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Research Artikel

A SYSTEMATIC LITERATURE REVIEW OF FORMATIVE ASSESSMENT IN HIGH SCHOOL PHYSICS LEARNING

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Abstract

Implementing formative assessment (FA) in physics learning has been widely acknowledged as an effective strategy for enhancing learning process and student performance. Unfortunately, there was a dearth of thorough research on formative assessment in high school physics learning, including publication opportunities, physics topics evaluated by prior studies, and forms of formative assessment investigated by prior studies. This review mapped studies on formative assessment in physics subjects in the high school context. The research method used was a systematic literature review by analyzing relevant research results from the Scopus databases that published over the past decade (from 2014 to 2023). A total of 17 articles were examined in this study. This study found that Q1 ranked journals were where the most articles with FA topics in high school physics subjects were published. Mechanics was the most common physics topic investigated by previous research. Technology-based formative assessment was the most common form of FA used by previous studies. The results of this review may benefit researchers, school leaders, and policy makers when they aspire to do research or facilitate the implementation of formative assessment in physics class.

Keywords*: Formative assessment; high school; physics; systematic literature review.*

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INTRODUCTION

Formative assessment provides valuable insights for educators, learners, and the advancement of knowledge acquisition (Williams, 2022). Formative assessment yields crucial data on student progress and concurrently gathers evidence pertaining to learning (Castleberry et al., 2023; Jackowska-Boryc & Pyzara, 2022). This data is employed to assess students' learning capabilities and to enhance learning in order to facilitate the attainment of desired learning outcomes. They acquire comprehension of the crucial measures required to enhance their learning and acquire proficiency in executing them (Heritage, 2007). It enables educators to adapt their instructional methods and assists students in recognizing their present condition in relation to the objectives they must strive for and the strategies to attain them (Akom, 2010; Soria et al., 2023; van den Ham & Heinze, 2022; van der Steen et al., 2022). Formative assessments have been demonstrated to enhance students' readiness for their summative exams (Li et al., 2021). The characteristics of formative assessments that could monitor and guide students' understanding in a sustainable manner were very relevant to supporting physics learning.

Physics learning was challenging because the material was full of interrelated concepts, abstract, and difficult for students to understand (Blickenstaff, 2010; Güzel, 2011; Planinic et al., 2012; Sarabando et al., 2016; Shi, 2013; Wild, 2023). Learners were tending toward physics learning as a surface approach that focuses on math and lecture-style teaching through textbooks (Thomas, 2013). In fact, a deep understanding of physics concepts was very important for students to understand the material as a whole.

But the application of innovative formative assessments in physics learning in Indonesia was limited (Puad & Ashton, 2021; Rachmawati et al., 2022; Tamah, 2020), and teachers still face some challenges in implementing formative assessment (Asare & Afriyie, 2023; LEE, 2023; Pillay & Balele, 2022; Wolf & Lopez, 2022), even though formative assessments could monitor and assist students' understanding. Research done by Khan et al. (2020) shows that teachers were lacking in monitoring the student learning process, and there was a lack of follow-up from teachers on the results of students' physics formative assessment. In addition, Browne (2016) showed that formative assessment was difficult to implement because teachers were more focused on understanding what they have taught rather than what students have learnt, as well as feedback that only focuses on grades. Teachers' difficulties in getting feedback were caused by the lack of time to get feedback from students and the lack of training on how to optimize good feedback during learning. One of the impacts of feedback that students do not get was that students do not know what their strengths and weaknesses are during physics learning, so the research conducted by Sasmita et al. (2023) was to develop a website as a formative assessment medium that can help teachers in overcoming the difficulties of formative assessment that has an impact on students, with results showing that 79% of students agree that the feedback obtained was able to increase student learning motivation and 70% of students agree that website assistance could help teachers control and guide students in the process of monitoring physics learning. Therefore, the application of appropriate formative assessment in physics learning was needed. For optimal formative assessment, physics learning was expected to be better able to guide students to understand physics concepts deeply and thoroughly.

An optimal formative assessment system for addressing students' difficulties in understanding physics material in high schools could incorporate multiple approaches. This system should include diagnostic tests to elicit student ideas and identify misconceptions, peer assessment activities to engage students in evaluating and providing feedback on each other's work, and "on-the-fly" assessment

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conversations between teachers and students. The diagnostic tests can help teachers consciously commit students to specific ideas so they can be negotiated later (McDermott & Shaffer, 2002). Peer assessment allows students to develop critical thinking skills and take ownership of their learning (Tsivitanidou & Constantinou, 2016). Meanwhile, assessment conversations enable teachers to dynamically adapt instruction based on emerging student needs, using the ESRU (Elicit, Student response, Recognize, Use) framework to guide productive interactions (Ruiz-Primo et al., 2006).

A notable pedagogical application involves teachers' use of formative assessment through cognitive diagnostic instruments to evaluate students' comprehension of kinematics problem-solving, particularly in calculating acceleration from velocity-time graphs. Following the completion of written assessments, instructors conduct detailed analyses of student responses to determine their comprehension levels across three developmental stages: sensorimotor, representational, and abstract (Akom, 2010). The instructional intervention involves providing individualized feedback via targeted sticky notes for each student. This approach specifically addresses common misconceptions, such as errors in tangent line construction on velocity-time graphs or inappropriate application of acceleration formulas. The feedback includes specific guidance; for instance: "The tangent line should be constructed at t = 10 seconds, rather than connecting coordinates (0,0) and (10,140). Review unit consistency in calculations." This immediate, tailored feedback mechanism serves a dual purpose: enhancing current problem-solving capabilities while facilitating deeper conceptual understanding of previously unmastered principles. The feedback methodology is calibrated to individual student comprehension levels and administered promptly following formative assessment completion (Pals et al., 2023b). The OECD in 2005 has documented the effectiveness of this approach in promoting error recognition and long-term conceptual development. Furthermore, empirical evidence indicates that students receiving this structured sticky note feedback demonstrate statistically significant improvements in kinematics concept comprehension compared to control groups not receiving such targeted interventions (Pals et al., 2023b).

Recent empirical studies across diverse educational contexts have consistently demonstrated the positive impact of formative assessment on student learning outcomes. These studies have shown formative assessment can improve academic performance (Anders et al., 2022; Goodwin & Nathaniel, 2023), enhance self-regulation skills (Mountain et al., 2023; Vinogradova & Skornyakova, 2022), reduce test anxiety (Ismail et al., 2022), and increase student motivation and engagement (Hsu & Liao, 2022; Nor & Wider, 2023). Furthermore, formative assessment has been found to be particularly effective in supporting language learners (Lyon, 2023; Zheng et al., 2023), and in promoting equity in science education (Gusho et al., 2023). Hence, it is imperative to undertake an additional investigation to delineate this formative assessment, and one viable approach is to carry out a Systematic Literature Review (SLR). Prior studies have conducted SLR on formative assessment (Febriani & Abdullah, 2018; Hartmeyer et al., 2018; Heil & Ifenthaler, 2023; Morris et al., 2021; Schildkamp et al., 2020; Wafubwa, 2020; Yan et al., 2021). Nevertheless, there is a limited amount of research available that investigates the application of formative assessment in the specific context of high school physics education. This study seeks to investigate the prospective publications that could result from researchers investigating this topic, as well as to map the formative assessments that have been provided by previous studies in the realm of high school physics education. The research inquiries to be addressed are as follows:

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1. What is the the prospect of research articles on the topic of formative assessment in high school physics, based on the characteristics of previously published articles?
2. What types of studies have prior researchers undertaken on the topic of formative assessment in high school physics?
3. What particular physics topics have past research focused on while investigating formative assessment in high school physics?

What are the particular forms of formative assessment in high school physics that prior research have investigated?The findings of this study can be advantageous for academics, school administrators, and policymakers that intend to conduct research and promote the integration of formative assessment. A better alignment between learning activities, learning objectives, and assessment of innovations was needed (Bøe et al., 2018). Therefore, this SLR would provide information to support this realisation.

METHOD

Review design

This study employed the SLR methods by discovering and thoroughly investigating articles in a systematic setting. SLR is a comprehensive evaluation of the existing research literature, conducted according to a predetermined plan or methodology, and providing a concise and comprehensive account of all pertinent information (Gough et al., 2017).

We adopted the SLR technique developed by Arksey & O'Malley, (2005), which allows researchers to systematically discover and synthesize existing literature on a certain issue, independent of the study's form. This design is appropriate for gathering information pertaining to the objective of this study, which is to present a comprehensive analysis of the formative assessment of physics education within the high school context. Arksey and O'Malley propose a five-stage process for conducting a SLR:

1. The research questions must be formulated.
2. It is necessary to identify research that are pertinent and applicable to the topic at hand.
3. Only chosen studies will be included for examination.
4. The data has to be charted.
5. The findings need to be compiled, condensed, and communicated.

Studies included in review

Figure 1 illustrates the procedure of conducting literature search and identifying relevant sources.

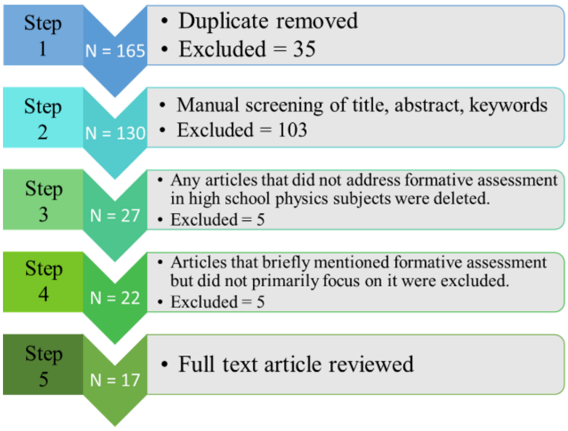

Figure 1. Systematic literature review process

The search took place on September 16, 2023. Scopus was selected as the primary database for this study's literature review. Its status as the largest academic database, combined with its comprehensive field coverage, carefully curated high-quality content, and global scope of publications, made it particularly suitable for our analysis (Baas et al., 2020; Sahib & Stapa, 2022; Vera-Baceta et al., 2019; Zhu & Liu, 2020). A total of 165 articles were found in the initial search. The identified keywords for guiding the literature search based on our research question were "formative assessment", "physics", and "high school". After conducting the initial search using the provided search term, we further examined the data and removed any articles detected as duplicates. Following the initial stage, we were left with a total of 130 articles.

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We continued to organize the articles by applying the criteria for excluding and including them during step 2, where the exclusion criteria for article selection included papers not published in peer-reviewed journals or conferences, those not written in English, publications older than 10 years, and articles not indexed in Scopus. To effectively address the specific purpose of our review, we utilized many criteria to determine which papers to include. The requirements were as follows: the publications must be in the form of peer-reviewed journal articles or conference proceedings, research conducted in the last 10 years, written in English, indexed in Scopus, and accessible in full-text version through the university library within a specified timeframe.

Following the completion of the second step, there were a total of 27 items remaining. Subsequently, we eliminated 5 publications that did not pertain to formative assessment in the specific context of physics education at the high-school or upper secondary school level. Studies were eligible for consideration if they explicitly mentioned to formative assessment and physics in the title, abstract, or keywords, and if they were conducted under the context of high-school education.

After eliminating these items, we were left with a total of 22 articles. Ultimately, the remaining 5 articles were excluded as they merely acknowledged formative assessment without it being the primary focus of their research. We were left with a total of 17 complete articles that were to be included for further study. The final data included in this review comprise 16 journal articles and 1 proceedings article.

Data classification and analysis

The articles provided were initially categorized based on their published characteristics, such as publication type, publication year, publication index, and research country. Publication features encompass the article's type (journal article or proceedings), the journal's ranking where it was published, the year of publication, and the country where the research for the article was conducted. The second classification is determined by the research methodology employed, which includes quantitative, qualitative, mixed-methods, research and development, design-based research, and action research. The final classification about examined physics topics is based on the domains covered for their formative assessment. The fourth classification is determined by the several forms of formative assessment, which are categorized according to the specific tools or methods utilized to implement them.

RESULTS AND DISCUSSION

The drive behind our review was to explore the potential and patterns of formative assessment research in high school physics education. We were particularly interested in investigating the theoretical and empirical claims that formative assessment can enhance the quality of learning. Inevitably the methods of implementing formative assessment will differ depending on the intended objective and the specific setting. Considering that formative assessment is an essential component of the learning process, it is logical to anticipate a degree of consistency in the studies that investigate this subject. Assuming the widespread consensus among academics regarding the basic idea of formative assessment, it is reasonable to expect that there will be connections in the approaches used to utilize this assessment type for enhancing the quality of learning. This mapping was generated to provide instructors and researchers with a clear overview of the potential for further research on the topic of formative assessment of high school physics learning. Table 1 presents list of studies included in review.

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Table 1. Studies included in review

No	Title	Author's name, year
1.	A comparative study of school-based assessment systems in physics: Azerbaijan lyceums and cambridge schools	Sharifov, (2020)
2.	A web-based formative feedback system development by utilizing isomorphic multiple-choice items to support physics teaching and learning	Kusairi, (2020)
3.	Analysis of students' understanding of motion in straight line concepts: Modeling instruction with formative e-assessment	Kusairi et al., (2019)
4.	Assessing implicit science learning in digital games	Rowe et al., (2017)
5.	Development of a formative assessment instrument to determine students' need for corrective actions in physics: Identifying students' functional level of understanding	Pals et al., (2023a)
6.	Do feedback strategies improve students' learning gain? Results of a randomized experiment using polling technology in physics classrooms	Molin et al., (2021)
7.	Effects of conceptual, procedural, and declarative reflection on students' structural knowledge in physics	Sarwar & Trumpower, (2015)
8.	Formative assessment as a tool to enhance the development of inquiry	Ganajová et al., (2021)
9.	Impact of formative assessment based on feedback loop model on high school students' conceptual understanding and engagement with physics	Ole & Gallos, (2023)
10.	Interactive engagement in rotational motion via flipped classroom and 5E instructional model	Rafon & Mistades, 2020)
11.	Kinematics card sort activity: Insight into students' thinking	Berryhill et al., (2016)
12.	Learning progressions as a simplified model: Examining teachers reported uses to inform classroom assessment practices	Alonzo et al., (2022)
13.	Physics formative feedback game: Utilization of isomorphic multiple-choice items to help students learn kinematics	Kusairi et al., (2020)
14.	Practicing formative assessment for computational thinking in making environments	Hadad et al., (2020)
15.	The effects of socrative-based online homework on learning outcomes in Vietnam: A case study	Anh & Phong, (2023)
16.	Toward Reducing Anxiety and Increasing Performance in Physics Education: Evidence from a Randomized Experiment	Molin et al., (2019)
17.	Implementation e-learning as a formative assessment to explore mastery concept's student on magnetic field material	Nikat et al., (2019)

Type of publications

Figure 2 shows the characteristics of the article, including the journal of publishing, the research location, and the publication year.

The reviewed articles were published within the timeframe of the past decade (2014-2023). According to Figure 2, the highest number of articles were published in 2020 (N=5), with 2019 following closely behind (N=3). Indonesia and the United States were the highest-ranking countries in the research, with a sample size of 4. The reviewed articles were sourced from Q1 journals (N=9), followed by Q2 journals (N=5), based on their journal ranking.

Regarding the year of publication, the highest number of articles were published in 2020, with a total of 5 articles. There was a noticeable increase in the number of publications between 2018 and 2020. Despite

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this, between 2020 and 2022, there was a noticeable decrease in the number of publications. The decline in educational research during the period 2020 to 2022 can be attributed to the global impact of the covid-19 pandemic. Educational researchers and instructors worldwide are currently adjusting their approaches to facilitate learning during the at present pandemic. Nevertheless, there is a noticeable upward trend in the number of publications happened in the 2022-2023 timeframe. It is predicted that there will be a continued increase in the number of publications on this topic. Because formative assessment has been widely recognized as an effective learning strategy (Lee et al., 2020; Wafubwa, 2020).

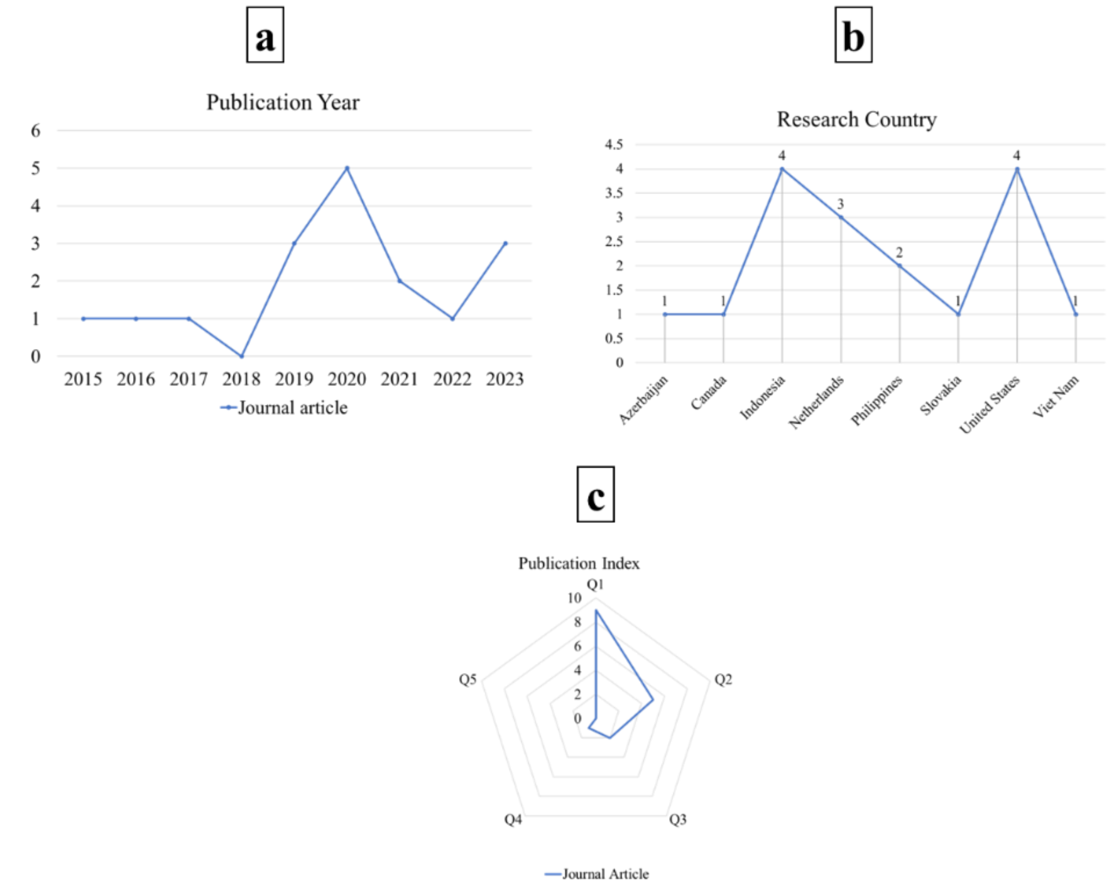

Figure 2. Publication type based on article characteristics in relation to the year of publication (a), research country (b), and ranking of the journal in which the article was published (c).

There were eight countries that recorded the publication of journal articles and proceedings on the topic of formative assessment in high school physics learning. These countries include Azerbaijan, Canada, Indonesia, Netherlands, Philippines, Slovakia, United States, and Vietnam. The United States and Indonesia were the top-ranking countries in terms of the number of publications. This finding aligns with data from Scimago regarding the ranking of countries based on publication numbers. The United States is currently the top-ranked country in terms of the number of publications from Scopus in the area of education (*SJR - International Science Ranking*, 2023).

The articles were primarily published in high-ranking journals, with nine articles in Q1 journals, followed by five articles in Q2 journals, and so on in a descending order of journal rankings. The topic of formative assessment in high school physics learning

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showed great potential for acceptance in Q1 journals. This presented a significant opportunity for further research that will contribute to the advancement of knowledge on this topic. A significant majority (62%) of the formative assessments found in Q1 journal articles were conducted using technology. In light of this trend, future researchers may investigate the implementation and development of formative assessment by integrating technology into their studies. Upon analyzing the article's characteristics, we proceeded to categorize the research methodologies employed in prior studies.

Research types

Figure 3 shows the numerous forms of research categorized according to the methodology and design employed in their respective studies.

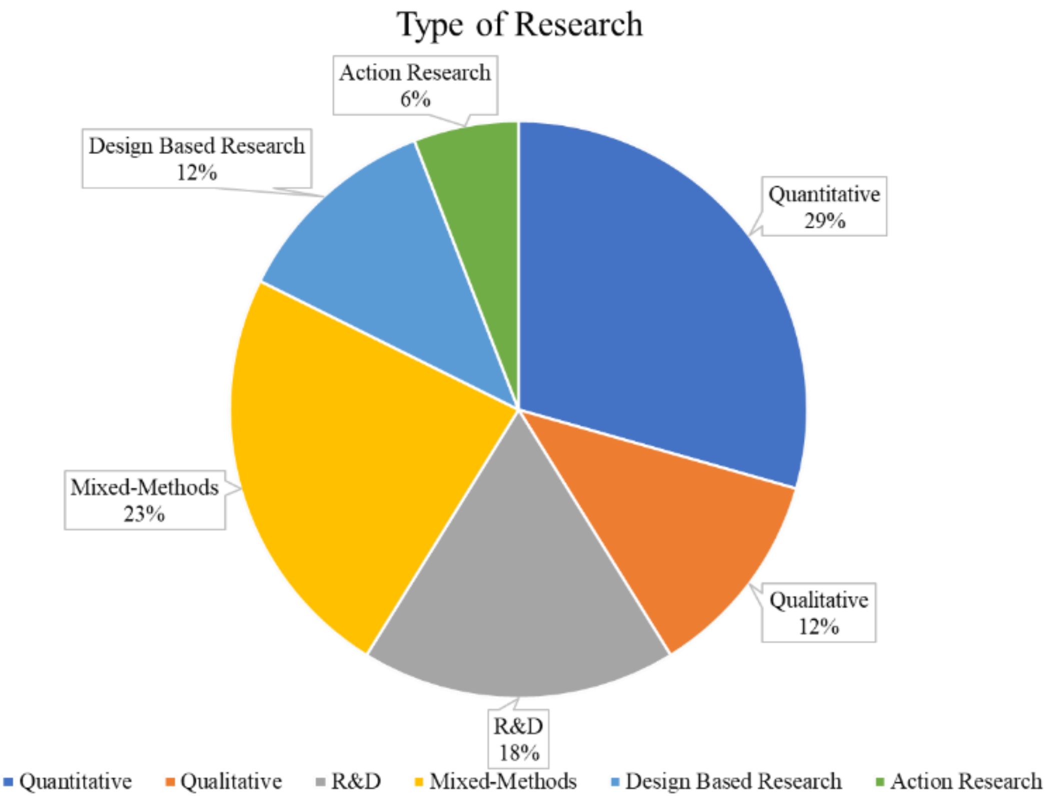

Figure 3. Research types

According to Figure 3, past studies have predominantly used quantitative methodologies and designs, representing 29% of the total. Subsequently, a combination of qualitative and quantitative research methodologies was employed, representing 23% of the study.

The distribution of research study types was diverse. It was observed that quantitative research was the most commonly used type, followed by mixed-methods, design-based research, R&D, qualitative, and action research. Quantitative research often incorporates investigating the efficacy of formative assessments through design such as quasi-experiments conducted on control and experimental groups (Anh & Phong, 2023; Ganajová et al., 2021; Molin et al., 2019, 2021). Afterwards, we analyzed the physics topics utilized as domains in their research on formative assessment topics.

Assessed physics's topic

Figure 4 shows the distribution of physics subjects assessed by formative assessments in prior research. Figure 4 shows that mechanics is the predominant concept chosen for formative assessment in the subject of physics. The remaining articles cover the

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concepts of electricity and magnetism, waves and light, and several other concepts.

The distribution of physics topic domains assessed by formative assessment studies remains concentrated. Most research focuses on mechanics. Many consider mechanics to be a fundamental subject that serves as a foundation for other areas of physics (Kusairi et al., 2019; Pals et al., 2023a). The topics covered in mechanics include kinematics, dynamics, and an introduction to mechanics. Previous studies often focus on the sub-topic of kinematics. The topics covered in this course encompass domain kinematics graphs, concepts of motion, and Newton's laws of motion, etc. Researchers often choose these domains based on their perceived significance as foundational topics in physics, which then serve as the basis for exploring more advanced areas of study. For example, kinematics serves as a fundamental foundation for dynamics. In addition, researchers have also highlighted the relevance of certain physics topics to our everyday lives (Berryhill et al., 2016; Kusairi et al., 2019, 2020). The researcher believes that mechanics is a topic that has a strong connection to students' everyday experiences. Others factor to consider is that students go on to struggle with grasping this particular subject concept (Kusairi et al., 2019; Pals et al., 2023a). The last mapping we did was of the ways in which researchers conduct formative assessment in their research.

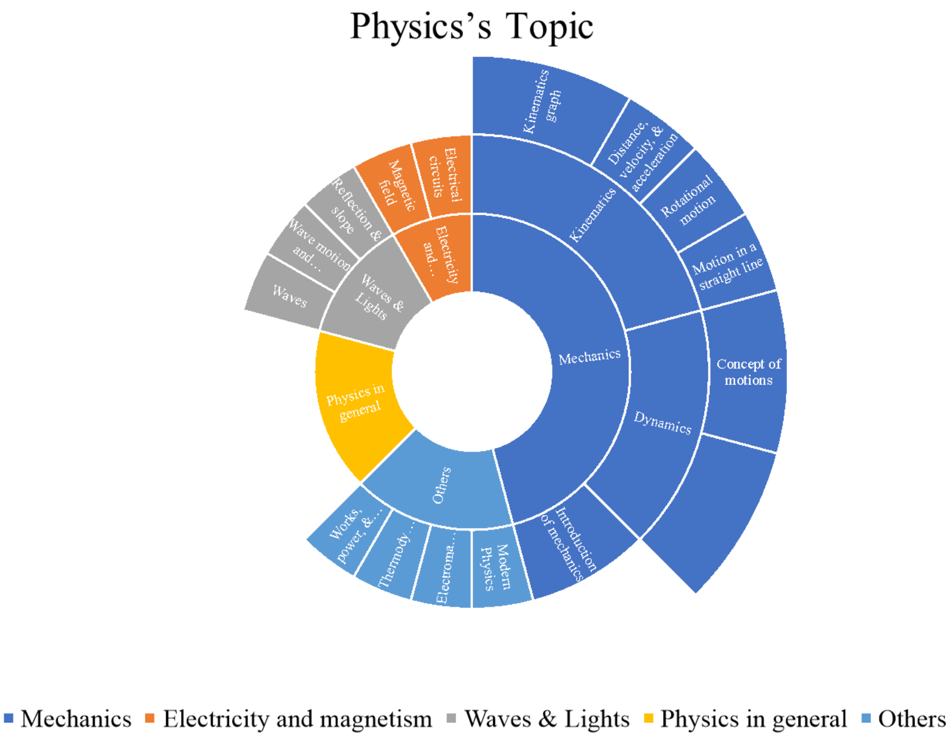

Figure 4. Distribution of physics topics assessed with formative assessments

Forms of formative assesment

Formative assessment is implemented using a variety of ways. The different approaches employed in prior research can be classified into several primary categories, including technology-based, test-based, reflection and informal feedback-based, card-based, graph/chart-based, and other. Refer to Figure 4 (See Figure 5).

According to Figure 5, technology-based formative assessment is the most extensively studied type of formative assessment, representing 25% of the studies. Subsequently, there will be a reflection & informal feedback

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based, accounting for 24% of the studies. Table 2 presents a comprehensive overview of the many types of formative evaluation employed in prior studies.

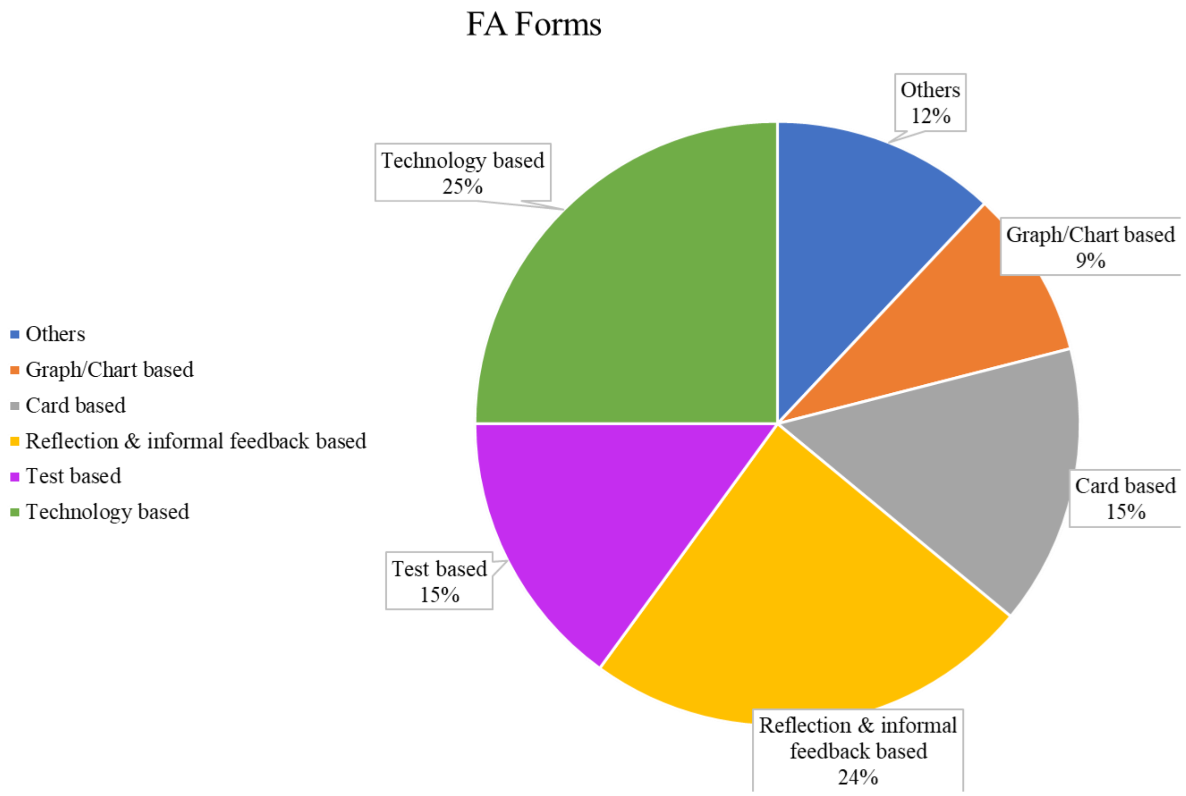

Figure 5. Formative assessment forms in categories

Table 2. Forms of formative assessment in high school physics learning

Category	FA forms	Number of Articles
Technology-based	Website	***1***
	E-learning	2
	Digital games	***1***
	Socrative web-based polling	1
	Digital games	1
	Online homework based on socrative website	1
	Clickers	1
Test-based	Daily tests	1
	Problem-based tests	1
	True-false statements	1
	Quizzes	1
	Homework assignments	1
Reflection & informal feedback based	Informal feedbacks	1
	Informal formative assessment	1
	Peer-review	1
	Self-assessment	1
	Written reflections	1
Card-based	Checklists	1
	Reflections	1
	Interview	1
	Self-assessment cards	1
	Cards mapping out the learning process	1
	Outgoing card	
	Task cards	1
	Card sort activity	1
Graph/Chart-based	Graphics	1
	Frayer Model	1
	Concept maps	1
Others	Metacognition	1
	Feedback Loop model	1
	Activities	1
	Observations	1

There were a wide range of formative assessment forms implemented or developed by researchers. We classify these variations into different categories, as illustrated in Figure 1. The most preferred base for formative

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assessment is technology-based. Technological advancements have prompted researchers to incorporate technology into their research, particularly in the area of assessment, specifically formative assessment (Hopfenbeck et al., 2023; Kaya-Capocci et al., 2022; Hopfenbeck et al., 2023; Kaya-Capocci et al., 2022). In addition to fulfilling the demands of the present era and obtaining technological opportunities for education, technology-based formative assessment offers unique advantages that are not easily achieved through non-technological assessment base (Hagos & Andargie, 2023; Rowe et al., 2017; Susithra et al., 2023; Wilkie & Liefeith, 2022; Hagos & Andargie, 2023; Rowe et al., 2017; Susithra et al., 2023; Wilkie & Liefeith, 2022). sUtilizing technology for formative assessment allows for quick feedback to be provided to students (Kusairi, 2020; Kusairi et al., 2019). For example, the utilization of polling technology in class can prompt students to engage in self-assessment, peer-assessment, and receive feedback from the teacher, thereby improving the learning experience.

Additionally, it offers students a greater amount of learning opportunities. For instance, FA can be implemented through the use of a website-based homework platform like Socrative (Anh & Phong, 2023). Technology provides students with plenty opportunities to reflect on their knowledge, extending beyond the confines of the classroom (Kusairi et al., 2019; Nikat et al., 2019). Furthermore, this FA base has the capability to offer precise feedback to students (Kusairi, 2020). Researchers or instructors can utilize technology, such as websites or computer programs, to assess students in an accurate way.

For instance, research on web-based formative assessment using isomorphic multiple-choice test forms that provide feedback personalized to each student's circumstances. This type of FA is thought to have the ability to provide more accurate assessments of students' abilities. Isomorphic multiple choice questions can help reduce the possibility of guessing, which is often seen as a weakness of multiple choice items (Kusairi et al., 2019). In some cases, such as with socrative-based websites, teachers have the ability to randomize questions and answers for formative assessments (Anh & Phong, 2023).

The second most often used method of formal assessment is reflection and informal feedback based. This basis of formative assessment offers advantages in practical aspects. This finding was in line with the findings obtained from research by Staberg et al. (2023). This FA base does not require a long time to be created. Moreover, this FA basis is more adjustable to accommodate the circumstances of the students and the learning at the time. Informal FA that enables peer conversation can reduce students' tedium and provide them adequate space to express their opinions while they listen to others' thoughts (Molin et al., 2021). Students can receive feedback from this FA base that is more detailed, more quickly, and personalised to their needs (Hadad et al., 2020). Its implementation is not without challenges, though. Especially in large courses, the teacher must use creativity to set up an effective learning environment (Hadad et al., 2020).

Formative assessment bases, such as those based on cards and graphs/charts, are still infrequently studied. Seldom were other forms of AF, including metacognition and the feedback loop model, studied. This type of formative assessment may be an area of future investigation. The use of formative assessment in learning may therefore be expanded by these bases of AF. As an illustration, consider the card-based brief exercise or feedback loop approach, which integrates learning and formative evaluation as essential components. This method dispels the common misconception that formative assessment is just used for scoring purposes.

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CONCLUSION

Publications on Formative Assessment (FA) in high school physics are dominated by the United States and Indonesia, with a peak of publications in 2020. The majority of studies utilised quantitative methods, with mechanics as the main focus. Technology-based assessment is the most commonly used form of FA. The significance of this topic is evident from the number of publications in highly reputable journals (Q1), suggesting that FA in physics was promising for further exploration.

Nonetheless, this study revealed some gaps that could still be explored in FA research in high school physics, such as the use of more diverse research methods (mixed-methods, case studies, grounded theory), deepening physics topics other than mechanics, and further investigation of lesser-used forms of FA such as metacognition, circle models, activities, observations, and artificial intelligence. The limitations of this study lie in the limited time span (one decade) and the focus that was only at the high school level. Considering the limitations of this study, future review studies were suggested to expand the time span, include other education levels, analyze collaboration between authors and institutions, and investigate sources with the highest citations.

This research suggests that formative assessment is a promising area for further study. Consequently, future researchers exploring formative assessment and aligning their studies with the characteristics outlined in this research are more likely to have their work accepted by academic journals.

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