Jurnal Penelitian Pembelajaran Matematika Sekolah (JP2MS) eISSN 2581-253X
Volume 9, No.3, Desember 2025, pp: 365-380
DOI: https://doi.org/10.33369/jp2ms.9.3.365-380

FORMATIVE FEEDBACK IN MATHEMATICS EDUCATION: A SYSTEMATIC REVIEW OF RESEARCH INSTRUMENTS AND LEARNING OUTCOMES

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Abstract

Formative feedback is an important aspect in mathematics teaching since it helps students to build mathematical thinking, enhance conceptual knowledge, and work toward better learning results. Although it is crucial, a consensus on the most effective feedback practices and research instruments to be used in the mathematics setting is limited. Numerous research studies implement various tools without a clear reference to mathematical capabilities, which leads to inappropriate research results and difficulties in the classroom. The research was based on a systematic literature review (SLR) to investigate the current application of different research instruments to measure formative feedback in mathematics education and its effect on student learning outcomes. Using ProQuest, Scopus, and EBSCOhost as the sources of data collection on the guidance of PRISMA protocols, key search words that were used were formative feedback and mathematics learning outcomes. The number of selected articles was 21, which was analyzed with the help of thematic and descriptive approaches. The review found six broad types of tools to provide formative feedback, namely, student feedback tools, gamification frameworks, structured frameworks, classroom artifacts, digital tools, and observation protocols. Student feedback tools and digital tools were most used among them as they also indicate a transition to interactive and personalized learning environments. These tools were often associated with six major learning outcomes, such as conceptual understanding, engagement, self-regulation, critical thinking, emotional responses, and motivation, with conceptual understanding and engagement being the most affected. Overall, the results suggest that formative feedback is an essential tool in improving mathematics learning yet also indicates the gap in the correspondence between the instruments of feedback and the specific mathematical skills. The study requires additional research to determine better links and create more productive and evidence-based feedback practices.

Keywords: Mathematics, Formative Feedback, Formative Assessment, Prisma, Systematic Literature Review

Cara menulis sitasi : Zaini, N. F. M. M., Mohamed, N. A., Idalisa, N., Mohamed, N. H., & Mohamed, N. F. (2025). Formative feedback in mathematics education: A systematic review of research instruments and learning outcomes. *Jurnal Penelitian Pembelajaran Matematika Sekolah (JP2MS)*, *9*(3), 365-380.

INTRODUCTION

The problems of many students are their inability to understand basic mathematical concepts. Such issues frequently cause misunderstandings and retardation in the learning process (Kultur and Kutlu, 2021). Students have difficulties with significant steps in problem-solving. These are reading the question, planning it, finding the answer, and proofreading their answer. It can be caused by a weak understanding and poor thinking skills (Sulistyani et al., 2021). The other problem is the lack of interest among students in math classes. Numerous students do not have engagement. This is made worse by the fact that they are not received with helpful or timely feedback. However, interaction is highly essential.

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It aids in the attitudinal inclination of students towards math. It also enhances their academic performance in school (Kültur & Kutlu, 2021).

These complications demonstrate why improved formative feedback is required to assist students in learning more intensely. Formative assessment is not merely about the assignment of grades. Its actual purpose is to assist teachers and students to be aware of what the student already knows and what he/she requires assistance with (Ayalon & Wilkie, 2020). Regrettably, there are still teachers who regard it as only a grading tool. This error may cause the ineffective utilization of the feedback and missed opportunities to assist students in developing (Kültür & Kutlu, 2021). Emotions are also important in providing feedback. Failure to provide feedback clearly can also render the students disappointed or disoriented rather than motivated (Lui and Andrade, 2022).

These emotional responses and challenges in the classroom may also complicate the use of good feedback. In recent years, the issue of formative feedback has been discussed more by individuals across the globe. It is perceived as an avenue for enhancing the teaching of math. Nevertheless, further studies are required. We should also learn how to apply it in the real classroom in the best way (Erika & Torulf, 2023). Previous research also reveals that there is not much information on how it influences other aspects, such as performing better on assignments or developing new skills (Lee et al., 2020). This paper is aimed at sealing those gaps. It examines the previous studies to determine the role of formative feedback in learning mathematics. The two questions are the basis of the review:

RQ1: What research instruments have been used to assess formative feedback in mathematics education?

RQ2: What kinds of learning outcomes are influenced by formative feedback in mathematics education?

METHODOLOGY

Systematic Literature Review Methodology

A Systematic Literature Review (SLR) is a systematic and thorough method of research by the researcher. It assists them in locating, perusing, and integrating findings of previous research. The approach assists researchers in drawing powerful conclusions on the basis of prior knowledge. The SLR was based on the PRISMA in this research. PRISMA is an acronym that represents Preferred Reporting Items of Systematic Reviews and Meta-Analyses. The rules assist in ensuring that the review is clear, fair, and conducted in a proper manner. This review was conducted in three systematic phases, which came in conformity to the research objectives, which included the formulation of the nature of research tools used in formative feedback research and synthesis of the learning outcome that covered mathematics education.

First, inclusion and exclusion criteria were established to make sure that only empirical studies published after 2020 and, more precisely, related to the concept of formative feedback in the context of mathematics were used. This was followed by the identification of the relevant data sources, and search strategies were formulated to enable sufficient coverage of the studies that covered both research instruments and learning outcomes. Lastly, the analyzed studies were evaluated with the help of the relevant analytic tools to classify the instruments mentioned in them and define the types of learning outcomes they addressed, thus aligning the purpose of the review, i.e., mapping the current practices and outlining the gaps that exist.

Inclusion and Exclusion Criteria

To make sure the articles were useful and of good quality, clear rules were set before the search began. These rules are called inclusion and exclusion criteria. Each article was checked to see if it matched the keywords "*formative feedback*" and "*mathematical learning outcomes*." Only articles that met all the inclusion rules and none of the exclusion rules were chosen. **Table 1** shows a clear summary of these rules.

Table 1: Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
Must be related to the keywords: *Formative feedback* and *Mathematical learning outcomes*	Articles not related to both keywords
Must focus on the field of Mathematics	Articles outside the Mathematics domain
Published between 2020 and 2024	Articles published before 2020
Written in English	Articles in other languages
Must be journal articles	Books, theses, and dissertations are excluded
Must be original research	Systematic reviews are excluded

Data Sources and Search Strategy

This systematic review used three large academic databases, which included ProQuest, Scopus, and EBSCOhost, in the data collection process. Two keywords were used to search, i.e., "formative feedback" and "mathematical learning outcomes". The combination was done to ensure that the search is focused on the objectives of the study. The PRISMA guidelines (Preferred Reporting Items to Systematic Reviews and Meta-Analyses) were adhered to in order to guarantee the review framework

and research rigor. A PRISMA flow diagram was used to record every stage of the selection process. The first search gave a result of 43,410 records.

Once 6 duplicates are eliminated, 204 unique articles were left. The following were then filtered according to the inclusion and exclusion criteria provided in Table 1. The inclusion criteria were that the articles had to be peer-reviewed and that they must have been published in the past 2 to 4 years, and that the articles had to be in the field of mathematics teaching and learning, specifically, formative feedback. They were screened, and out of 59 full-text articles, 59 were assessed as eligible. Among them, 38 were eliminated as they did not correspond to the criteria or did not have appropriate data. Finally, 21 articles were picked to analyze. Figure 1 below describes the whole process of the selection, in accordance with the PRISMA flow chart.

Data Analysis

This review used two kinds of analysis, i.e., thematic analysis and descriptive analysis. The descriptive analysis looked mainly at the types of research tools used. It also studied how these tools affected students' learning results. At the same time, a thematic analysis was done. This helped understand deeper patterns in the qualitative data. Thematic analysis is common in qualitative research. It helps researchers find and explain repeating ideas or themes in the data.

Clarke et al. (2015) said that this method gives a deep and detailed understanding. It shows important stories and ideas that may not be easy to see at first. This study used the thematic analysis steps from Braun and Clarke (2006) and Saraswati (2020). Saraswati (2020) indicated that the thematic analysis in this review underwent six steps, which are systematic and helped to support the aims of research instruments identification and related learning outcomes synthesis. The familiarization with the data was the starting point of the process, where all the chosen articles were read carefully to get familiar with their situation and methodological peculiarities.

The first codes were then developed to record appropriate information pertaining to the nature of formative feedback tools and the outcomes of learning that were being reported. The codes were then sorted into broader categories at the theme-searching phase, enabling patterns across the studies to arise. Reviewing and refining the themes were then carried out to make sense, and the themes were set to be consistent with the research focus. After this, each theme was clearly defined and named to reflect the distinct categories of instruments and outcomes. Lastly, the thematic inferences were summarized and presented in a systematic fashion, which allowed the review to outline the existing practices and indicate gaps in applying the formative feedback tools in teaching mathematics.

Following these structured steps helped ensure the analysis was both rigorous and consistent. As a result, meaningful insights were able to emerge clearly from the literature.

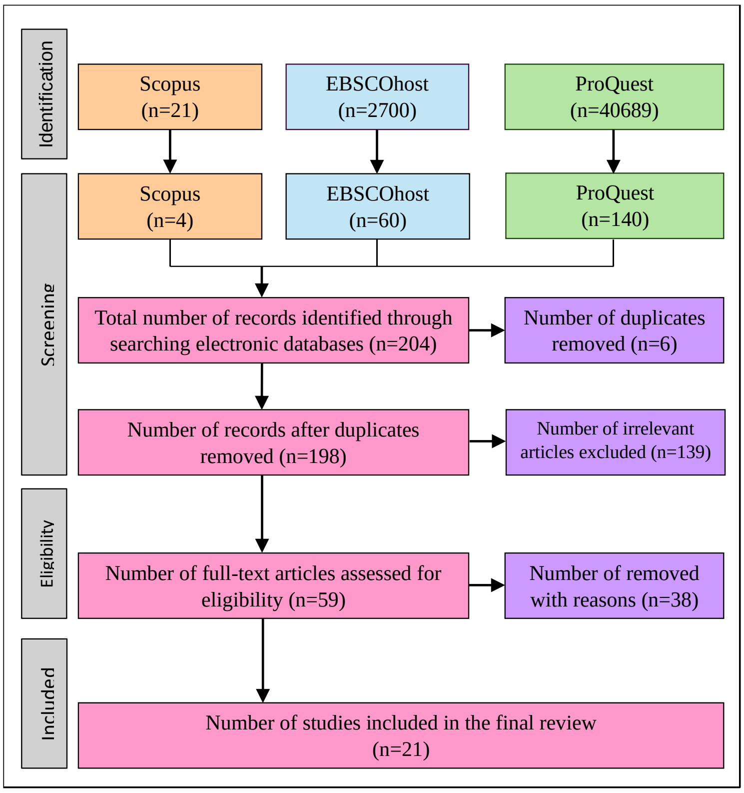

Figure 1. Prisma Flow Diagram Illustrating The Article Selection Process For The Systematic Literature Review On "Formative Feedback" And "Mathematical Learning Outcomes".

RESULTS AND DISCUSSION

Results

Thematic Analysis

This review included 21 research articles. The selection was based on two main research questions. Each article was studied carefully to find out two things. First, what kinds of research tools were used to give formative feedback? Second, how do these tools affect students' math learning?

Table 2 gives a clear summary of all the studies. It shows important details like the authors, year of publication, types of tools used, and the effects on students' learning. This table also helps us see the different tools used in various situations. It shows how each tool supports students in learning mathematics.

Table 2. Summary and Comparison of Selected Articles Based on Research Instruments and Learning Outcomes

No.	Author(s)	Year	Research instruments	Impacts on students' mathematical learning outcome
1	Téllez et al.	2024	• LLM-Based Feedback • Student Feedback tools	• Conceptual Understanding • Self-Regulation • Emotional Responses
2	Fuentes-Riffo et al.	2023	• Gamification framework • Student Feedback tools	• Engagement • Motivation • Conceptual Understanding
3	Chihodzi et al.	2023	• Classroom Artifacts • Student Feedback tools	• Conceptual Understanding • Self-Regulation
4	Rakes et al.	2023	• PDSA Cycle • Student Feedback tools • Observation Protocols	• Critical Thinking • Engagement
5	Safadi & Hawa	2021	• Structured Framework • Student Feedback tools	• Conceptual Understanding • Self-Regulation
6	Balaskas et al.	2023	• Gamification framework • Student Feedback tools	• Engagement • Conceptual Understanding • Motivation
7	Urrutia & Araya	2023	• Digital Tools • Student Feedback tools	• Conceptual Understanding • Engagement
8	Piñero Charlo et al.	2022	• Gamification framework • Structured Framework	• Engagement • Conceptual Understanding

9	Ibragimov & Kalimullina	2021	• Digital Tools • Student Feedback tools	• Self-Regulation • Conceptual Understanding
10	Muhammad Sofwan et al.	2021	• Observation Protocols • Student Feedback tools	• Engagement • Conceptual Understanding
11	Barana et al.	2021	• Digital Tools	• Motivation • Self-Regulation
12	Fyfe & Brown	2020	• Structured Framework • Student Feedback tools	• Engagement • Emotional Responses
13	Clincy et al.	2022	• Digital Tools • Gamification framework • Student Feedback tools	• Engagement • Conceptual Understanding • Self-Regulation
14	Mangwiro & Machaba	2022	• Observation Protocols • Structured Framework	• Critical thinking • Engagement
15	Iannone and Vondrova	2023	• Observation Protocols	• Engagement • Conceptual Understanding
16	Chang et al.	2021	• Peer Assessment Tools • Digital Tools • Structured Framework	• Conceptual Understanding • Critical Thinking • Engagement
17	Divjak et al.	2022	• Digital Tools • Student Feedback tools	• Conceptual Understanding • Motivation
18	Juma et al.	2022	• Digital Tools • Student Feedback tools • Gamification framework	• Conceptual Understanding
19	Nurzatulshima et al.	2021	• Student Feedback tools • Classroom Artifacts	• Critical thinking • Engagement • Emotional responses

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			• Structured Framework	
20	Rumanová et al.	2020	• Student Feedback tools • Classroom Artifacts • Observation Protocols	• Conceptual Understanding • Critical thinking
21	Chu et al.	2021	• Gamification framework • Digital Tools • Observation Protocols	• Engagement

Table 3. Thematic Synthesis Matrix: Instrument Categories x Learning Outcomes

Instrument category	Conceptual understanding	Self-regulation	Emotional responses	Critical thinking	Engagement	Motivation
Student feedback tools	12	5	3	3	8	3
Classroom artifacts	2	1	1	2	1	0
Structured framework	3	1	2	3	5	0
Gamification framework	5	1	0	0	5	2
Observation protocols	3	0	0	3	5	0
Digital tools	5	3	0	1	4	2
others	2	1	1	2	2	0

Implemented Research Instruments for Formative Assessment

The first research question (RQ1) aimed to explore the types of research instruments used in formative assessment within the field of mathematics education.

RQ1: **What research instruments have been used to assess formative feedback in mathematics education?**

A descriptive analysis was conducted to answer this research question, and frequency bar charts were used to achieve this, as shown in Figure 2. This aided in establishing the patterns and trends in the chosen studies. The review showed that numerous types of research tools are generally used in formative

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feedback research in mathematics education. These are student feedback tools, gamification models, formal frameworks, classroom artifacts, technology-related tools, and observation guidelines. Besides these domineering, some of the new tools were found and registered as LLM-based feedback systems, PDSA cycles, and peer assessment tools, but were classified as others because they were found in low frequency. These categories combined give a comprehensive picture of the resources applied to create formative feedback and ensure the purpose of the study, mapping the current picture of the research instruments in mathematics education after 2020.

Student feedback tools were the most used among them. This puts emphasis on the spread of student voice in teaching and learning. Gathering student feedback will enable the educators to learn more about the needs and experiences of learners. To illustrate, Tellez et al. (2024) focused on the ways feedback tools can facilitate reflective learning and help students improve. These instruments also represent the general tendencies in contemporary mathematics education. Interactivity, motivation, and individualized learning have now become a major concern. Ibragimov and Kalimullina (2021) argue that digital communication platforms such as Microsoft Teams can be used to make two-way communication. This comes in handy, especially in self-directed learning. These tools assist students in monitoring their progress, and the teachers can modify teaching on the fly. This leads to responsive and effective learning. These tools are distributed as illustrated in Figure 2.

Other tools, like structured frameworks, gamification frameworks, and observation protocols, were also present in the reviewed works. Structured designs have a tendency to embrace processes with steps and experimental designs. Those provide a methodical approach of guiding the learning process and measuring the student performance (Fyfe and Brown, 2020). Gamification frameworks, including online quizzes or escape-room-type activities, can be used to make the learning process more enjoyable by integrating the element of a game in math classes (Piñero Charlo et al., 2022). In the meantime, observation protocols involve classroom observations and interviews as in-depth and qualitative data gathering. The approaches give important learning points to teacher practice and students (Mangwiro and Machaba, 2022). Although these tools could not be noted as the most popular ones, their regular presence demonstrates their usefulness in improving the quality of teaching and learning among students.

Finally, some tools were not used on a regular basis but were worth mentioning. These are large language model (LLM)-based feedback, PDSA (Plan-Do-Study-Act), and peer assessment tools. This is because they are still novices in the field of mathematics education research, which is evidenced by their limited appearance. Nevertheless, they can be very promising. The tools might be particularly helpful in long-term learning and reflection practice. It is only a matter of time before their comprehensive effect can be fully realized by more research.

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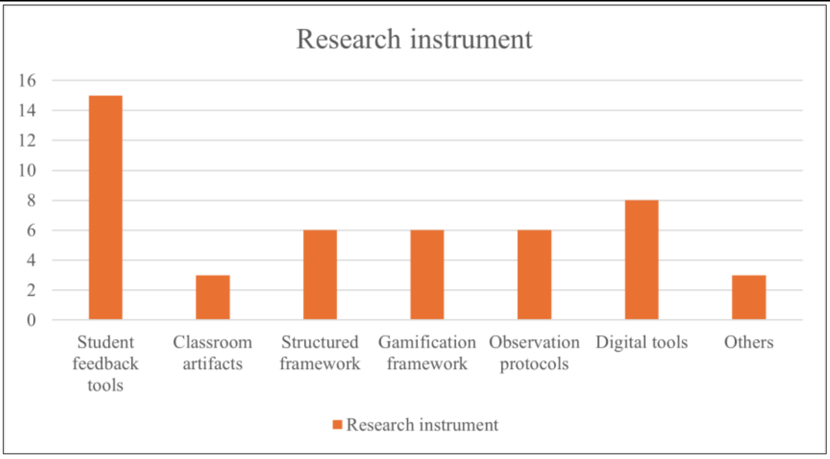

Figure 2. Frequency Distribution Of Research Instruments Implemented In Formative Feedback Within Mathematics Education

The Effects on Students' Learning Outcomes

This section answers the second research question (RQ2): **What kinds of learning outcomes are influenced by formative feedback in mathematics education?** To find the answer, the data from the selected studies were analyzed. Frequency bar charts were used to spot common patterns.

The results in Figure 3 indicated that there were six overall learning outcomes attributed to formative feedback. First, it also improved the conceptual knowledge of students as they were able to clear up and cement their knowledge. Second, the self-regulation was developed with the help of formative feedback that helped learners to track their progress and change their learning strategies. It also affected the emotional reactions, in either the confidence-building or the anxiety-generating effect, depending on the method used in delivering the feedback. The feedback also stimulated critical thinking, which caused the students to question their rationale and better the quality of their work. Moreover, it enhanced student interaction, which means that it encouraged active learning activities. Lastly, the formative feedback also acted as a motivational learning tool as it encouraged learning among learners, and they were motivated to continue learning.

The most prevalent outcomes were conceptual understanding and student engagement. Indicatively, Iannone and Vondrova (2023) indicated that feedback enables students to have a better understanding of math concepts. Fuentes-Riffo et al. (2023) demonstrated that students learn better when they are engaged and receive helpful feedback. This implies that feedback has to be effective through clear explanations of ideas and the involvement of students in learning. This was supported by Urrutia and Araya (2023), as well. Their results showed that machine learning tools are capable of determining student errors very fast through natural language processing. They provide timely and precise feedback. This can assist students in thinking over their answers, correcting erroneous answers, and get to learn more about mathematics.

Student engagement refers to the level to which students like, pay attention and participate in the classroom. Math was more enjoyable and accessible through interactive and game-based feedback. Students are more engaged; they perform better, get more motivated, and like to learn more when they are more engaged. Fuentes-Riffo et al. (2023) also discovered that rewards and games assisted students in remaining active in classroom assignments. Less frequently, but not without importance, some outcomes were also mentioned. These are emotional response, self-regulation, and critical thinking. To

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illustrate, in Fyfe and Brown (2020), it was demonstrated that good feedback may reduce anxiety and develop student confidence. This provides a friendly and secure classroom.

Self-regulation implies that students are able to manage and direct their learning. According to Tellez et al. (2024), this is a skill that is valuable in the long run. Critical thinking aids students in addressing problems in a better way. According to Chang et al. (2021), it also assists students to go beyond the superficial steps and think more deeply. The least mentioned and yet important was motivation. It provides students with the impetus to take on challenging tasks. In-game-based learning, motivation plays an essential role. According to Fuentes-Riffo et al. (2023), gamification enhanced motivation, decreased stress, and boredom. They are typical pitfalls in the learning of math. Thus, motivation can result in improved performance of students.

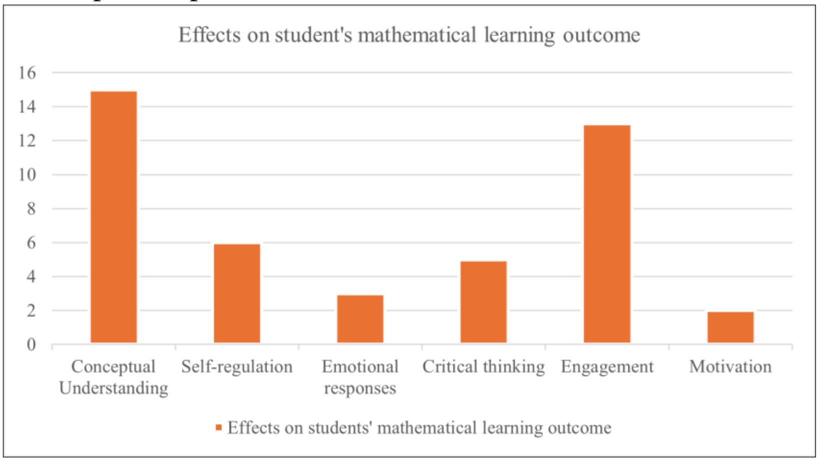

Figure 3. Frequency Distribution Of Learning Outcomes Influenced By Formative Feedback In Mathematics Education

Discussion

Descriptive Analysis of Implemented Research Instruments for Formative Assessment

Based on the findings in Figure 2, we can note that the analysis reveals significant information on the trends in the formative feedback in mathematics education during 2020-2024, with the shift towards student-centered paradigms and the growing use of digital tools and gamification frameworks. The movement to student-centered assessment paradigms and practices, according to the Assessment for Learning (AfL) paradigms, is a revolutionary change in education. It has been emphasized that research points to the effectiveness of formative feedback mechanisms in the evaluation of students, in addition to their active participation in facilitating their own learning processes. This teaching concept focuses on student agency, metacognition, and co-created learning spaces, allowing students to learn on a deeper level and think critically. To discuss, e.g., (Vaughan & Uribe, 2024).

Indicatively, research indicates that efficient formative feedback entails proper communication of learning objectives and actionable feedback that is actionable, which makes students autonomous in the learning journeys (Morris et al., 2021). The prevalence of digital tools and gamification models, as mentioned, is also in line with the post-pandemic changes in education. These tools are vital in improving mathematical reasoning and engagement among the learners. Artificial intelligence can be used to provide personalized feedback, adaptive evaluation, and real-time monitoring, resulting in meaningful and interactive learning experiences in the form of digital ecosystems, including intelligent tutoring systems, gamified feedback platforms, and interactive dashboards (Badshah et al., 2023; Procopio et al., 2024). The examples are those of formative assessment activities aided by tools such as GeoGebra and

Scratch that combine the principles of neuroscience and promote collaborative mathematical thinking and procedural fluency (Procopio et al., 2024). Also, gamification has been indicated to encourage students, maintain their motivation for formative activities, and improve their long-term memorization of mathematical concepts (Montenegro-Rueda et al., 2023).

In spite of these innovations, the fact that we have observed that there is a low number of AI-driven feedback tools (e.g., large language models and adaptive tutoring systems) indicates a major research gap. ChatGPT, MathGPT, and intelligent reasoners represent AI technologies that have enormous potential to improve formative assessment practice by providing personalized feedback and customized scaffolding according to the real-time analysis of the data (Shahzad et al., 2024; Torres-Peña et al., 2024). Such systems may enhance procedural fluency, conceptual learning, and adaptive reasoning problems in mathematics education, but have been extensively studied in the literature; little is known about their combination (Li, 2024; Zhang et al., 2024).

The lack of studies that examine the use of AI is an indication of untapped possibilities to be explored in the future, especially in developing AI-enhanced formative assessment systems (Shahzad et al., 2024). Indicatively, research syntheses indicate that in the higher education context, digital formative assessments that use interactive feedback mechanisms have become more common and greatly enhance student learning outcomes and retention (Luo et al., 2024). Nevertheless, the scarcity of research on AI-driven tools supports the necessity of interdisciplinary studies dedicated to the scalability of these tools, ethical issues, and pedagogical consistency (Shahzad et al., 2024).

Descriptive Analysis of the Effects on Students' Learning Outcomes

Figure 3 underscores the critical tendencies in the learning outcome of students in mathematics, with Conceptual Understanding (15) and Engagement (13) being the most widely reported outcomes. This fact highlights their important contribution to solving the long-standing issues in mathematics education. Students find it difficult to cope with abstract concepts and the application of knowledge to problem-solving situations. A focus on a conceptual knowledge base allows building robust mathematical schemas, which allow laying the groundwork of understanding that is necessary for more profound learning (Mokhithi et al., 2025). The popularity of Engagement can be associated with the growing adoption of digital and gamified solutions, as shown in Figure 2.

The interventions that are mediated by technologies, especially gamification and interactive digital platforms, actively involve the attention of students and stimulate their continued interaction and engagement with mathematical content (Lee and Paul, 2023). Studies indicate that these tools establish active learning experiences, which will stimulate the need to persist in solving the problem-solving assignment and offer an effective platform on which iterative learning can occur (Lee & Paul, 2023). This observation can be supported by earlier research that has highlighted the importance of environmental intricacy and the use of novel pedagogical practices in encouraging student interest in various learning environments (Maričić & Lavicza, 2024).

Although positive gains have been made in terms of conceptual knowledge and interaction, the evidence on the formation of such higher-order thinking as Critical Thinking remains quite weak (5), which creates a major gap. Although the training of the foundational skills is paramount, the relative lack of the development of the higher-order reasoning, analysis, and reflective thinking indicates the

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necessity to introduce specific pedagogical techniques. Critical thinking has been known to play a significant role in mathematics learning, as it helps students to creatively and methodically analyze and evaluate mathematical problems (Rulida, 2025). To give an example, flipped classrooms and problem-based learning have proven to be a good way of improving the ability of students to think critically and reflectively.

The research in the future must aim at incorporating formative feedback systems into the educational approaches to facilitate these skills by using assessment mechanisms that require the students to defend, assess, and fine-tune their problem-solving strategies (Rojas and Benakli, 2020). Equally, relatively low incidences of the Emotional Responses (3) and Motivation (2) in the analysis would highlight the inadequate application of the affective aspects in the existing process of instruction. Anxiety, frustration, and enjoyment are examples of emotions that influence learning considerably, and it is proven by the connection between achievement emotions and academic outcomes through the prism of Control-Value Theory (Pekrun, 2024).

Nevertheless, numerous interventions in mathematics education are highly cognitive, and very little has been done in terms of investigating emotion regulation strategies that can be used to support persistence and resilience. As an example, there is a report that the Medical Emotion Scale tool may be used in different educational settings, and as a result, the level of emotional involvement and learning results are strongly correlated (Hsu et al., 2025). The possible solution to this gap could be the establishment of emotionally supportive learning conditions that promote positive affect and alleviate anxiety, especially during difficult math problems (Schindler and Bakker, 2020).

Motivation (although the designation is humbly presented) is one of the main prompts of involvement and success in mathematics. It has also been revealed that both intrinsic and extrinsic motivational variables have a direct influence on the willingness of students to engage and exert effort in the long run (Ferrer et al., 2020). According to self-determination theory, autonomy, competence, and relatedness should be promoted within the learning context, and these aspects may positively impact engagement and intrinsic motivation, thereby encouraging better mathematical performance (Yang et al., 2025).

An important skill that comes out with a moderate representation in Figure 3 is self-regulation (6). Self-managed students are in a better position to plan, track and review their achievements, which give them the means of adjusting their strategies in learning to achieve the best results. Nonetheless, the development of the process of self-regulation requires scaffolding in the curriculum. Adaptive digital tools and real-time feedback mechanisms were found to facilitate self-regulated learning as they allow students to reflexively consider their learning process and implement the required changes (Mejeh et al., 2024).

CONCLUSION

This is a systematic literature review that examined the application of formative feedback and its evaluation in math education. It also discussed the impact of this feedback on the learning outcomes of students. A total of 21 peer-reviewed articles (published between 2020 and 24) were reviewed. It adhered to PRISMA to have a concise and systematic process. It was aimed at providing a revised and more detailed perspective of the functioning of formative feedback in math classrooms. The first objective was to establish the tools that were used to measure formative feedback. The review established six primary types of tools, i.e., student feedback platforms, gamification frameworks, structured frameworks, classroom artifacts, digital tools, and observation protocols. Student feedback tools were most used among them. This demonstrates that a good number of teachers are giving more consideration to student-centered learning. Gamified activities as well as digital tools were also popular. They ensured that feedback was more interactive and enjoyable.

Structured frameworks and observation methods provided more specific and detailed perspectives of student progress. The second objective was to determine the learning outcomes that were most influenced by formative feedback. The review identified six major outcomes, i.e., conceptual knowledge, student engagement, self-regulation, critical thinking, emotional response as well as motivation. The most mentioned ones were conceptual understanding and student engagement. This demonstrates that feedback assists students in comprehending and remaining engaged in the learning process. Other less frequent outcomes, such as emotional response and motivation, were also significant. They make students interested and continue their trials even in case when math can be difficult. Concisely, the results indicate that formative feedback does not simply indicate errors. It assists the students to learn intensively, feel empowered, and become the drivers of their learning. But some gaps were also identified in the review. As an example, AI-based feedback tools are not utilized extensively.

In addition, there is a lack of research on the long-term effectiveness of feedback as well as its efficacy in students of other backgrounds. Going forward, emerging tools, including artificial intelligence, learning analytics, and natural language processing, should be examined in future research. Such technologies can provide more individualized and immediate feedback. The functionality of culturally responsive feedback in multilingual and diverse classrooms should also be explored by researchers. There is a need to conduct longitudinal studies to have insight into how formative feedback can influence learning in students over time, particularly in developing higher-order thinking and problem-solving skills.

More rigorous research designs should be used in the future, as well. Mixed-methods studies and randomized controlled trials may be useful in strengthening the relationship between feedback practices and student outcomes. Lastly, it is important to incorporate the voices of the underrepresented students and teachers to develop more comprehensive and inclusive feedback approaches to mathematics teaching.

REFERENCES

Ayalon, M., & Wilkie, K. J. (2020). Investigating peer-assessment strategies for mathematics pre-service teacher learning on formative assessment. *J Math Teacher Educ, 24,* 399–426. https://doi.org/10.1007/s10857-020-09465-1

Badshah, A., Ghani, A., Daud, A., Jalal, A., Bilal, M., & Crowcroft, J. (2023). Towards Smart Education through Internet of Things: A Survey. *ACM Computing Surveys, 56*(2), 1–33. https://doi.org/10.1145/3610401

Balaskas, S., Zotos, C., Koutroumani, M., & Rigou, M. (2023). Effectiveness of GBL in the engagement, motivation, and satisfaction of 6th grade pupils: A Kahoot! Approach. *Education Sciences, 13*(12), 1214. https://doi.org/10.3390/educsci13121214

Barana, A., Marchisio, M., & Sacchet, M. (2021). Interactive feedback for learning mathematics in a digital learning environment. *Education Sciences, 11*(6), 279. https://doi.org/10.3390/educsci11060279

Chang, D., Hwang, G.-J., Chang, S.-C., & Wang, S.-Y. (2021). Promoting students' cross-disciplinary performance and higher order thinking: A peer assessment-facilitated STEM approach in a mathematics course. *Educational Technology Research and Development*, *69*(6), 3281–3306. https://doi.org/10.1007/s11423-021-10062-z

Chihodzi, B., Mwakapenda, W., & Ngulube, B. (2023). Ticks and crosses in primary mathematics assessments: What purpose do they serve? *Pythagoras*, *44*(1). https://doi.org/10.4102/pythagoras.v44i1.647

Chu, H.-C., Chen, J.-M., Kuo, F.-R., & Yang, S.-M. (2021). Development of an Adaptive Game-Based Diagnostic and Remedial Learning System Based on the Concept-Effect Model for Improving Learning Achievements in Mathematics. *Educational Technology & Society*, *24*(4), 36–53.

Clincy, M., Melzer, K., Schaaf, G., Eichhorn, A., & Verné, N. (2022). Inside the "sandbox": The effects of unlimited practice for summative online-tests. *International Journal of Emerging Technologies in Learning*, *17*(23), 115–127. https://doi.org/10.3991/ijet.v17i23.35939

Divjak, B., Žugec, P., & Pažur Aničić, K. (2022). E-assessment in mathematics in higher education: a student perspective. *International Journal of Mathematical Education in Science and Technology*, 1–23. https://doi.org/10.1080/0020739x.2022.2117659

Erika, B., & Torulf, P. (2023). The effect of a formative assessment practice on student achievement in mathematics. *Frontiers in Education*, *8*(23). https://doi.org/10.3389/feduc.2023.1101192

Ferrer, J., Ringer, A., Saville, K., A Parris, M., & Kashi, K. (2020). Students' motivation and engagement in higher education: the importance of attitude to online learning. *Higher Education*, *83*(2), 317–338. https://doi.org/10.1007/s10734-020-00657-5

Fuentes-Riffo, K., Salcedo-Lagos, P., Sanhueza-Campos, C., Pinacho-Davidson, P., Friz-Carillo, M., Kotz-Grabole, G., & Espejo-Burkart, F. (2023). The influence of gamification on high school students' motivation in geometry lessons. *Sustainability*, *15*(21). https://doi.org/10.3390/su152115615

Fyfe, E. R., & Brown, S. A. (2020). This is easy, you can do it! Feedback during mathematics problem solving is more beneficial when students expect to succeed. *Instructional Science*, *48*(1), 23–44. https://doi.org/10.1007/s11251-019-09501-5

Hsu, Y.-P., Meyen, E. L., & Lee, Y.-J. (n.d.). Understanding Emotional Analytics for Student Engagement. In *Advances in Higher Education and Professional Development* (pp. 70–102). IGI Global. https://doi.org/10.4018/978-1-5225-5769-2.ch004

Iannone, P., & Vondrová, N. (2023). The novelty effect on assessment interventions: A qualitative replication study of oral performance assessment in undergraduate mathematics. *International Journal of Science and Mathematics Education*, *22*, 375-397. https://doi.org/10.1007/s10763-023-10368-9

Ibragimov, G. I., & Kalimullina, A. A. (2021). Descriptors derived from feedback on teaching mathematics in school. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(10). https://doi.org/10.29333/ejmste/11185

Juma, Z. O., Owino, I., & Obiero, M. (2022). Delivery of Integral calculus at Maseno University: Is STACK really playing an Integral part? *International Journal of Emerging Technologies in Learning (IJET)*, *17*(23), 64–68. https://doi.org/10.3991/ijet.v17i23.36621

Kültür, Y. Z., & Kutlu, M. O. (2021). The effect of formative assessment on high school students' mathematics achievement and attitudes. *Journal of Pedagogical Research*, *5*(4), 155-171. https://doi.org/10.33902/JPR.2021474302

Lee, H., Chung, H. Q., Zhang, Y., Abedi, J., & Warschauer, M. (2020). The effectiveness and features of formative assessment in US K-12 education: A systematic review. *Applied Measurement in Education*, *33*(2), 124–140. https://doi.org/10.1080/08957347.2020.1732383

Lee, J., & Paul, N. (2023). A Review of Pedagogical Approaches for Improved Engagement and Learning Outcomes in Mathematics. *Journal of Student Research, 12*(3). https://doi.org/10.47611/jsrhs.v12i3.5021

Li, M. (2024). Integrating Artificial Intelligence in Primary Mathematics Education: Investigating Internal and External Influences on Teacher Adoption. *International Journal of Science and Mathematics Education, 23*(5), 1283–1308. https://doi.org/10.1007/s10763-024-10515-w

Lui, A. M., & Andrade, H. L. (2022). Inside the next black box: Examining students' responses to teacher feedback in a formative assessment context. *Frontiers in Education, 7*, 751549. https://doi.org/10.3389/feduc.2022.751549

Luo, Z., Abbasi, B. N., Yang, C., Li, J., & Sohail, A. (2024). A systematic review of evaluation and program planning strategies for technology integration in education: Insights for evidence-based practice. *Education and Information Technologies, 29*(16), 21133–21167. https://doi.org/10.1007/s10639-024-12707-x

Mangwiro, C., & Machaba, F. (2022). Teacher questioning techniques to elicit learners' mathematical thinking. *The International Journal of Science, Mathematics and Technology Learning, 30*(1), 51–66. https://doi.org/10.18848/2327-7971/cgp/v30i01/51-66

Maričić, M., & Lavicza, Z. (2024). Enhancing student engagement through emerging technology integration in STEAM learning environments. *Education and Information Technologies, 29*(17), 23361–23389. https://doi.org/10.1007/s10639-024-12710-2

Mejeh, M., Sarbach, L., & Hascher, T. (2024). Effects of adaptive feedback through a digital tool – a mixed-methods study on the course of self-regulated learning. *Education and Information Technologies, 29*(14), 1–43. https://doi.org/10.1007/s10639-024-12510-8

Mokhithi, M., Campbell, A. L., Shock, J. P., & Padayachee, P. (2025). 'I call it math therapy': student narratives of growth, belonging and confidence in mathematical thinking workshops. *International Journal of Mathematical Education in Science and Technology*, 1–26. https://doi.org/10.1080/0020739x.2025.2564193

Montenegro-Rueda, M., Fernández-Cerero, J., Mena-Guacas, A. F., & Reyes-Rebollo, M. M. (2023). Impact of Gamified Teaching on University Student Learning. *Education Sciences, 13*(5), 470. https://doi.org/10.3390/educsci13050470

Morris, R., Perry, T., & Wardle, L. (2021). Formative assessment and feedback for learning in higher education: A systematic review. *Review of Education, 9*(3). https://doi.org/10.1002/rev3.3292

Muhammad Sofwan, M., Tajularipin, S., Ahmad Fauzi, M. A., & Aida Suraya, M. Y. (2021). Implementation of oral questioning in assessing student learning in mathematics teaching in primary schools. *Turkish Journal of Computer and Mathematics Education (TURCOMAT), 12*(5), 137–143. https://doi.org/10.17762/turcomat.v12i5.805

Nurzatulshima, K., Zakiya, A., Saoud, A., & Zeinab, Z. (2021). Assessment practices of mathematics teachers in Oman. *Turkish Journal of Computer and Mathematics Education, 12*(14), 4217-4224.

Pekrun, R. (2024). Control-Value Theory: From Achievement Emotion to a General Theory of Human Emotions. *Educational Psychology Review, 36*(3). https://doi.org/10.1007/s10648-024-09909-7

Piñero Charlo, J. C., Noriega Bustelo, R., Canto López, M. del C., & Costado Dios, M. T. (2022). Influence of the algorithmization process on the mathematical competence: A case study of trainee teachers assessing ABN- and CBC-instructed schoolchildren by gamification. *Mathematics, 10*(16), 3021. https://doi.org/10.3390/math10163021

Procopio, M., Fernández-Cézar, R., Fernandes-Procopio, L., & Yánez-Araque, B. (2024). Neuroscience-Based Information and Communication Technologies Development in Elementary School Mathematics through Games: A Case Study Evaluation. *Education Sciences, 14*(3), 213. https://doi.org/10.3390/educsci14030213

Rakes, C. R., Wesneski, A., & Laws, R. (2023). Building mathematics learning through inquiry using student-generated data: Lessons learned from Plan-Do-Study-Act cycles. *Education Sciences, 13*(9), 919. https://doi.org/10.3390/educsci13090919

Rojas, E., & Benakli, N. (2020). Mathematical Literacy and Critical Thinking. In *Teaching College-Level Disciplinary Literacy* (pp. 197–226). Springer International Publishing. https://doi.org/10.1007/978-3-030-39804-0_8

Rumanová, L., Vallo, D., & Záhorská, J. (2020). The impact of formative assessment on results of secondary school pupils in mathematics: One case of schools in Slovakia. *TEM Journal, 9*(3), 1200–1207. https://doi.org/10.18421/tem93-47

Rulida, L. Jr. S. (2025). Student Engagement in Blended Mathematics Learning: The Role of Perceived Teaching Performance and Critical Thinking Skills. *Asian Journal of Education and Social Studies, 51*(5), 573–582. https://doi.org/10.9734/ajess/2025/v51i51941

Safadi, R., & Hawa, N. (2023). Learning from erroneous examples in the mathematics classroom: Do students with different naïve ideas benefit equally? *Instructional Science, 52,* 277-308. https://doi.org/10.1007/s11251-023-09648-2

Schindler, M., & Bakker, A. (2020). Affective field during collaborative problem posing and problem solving: a case study. *Educational Studies in Mathematics, 105*(3), 303–324. https://doi.org/10.1007/s10649-020-09973-0

Shahzad, M. F., Xu, S., & Zahid, H. (2024). Exploring the impact of generative AI-based technologies on learning performance through self-efficacy, fairness & ethics, creativity, and trust in higher education. *Education and Information Technologies, 30*(3), 3691–3716. https://doi.org/10.1007/s10639-024-12949-9

Sulistyani, D., Subekti, E. E., & Wardana, M. Y. S. (2021). Students' learning difficulties review from mathematics problem-solving ability in third-grade elementary school. *Indonesian Journal of Educational Research and Review, 4*(2), 345–351. https://doi.org/10.23887/ijerr.v4i2.30310

Téllez, N. R., Villela, P. R., & Bautista, R. B. (2024). Evaluating ChatGPT-generated linear algebra formative assessments. *International Journal of Interactive Multimedia and Artificial Intelligence, 8*(5), 75. https://doi.org/10.9781/ijimai.2024.02.004

Torres-Peña, R. C., Peña-González, D., Chacuto-López, E., Ariza, E. A., & Vergara, D. (2024). Updating Calculus Teaching with AI: A Classroom Experience. *Education Sciences, 14*(9), 1019. https://doi.org/10.3390/educsci14091019

Urrutia, F., & Araya, R. (2023). Automatically detecting incoherent written math answers of fourth-graders. *Systems, 11*(7), 353. https://doi.org/10.3390/systems11070353

Vaughan, M., & Uribe, S. N. (2024). Re-examining our feedback model: strategies for enhancing student learning and cultivating feedback literacy through formative assessments. *Assessment & Evaluation in Higher Education, 49*(5), 711–723. https://doi.org/10.1080/02602938.2024.2323468

Yang, J., Chen, Y., & Wang, Y. (2025). Exploring the Interplay of Motivation, Engagement and Critical Thinking Among EFL Learners: Evidence From Structural Equation Modelling. *European Journal of Education, 60*(3). https://doi.org/10.1111/ejed.70187

Zhang, F., Wang, X., & Zhang, X. (2024). Applications of deep learning method of artificial intelligence in education. *Education and Information Technologies, 30*(2), 1563–1587. https://doi.org/10.1007/s10639-024-12883-w