teachers responded to the call. As compensation for their time, we gave each participant a movie ticket.

Data analysis

The quantitative data was processed using the Jasp software, and the qualitative information with the QDA-Miner software.

The qualitative information obtained in the first stage was combined with that provided by in-depth interviews in the second stage. A thematic analysis was carried out, prioritising a reflective process. The first three authors carried out an analysis similar to that described by Fereday and Muir-Cochrane (2006), which was as follows:

- Collaboratively, a content manual was developed based on the five strategies and 26 practices of the questionnaire. When the interview

content could not be associated with one of the 26 practices, it was coded with the expression: “new practices: (descriptive term)”.

- We independently coded the three interviews and the answers to the open questions using QDA Miner.
- Finally, we shared the independent coding, adjusted the codes and themes, and solved conflicts through discussion and review of formative assessment theory.

RESULTS

The main results of each question that guided the research are shown below.

How often do in-service mathematics teachers use FA practices as proposed by Wiliam? Why do teachers use them?

Table 2 shows that the mathematics teachers of our sample value the 26 FA practices above the midpoint of the Likert scale (1-7), which is why the practices are frequent in the context of mathematics education. We also present in Appendix B the results of the complete qualitative coding.

Table 2

Descriptive statistics of the 26 FA practices

N.		Average	D.E.
Strategy 1: Clarify and share learning goals and achievement criteria			
1	I report what errors they should avoid when they do their homework in class	5.067	1.780
2	I explain what they will learn in this class	4.867	1.795
3	I detail what they have to know to solve the task successfully	4.300	2.152

4	I explain the objectives of the tasks I propose	5.100	1.494
Strategy 2: Build situations that generate evidence of learning			
1	I make them explain what they do not understand	5.933	1.413
2	I make them explain what they learned	5.567	1.431
3	I come near them to know what they did, even if they do not raise their hands to say it	6.133	1.137
4	I ask them how they know whether an answer is correct or incorrect	6.067	1.574
5	I encourage them to comment and ask questions in class	6.633	0.556
Strategy 3: Provide feedback			
1	I give them feedback that helps them understand why they were wrong	6.167	1.053
2	I explain how to do their jobs better	5.767	1.455
3	I make comments that help them to improve what went wrong	6.100	0.960
4	When they do something well in a task, I use it as an example so that they continue to improve	5.800	1.186
5	I explain the slogan to them in a new way if they did not understand it the first time	6.067	1.660
6	I give them just enough help (neither too little nor too much) so that they can solve the tasks	5.767	1.455

7	I write comments on our tasks or writings about what they have to improve	4.933	2.033
Strategy 4: Activate collaborative peer learning			
1	I make them work as a team	6.033	1.098
2	I make them investigate and learn for themselves	5.267	1.363
3	I make them correct each other's work as a learning method	4.200	1.584
4	I teach them to work as a team	4.900	1.749
Strategy 5: Involve the student and promote self-regulation			
1	I ask them to reflect on what works best for them and what costs them the most	4.533	1.548
2	I get them to think about different paths they can take when they get stuck on a task	5.833	0.102
3	I encourage them to feel competent to perform the tasks	6.467	0.681
4	I answer them with new questions that help them think	6.033	1.129
5	I encourage them to make an effort even if it costs them	6.433	0.568
6	I ask them how they plan to improve the mistakes or comments that I pointed out to them in their assignments	5.367	1.402

I encourage them to give their opinions and ask questions (item 2.5). It is a practice that, in addition to obtaining the highest mean (M= 6.6, SD= 0.5)

of the set of practices presented, contains qualitative information that enriches and contextualises its implementation in the context of the ME and the FA.

> *(E3) It seems to me that in everyday classes, in the context of sharing, a student is requested to intervene, and, in turn, we ask the rest of the class to give their opinion about the student's intervention. Not saying what is right, what is wrong, but giving him/her feedback, or giving him/her tools to advance in learning, right? When one generates discussions or exchange, I think one is assessing every day, and in that sense, I think there is a component of formative assessment.*
>
> *(E3) Let us say that I try to encourage much discussion in class about what one says about what the other says: "What do you think of what this one said? What do you think of what that one said?"*
>
> *(E3) It was interesting because, uh, that topic guided the discussion in the next class, because it was not just a question of openly giving an opinion about the classmate's work, but it was, well, giving an opinion about the classmate's work based on specific criteria, based on specific rules, then it was generated as a much more organised, much deeper discussion. This... the balance was positive, it was positive*
>
> *(RA) The fact of presenting tasks with open questions, that generate discussion, that students "go to the blackboard", that they must present their arguments. Help them ask questions to their own classmates. I try to be very careful about the students' self-esteem so that they feel comfortable raising any questions or answering and explaining [anything] to their classmates.*

I make comments that help them understand why they were wrong (item 3.1). It is a second practice that teachers in the sample report using very frequently (M=6.1, SD=1.0) and enrich with the information provided from the interviews and open answers. The fragments show that it is a highly sensitive practice in mathematics education, because it is valued important and at the same time it is challenging. They also show the close connection that teachers establish between making constructive comments to the student and formative assessment.

> *(E1) That it did not comply with the general aspects that we had requested for the slogan, right? of things that we had*

scheduled in the topic to evaluate. So, then, the doubt arose: well, precisely in this matter of giving them a formative assessment, of marking the aspects and that they reelaborate it and give them back to us.

(E3) Well... give them feedback on what they has done in the previous stage, well, so that they continue improving, it seems that there is also formative assessment there. Not necessarily a grade, right? Otherwise, to give tools or comments or suggestions that help the student improve, overcome their difficulties and learn.

(E3) ... partly, it is more difficult because no, because one has to start looking at aspects of the student's work and how to make comments to help them improve, right? I mean, the assessment is not summed up in a number or in a value judgment, good, bad, more or less, but actually, there is the challenge of being able to give the students feedback, but in such a way that what we say to them really helps them overcome their difficulties or advance in their learning. In other words, to answer your question, I think it is more difficult, it is more difficult, I think it is also more enriching, but I think it is more difficult, yes.

I go near them to know what they did even if they don't raise their hands to say so (item 2.3) is a third very frequent practice to implement according to our findings (M=6.1, SD=1.0). We transcribed fragments of the interviews that exemplify and show their closeness to practices related to collaborative learning and mathematical dialogue between teacher-student in a more personalised way.

(E1) How to talk with the student one-on-one or work in small groups to be able to apply because... I don't know, it could be that the method, I think, that I don't know, that it could be something that affects, or the need for a specific attention so that they correct it with each other, to have a feedback, to ask them to reflect, to specify what they have to be clear about so that it comes out successfully, requires a more detailed work.

(E1) When I mention them for EPI [Including Pedagogical Space]. That it is an hour that is designed so that fewer children

come. Work more on one thing... kind of a face-to-face meeting with the student.

(RA) There are errors that some make that I prefer to explain to them in private and not expose them in class.

Which practices are less frequent and why?

We identified the practices the teachers in the sample reported performing less frequently.

I report what errors they should avoid (item 1.1) is the practice that comes up most mentioned in the qualitative collection as seen in Appendix A. It is mentioned 17 times by 100% of our participants. It is presented as a problematic practice that, although associated with formative assessment, should be adapted to the specific context of mathematics education. Some excerpts from interviews that get closer to how mathematics teachers conceive error are transcribed and provide clues to understand the infrequent use of the practice of informing students about the errors they should try to avoid. The error is seen as an opportunity in the learning process, it is welcomed and integrated from its didactic potential and understood as inherent to the learning process.

(E1) Well, as an opportunity. The error speaks precisely of something to be analysed and deepened and that we can make the most of it. And without a doubt, many times, much more interesting things come out from errors than from success... it's like the message I try to convey to them of it: "It's good that your are wrong!". Because from those errors we can retrace our steps, right? the path we took. And analyse why it was an error, why it happened, how I argue it, and how… (he thinks). Yes, I think it is a very powerful tool, very valid, very necessary.

(E2) The error is part of what will happen to you when you learn. Just like when you ride a bike, you are going to fall, and just because you fall does not mean that you will never learn to ride a bike. So, that kind of thing, using and retaking their errors to show where the error is, where it came from, what do I have to modify so that this error does not appear, or show them, too, how many times, beyond an error, it is a strategy that

in one context served me well, but when I change the context, it stops working.

(E3) It is what we always say, the didactic use of error. In math class one can make errors, because we understand that from the error is that you learn, right? I always tell the, the little ones, I say: If faced with each topic that we are working on, this one, there is no error, there is nothing, it is because what I presented did not contribute anything. I mean, they didn't grow. On the other hand, if I teach something that was not understood at all, that nobody can do anything, well, that didn't contribute anything either. But where is the funny thing, that you teach something that at first causes you difficulties, and you kind of stumble, so you're kind of wrong, but maybe... but something you can do, and something you can't. And well, that coming and going, it is from those difficulties or on the basis of those difficulties that you overcome yourself and learn.

On the other hand, the practice, I make them correct the work with each other as a learning method (item 4.3) presents the lowest mean (M= 4.2 SD= 1.5) of the set of 26 practices. However, it is not questioned by the teachers; on the contrary, it is considered an interesting and feasible practice to implement, although it is rare in the mathematics classroom.

(E1) This, I have done [it], it is not the most usual, the first, (pointing) to correct works with each other. It's not the most usual but I do it. I mean, at some point in the year, they will surely come across that. Mainly these practices, it is possible that I see them more specifically here in the high school at the time of the inclusive pedagogical space. There, yes, I can apply this more.

(E2) The times that I have worked with it, it works much better for me because they have to put their eyes and gaze on the objective to be achieved. That, sometimes, it is very difficult for them to put it on when they are the ones who are working. On the other hand, if I have to correct something to the other and I know what the goal I want to achieve is, it is easier for them to look at it.

(E3) Why don't I...Because in reality it would be super valuable: When one, when one looks at someone else's work

and has to think about what they thought, what is good and what is bad, one learns, too, no? This... The truth is that it will be a matter of practicality, but not even that. I don't know, I don't know, the truth is I can't really tell you why.

What formative assessment practices do mathematics teachers report performing that are not included in the proposed repertoire?

Table 3 presents the nine new practices proposed by the teachers in the sample.

Table 3

Novel formative assessment practices provided by mathematics teachers

Strategies	Practices
Activate collaborative peer learning	In team assignments, assign a separate grade for the student and for the group.
	Promote activities where they have to explain themselves to each other
Clarify and share learning goals and achievement criteria	Encourage them to discover the learning goal after having worked in class
	Present the topic from the beginning of the process so that they understand where we are going.
Involve the student and promote self-regulation	Generate an environment of trust and motivation.
Build situations that generate evidence of learning	Do activities and exercises that are not scored.
	Propose open activities where everyone can do something that allows me to observe how they are learning.

Provide feedback	Use the Inclusive Pedagogical Space (IPS) with small groups of three or four students exclusively for feedback
	Give feedback on the same work over and over again, keep a back-and-forth and assign a final date when it will be graded. (Iterative feedback)

What obstacles do teachers meet in the implementation of these FA practices?

Table 4 presents the results obtained in the qualitative analysis regarding the obstacles that the teachers mention in implementing the formative assessment. First, the planning and implementation of the formative assessment, which is mentioned by the total number of participants, represents a frequency of mention significantly higher than the rest of the obstacles mentioned.

Table 4

Obstacles identified by teachers to implement the FA

Code	% Frequency of mention
Laborious planning and implementation of the FA	8.00%
Tension between FA and SA (summative assessment)	6.10%
Time shortage	3.80%
Class routines, framing	3.80%

Emotional factors	3.30%
Other factors	1.90%

We present below fragments that refer to the difficulty involved in planning with its consequences in the time of additional working hours:

> *(E2) Why? Because the time is short, really, time is too short. Because you have to generate activities that are of different types. There is a lot of material, but you have to select, you have to analyse, see how you are going to use it, what you are going to do with it.*
>
> *(E3) It is quite a challenge. For the teacher, it may be easier, right? To do what he always does… (recording cracks) what is more frequent, well, I put this in writing, "I put the grade, a number and that's it ". This other thing I tell you yes (and emphasises) partly, it is more difficult because no, because one has to start looking at aspects of the student's work and how to make comments to help them improve, right? I mean, the assessment is not summed up in a number or in a value judgment, good, bad, more or less, but actually, there is the challenge of being able to give the students feedback, but in such a way that what we say to them really helps them overcome their difficulties or advance in their learning. In other words, to answer your question, I think it is more difficult, it is more difficult, I think it is also more enriching, but I think it is more difficult, yes.*
>
> *(E3) That the working conditions are given so that the teacher can really implement these strategies in the class, without being involved, this, well... it continues taking hours away from the teacher's life.*

The second group of obstacles that teachers mentioned refers to the tension between formative and summative assessment, like the previous factor, it was mentioned by 75% of the interviewees and occupied 6.10% of the total material. We transcribed representative fragments:

(E1) For example, one could be, thought of as a recent thing, this that happened to us as a team to face this: "Well, let's see, some little kids delivered this wrong, with things that we asked them that they did not.. . that they considered that they did not take them into account". Well, I think so, and it's a whole team-level discussion that we're having. I believe that this, as well as how they delivered it and being that they had "x" amount of time and a certain amount of instances to do it well, we have to score it to obtain a grade, call it judgment, grade, whatever you want. But do tell them: "Well, look, this delivery of yours was like this and that is not going to change. You rework it so that you get used to the fact that a job is delivered well and is delivered with certain conditions, more so if they specified it to you beforehand". So, why do I say this, because a limitation could be like continuously approaching the student: "Well, it didn't work out for you, try again; It didn't come out, try again". It is kind of assisting too much, which is not good, either.

(E1) So I say: "Well, to what extent do you see the formative?" I consider that there must be landmarks where they get a grade and say: "well, ok, I did not complete this stage", according to… Be frustrating, be negative, be whatever you want. Ok, they must get that rating.

(E1) But it doesn't mean that I'm not going to stop giving 2 in the logbook or that number in the logbook because it's a reality, it was a starting point if you want to call it so. But otherwise, of course, if I bring you closer, I bring you closer, I bring you closer, obviously at some point you will even be 12. But how genuine is that grade?

(E2) Yes, these are more frequent. What happens is that these more frequent ones you can use as formative or you can use it as a common and wild summative. Of course, the issue is how you face it more than what you do.

(E3) Not limiting ourselves like...No, because I say I oppose it to the summative assessment, no, well, what I say, you give it a grade and that work is finished, period, and that's it. I understand formative assessment as part of a process so the

purpose is... yes, for the student to learn, that is, yes, I see it that way.

Teachers mention the time factor as necessary to be able to carry out their formative assessment practices, being reported by the three in-depth interviews (75%) and the class routines/setting by two of the interviews (50%).

Regarding the time it takes:

> *(E1) I consider that...in reality what I see in these, that they are the least frequent, that they have a tendency like... like, a more individualised attention to apply them, right? And that thing, really, I don't know if we have that time. Talking with the student one-on-one or work in small groups to be able to apply because... I don't know, it could be that the method, I think, that I don't know, that it could be something that affects, or the need for specific attention so that they correct it with each other, to have feedback, to ask them to reflect, to specify what they have to be clear about so that it comes out successfully, requires a more detailed work. I don't know to what extent it is always possible to do so.*
>
> *(E2) The only difficulties we could have are instrumentation, times, spaces, interacting with others for this to work.*
>
> *(E3) Yes, formative assessment is too time consuming. And well, it is well known that the reality of the teacher here, in this country, this... well, is characterised by many hours of work, by many things that one does at home, etc.*

DISCUSSION

Formative assessment provides valuable information on the student's understanding of mathematical concepts and improves academic results (Polly, Wang, Martin, Lambert & Pugalee, 2017), however, more depth is still required on how to implement FA in ME properly. Ohlsen (2007) points out that, while the NCTM (2000) and its standards promote a constructivist view of mathematics learning and the use of formative assessment techniques in accordance with it, the reality is that the majority of professors associated with the said association, preferably still employs closed examinations and summative techniques.

The teachers report collecting evidence on students' mathematical thinking based on the dialogue between teacher and student and the dialogue between students and their peers. We found that collaboration between peers, explaining to each other, and justifying their thinking repeatedly ("why they are the guest of each class", pointed out E3) is a practice perceived as frequent in mathematics education. Also, our study identified practices that teachers use and that were not considered in our questionnaire, so they constitute a valuable contribution that adapts our tool to the context of mathematics education — iterative feedback within the feedback strategy. The teachers report a feedback process that is repeated over and over again, with the aim of helping students improve their production, even qualifying intermediate stages of the process. From the FA literature, it is called a practice of short feedback cycles (Klute, 2017). Another novel practice was encouraging their students to persist, which is associated with promoting self-regulated learning (Curione, Huertas, Ortuño & Piriz, 2019).

Although the participants report that organising the class collaboratively is a usual practice in the ME, however, the concrete practice of "I make them correct the work with each other" was not usual. Black and Wiliam (1998a) suggest that actively involving students in the assessment process -co-assessment- is a way of reducing the burden of FA on teachers. Despite this, the mathematics teachers in our sample do not capitalise on the power of peer co-assessment processes. It is worth asking whether the co-responsibility of teachers with apprentices meets this limit because it supposes, as Schildkamp (2020) points out, changes in power relations. However, all our interviewees accepted this practice as a valuable recommendation, without finding clear arguments to justify why it was rare (E3: This... The truth is that it will be a matter of practicality, but not even that. I don't know, I don't know, the truth is I can't really tell you why.)

Our study also identified disagreements. The strategy of sharing learning goals involves practices that could become problematic in ME. On the one hand, the error constitutes a learning opportunity and, as could be observed, it is integrated into mathematics classes due to its didactic potential. From the point of view of the teachers who participated in this study, students should not be alerted about errors to prevent them from making them, on the contrary, they understand that making mistakes is inherent to the learning process. On the other hand, the participants point out that in ME the task is generally set, but the objectives are made explicit in its development, when the mathematical object that emerges from the tasks to be solved has been built and not before. This may be an indication that learning is prioritised through problem solving.

Finally, the obstacles reported by the teachers in our study are mostly in line with the findings at the international level, the integration between FA and SA is possible but complex (Buchholtz et al., 2018). Significant tensions are created when the same person, i.e., the teacher, is required to simultaneously fulfil formative and summative functions. In addition, on the one hand, planning is laborious to implement, it is necessary to meet the other to design feedback strategies that are complex and take a long time when, on the other, the teacher's employment contract is fundamentally limited to the work he or she does within the classroom.

CONCLUSION

This study made it possible to contribute to identifying and understanding FA practices that are feasible to implement in secondary education mathematics classrooms and the obstacles to their implementation. The strategies of collecting evidence, feedback, collaboration, and self-regulated involvement in learning are viable and frequent in mathematics education; however, the strategy of clarifying and sharing goals requires adaptation. In turn, teachers state that implementing formative assessment creates tensions with the summative function, which is also part of their professional role, is very laborious to implement and, consequently, takes too much time outside the classroom.

LIMITATIONS

Our study sample was intentional and called teachers who do not represent the mathematics education teachers in the country for different reasons. Only 36.6% of the sample works exclusively in public educational centres, while public education represents 60% of high schools in Uruguay.

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AUTHORSHIP CONTRIBUTION STATEMENTS

A.B., M.O. and K.C. contributed to the conceptualisation of the research project. A.B., M.B., M.O. developed data curation and formal analysis (A.B., M.B., M.O. were in charge of qualitative data analysis and M.B. of quantitative data). M.O. was in charge of the investigation supervised by A.B. The methodology was developed by A.B., M.B., M.O. and K.C. A.B. managed the project. The resources were provided by A.B. and data analysis software by M.B. A.B., M.B., K.C. and P.B. validated and visualised the work. A.B. and M.B. wrote the original draft and partnered with K.C., M.O., and P.B. for review and final editing.

DATA AVAILABILITY STATEMENT

The data supporting the results of this study will be made available by the corresponding author, A.B., upon reasonable request.

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APPENDIX A

Table 5

Qualitative Coding

N.		Frequency	%
Strategy 1: Clarify and share learning goals and achievement criteria			
1	I report what errors they should avoid when they do their homework in class	17	8.00%
3	I detail what they have to know to solve the task successfully	5	2.40%
4	I explain the objectives of the tasks I propose	3	1.40%
-	Design classes in reverse-mode. I start by telling them about the learning goals and then, with activities, we get closer.	1	0.50%
-	I make explicit where we are and where we are going, that is, how what we are learning now connects with what we want to achieve.	6	2.80%
-	Encourage them to discover the learning goal after having worked in class.	2	0.90%
-	Present the topic from the beginning of the process so that they understand where we are going.	4	1.90%
Strategy 2: Build situations that generate evidence of learning			
1	I make them explain what they do not understand	3	1.40%
2	I make them explain what they learned	7	3.30%

3	I come near them to know what they did, even if they do not raise their hands to say it	4	1.90%
4	I ask them how they know whether an answer is correct or incorrect	3	1.40%
5	I encourage them to comment and ask questions in class	8	3.80%
-	Do activities and exercises that are not scored.	3	1.40%
-	Propose open activities where everyone can do something that allows me to observe how they are learning.	4	1.90%
Strategy 3: Provide feedback			
1	I give them feedback that helps them understand why they were wrong	10	4.70%
3	I make comments that help them to improve what went wrong	7	3.30%
7	I write comments on our tasks or writings about what they have to improve	2	0.90%
-	Use the Inclusive Pedagogical Space (IPS) with small groups of three or four students exclusively for feedback	1	0.50%
-	Give feedback on the same work over and over again, keep a back-and-forth and assign a final date, when it will be graded. (Iterative feedback)	5	2.40%
Strategy 4: Activate collaborative peer learning			
1	I make them work as a team	6	2.80%

2	I make them investigate and learn for themselves	4	1.90%
3	I make them correct each other's work as a learning method	9	4.20%
4	I teach them to work as a team	2	0.90%
-	In team assignments, assign a separate grade for the student and for the group.	2	0.90%
-	Promote activities where they have to explain themselves to each other	2	0.90%
Strategy 5: Involve the student and promote self-regulation			
1	I ask them to reflect on what works best for them and what costs them the most	8	3.80%
2	I get them to think about different paths they can take when they get stuck on a task	6	2.80%
3	I encourage them to feel capable and competent to perform the tasks	2	0.90%
4	I answer them with new questions that help them think	4	1.90%
5	I encourage them to make an effort even if it costs them	1	0.50%
-	Generate an environment of trust and motivation.		
Obstacles identified by teachers to implement the FA			
-	Emotional factors	7	3.30%
-	Large groups	1	0.50%

-	Absences and drop outs	3	1.40%
-	Laborious planning and implementation of the FA	17	8.00%
-	Time shortage	8	3.80%
--	Class routines, framing	8	3.80%
-	Tension between FA and ES	13	6.10%

APPENDIX B

GUIDELINES for the development of interviews

1. Presentation, framing (time, recording, acknowledgements, etc.). Why was he/she chosen for the interview...
2. *We are investigating the formative assessment practices used by mathematics teachers in their classrooms. We want to understand which are the most frequent. We think it is important to tell you what we understand by FA to...* (propose Wiliam's simple definition).

1. Clarify, share, and understand learning goals and achievement criteria;

2. Design effective class discussions, questions, and assignments that lead to evidence about learning;

3. Provide feedback that enables students to move forward;

4. Promote students as teaching resources for other students;

5. Promote students as owners of their own learning.

3. *First of all, we would like to know if you already knew the concept, given that it is relatively new, and if so, tell us a little about it, if it was in your training, if it was through a seminar you took on your own, some colleague, etc....*

Know the teachers' conception of FA, when they came into contact with the concept (whether it was in training or in other courses), what approaches they have had on the subject (books, conferences, training, etc). If they have always incorporated it into your practice, or since when and why.

4. As you know, we did a preliminary consultation with math teachers, but quantitatively, I'm going to name the three that, according to this survey, are the most frequent. The idea would be for you to tell me everything you think about this: why do you think it was like that, how are they applied...

    a) I make them work as a team (6.03)
    b) I make comments that help them understand what they did wrong (6.17)

5. I ask them how they know whether an answer is correct or incorrect (6.06)

    Now, the same as the previous one, but the three that were the least frequent, according to the opinion of the math teachers...

    a) I make them correct each other's work as a learning method (4.2)
    b) I ask them to reflect on what works best for them and what costs them the most (4.53)
    c) I detail what they have to know to solve the task successfully (4.3)

6. You know that in the questionnaire that I mentioned to you before, something very interesting came up in the open part, when it said Notes. Some teachers talked about the importance of the math error and the process that it has in learning and problem solving.
7. We are already finishing, so we would like to ask you if you think FA is a construct that can make a difference in student learning, that is, if you see it as having potential, and if you see limitations or problems in putting it into practice

    a) What would be the advantages or positive aspects?

b) What would be the disadvantages or difficulties?

8. We're done, I don't know if you want to ask or add something. Final thanks and gift delivery.