Online Formative Assessment in Higher STEM Education; A Systematic Literature Review

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Abstract

Online formative assessment in higher education Science Technology Engineering and Mathematics (STEM) is gaining attention in recent years based on the increasing use of online learning. This study, aimed at critically reviewing studies on online formative assessment in Higher education STEM between 2011 to 2020. The study adopted a qualitative research design to analyze studies based on specific themes. 1402 articles were systematically searched through Scopus, web of science, and google scholar databases. However, only 12 studies were included in this study after satisfying the inclusion criteria. All data analyses were done using the Endnote X9 reference manager. The findings reveal that, evidence about online tools used, theories used in the learning and assessment process, the domain of learning outcome assessed, assessment of practical skills, and form of assessment used have been implicitly described. However, the online formative assessments have shown great potential of yielding immediate feedback. Therefore, future studies can engage in a more extensive study on areas such as online assessment tools for assessing practical skills and strategies that can enhance the effectiveness of online formative assessment which encompasses all domains of learning outcome within STEM higher education.

Keywords: Formative assessment, STEM education, Online formative assessment, Higher education

INTRODUCTION

Online learning is becoming an essential component of education in the 21st-century technological era. The impact of the COVID-19 pandemic has left many higher institutions with no better option of sustaining the learning progress of their students rather than to embrace partial to full-scale implementation of online learning (Adnan, 2020; Deepika, 2020; Dhawan, 2020; Elzainy et al., 2020). According to Schleicher (2020), many privileged students and institutions have found online learning as a suitable alternative that replaced conventional learning whereby physical presence within the school environment is required. This mode of learning was proved to be beneficial to students as though may have some challenges (Allo, 2020).

A quit number of recent reviews synthesized and evaluated findings on online learning thereby highlighting some benefits and major challenges that come with this mode of learning. Wu et al. (2018), highlighted that online learning increase flexibility, accessibility, and convenience to nursing preceptors. Davis et al. (2018) on the other hand highlighted one of the major challenges encountered with online learning is that it fails to sustain student's attention over time. However, few of these recent studies have addressed issues on online assessment (Gikandi et al., 2011). Amongst the few studies on online assessment, a limited number of them have addressed online formative assessment in higher Science Technology Engineering, and Mathematics (STEM) education. This is important as it forms a key part of every form of education (Christopher & Köcher, 2016).

Assessment is cardinal to formal higher education (Gikandi et al., 2011; Sangwin & Köcher, 2016). According to Ventista (2018 p.165), "assessment is an important topic to be examined because it can be a powerful learning tool." Assessment defined by Gao et al. (2020), refers to a conscious attempt to track student learning through multiple means to assess where students are concerning one or more particular learning goals. These techniques could be in regards to face-to-face or online assessment strategies. Though assessment is a critical component of education, Sangwin & Köcher, (2016), opined that all forms of assessments need to strike a balance in the constructive alignment with important assessment issues such as reliability, validity, and practicality. Perhaps, substantial studies have been carried out on assessment as a way towards improving assessment practices and improving learning, a review of studies by Gao et al. (2020), indicates that most assessments are centered on monodisciplinary knowledge and affective domain, as well as transdisciplinary affective domain.

STEM education is recognized among the effective ways to enable students become self-regulated learners (Anwari et al., 2015; Ventista, 2018). The unique aspect of this study is that having seen that STEM education is better recognized as a field comprising of integrated knowledge from Science, Technology, Engineering and Mathematics rather than treating it as a field comprising independent fields put together, (Gonzalez & Kuenzi, 2012; McDonald, 2016), students can apply various motor skills in carrying out STEM project-related learning activities (Robert & Scott, 2013; Lestari & Sumarti, 2018). Assessing these skills often has been through teacher's physical observation when the students engage in the project learning activity. Therefore, this study examined how use of online assessment has been carried out formatively to assess these skills while the learning progresses.

Assessment in STEM education is critical in enhancing effective teaching practices and promote students' overall learning through the provision of feedback to both teachers and students. This feedback normally holds for both formative and summative assessment. According to Gikandi et al. (2011), having understood the fact that either form of assessment can be distinct in features when implemented through online medium, educationists need to rethink plausible pedagogies that can facilitate meaningful learning through the implementation of promising online formative assessments activities. The expectation of students' academic achievement in STEM needs to be equilibrated with the online formative assessment opportunities for students to fulfill up to their expectations.

Formative assessment is an important element that intends to support learning (Ventista, 2018). According to Gotwals et al. (2015), Formative assessment is an integral part of teaching in which teachers obtain information of what their learners know and use it to adjust their teaching methods towards enhancing students' learning. In critique, though this may be beneficial to the entire teaching and learning process, some teachers may be reluctant in their innovativeness and creativity during the teaching and learning process such that, they would only claim students' response feedback and adopt it as their form of ideas and explanations. However, effective teachers who strive for meaningful learning of their students engage them in the formative assessment process to identify the extent of learning and areas of misconception thereby provide means for solutions (Elmahdi et al., 2018).

Online formative assessment in higher education is a significant component in online education most especially with the increasing implementation of online learning globally (Schleicher, 2020). One of the viable means to trace the learning progress of students within an online learning environment is through online formative assessment. This is concerning the COVID-19 and the recent strain of the virus which led to the suspension of face-to-face learning in many countries of the world thereby having institutions of higher learning left with an option for online learning (Allo, 2020; Schleicher, 2020). Theories are essential aspects of social science that provide some base to research studies (Ghaicha, 2016). There are a several theories of psychology and education that can be linked with assessment in education. For example, Black and Wiliam (2009), developed a theoretical framework that was grounded on Vygotsky's cultural historical activity theory. Their framework stem from two main points that relate well with formative assessment which this study was grounded on: a) teacher's role and learning regulation; b) feedback and student-teacher interaction. Black and Wiliam (2009) framework theorized formative assessment looking at students as key contributors to having an effective formative assessment by their act of self-regulated learning (Boekaerts et al., 2005). Furthermore, to them, teacher's role in achieving the best of formative assessment is to provide practical guidance that helps in monitoring students' learning. The teacher can be a controller or conductor while students become passive or actively involved in the formative assessment. The learning progress as determined through formative assessment with respect to how effective students handle information within their cognition

can be traced to information processing theory (Boekaerts et al., 2005; Greene et al., 2007)

Rationale

Formative assessment plays significant role in teaching and learning (Haug & Ødegaard, 2015). Based on Baleni (2015), formative assessment comprises guidelines to observe learning progress thereby enabling the teacher to understand a better approach that can enhance better learning within an ongoing teaching and learning process. Formative assessment contributes to students' ability to engage in self-reflection and continues self-evaluation (Boekaerts et al., 2005; Black & Wiliam, 2009) of what they are learning and the extent of their mastery of the concepts being presented (Hansen & Ringdal, 2018). The importance and contribution of formative assessment in learning may not be overemphasized. However, little attention has been given to online formative assessment as compared with summative assessment (Gikandi et al. 2011). Recently, the prolonged suspension of face-to-face learning and resultant switch to online learning by many higher institution has increased more attention on the online formative assessment as well (Adedoyin & Soykan, 2020; Adnan, 2020; Fuad & Rahim, 2020). Even though there is increasing adoption of online formative assessment in higher education, the challenges to its implementation are still persistent in STEM education (Jeong et al., 2020).

Therefore, it is important to examine how online formative assessment helps in scaffolding STEM learning amidst the suspension of face-to-face learning and a corresponding increase in online learning across the globe (Adedoyin & Soykan, 2020). Search of literature on formative assessment showed many research literatures in google scholar database. However, amongst the review literature on online formative assessment, the literature search did not reveal any systematic review on online formative assessment in STEM education. Therefore, this paper aims to provide a brief overview of how online formative assessment helps in facilitating students' learning in STEM higher education over the years between 2011 and 2020.

METHODOLOGY

This article employed a qualitative systematic review technique which involves the use of systematic criteria to allow extensive analysis, critique, and synthesis of relevant studies; the process involved in the review constitutes of three major steps which include literature search, reviewing, and writing the literature review (Gikandi et al., 2011). Furthermore, the methodology used in this review employed the Prisma 2019 flow chart for the search strategies, inclusion and exclusion criteria which involve identification, screening, eligibility, and finally, the included relevant articles for the review (Kamioka, 2019). Below are the explanations of the steps involved in the search down to the final inclusion of relevant articles:

Finding the Literature

Several searches were done using different search terms to ensure wide coverage of articles published in high-impact journals which are indexed in Scopus, Web of Science, or google scholar. The search term used to identify literature through the Scopus database was done twice. The first search termed which yielded 40 results is provided herein:

> TITLE-ABS-KEY ("Online formative assessment" OR "e-assessment" OR "Web-based formative assessment") AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011)) AND (EXCLUDE (SUBJAREA , "MEDI") OR EXCLUDE (SUBJAREA , "PSYC") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "DECI") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJA

> REA , "EART") OR EXCLUDE (SUBJAREA , "ENVI") OR EXCLUDE (SUBJAREA , "HEAL") OR EXCLUDE (SUBJAREA , "VETE") OR EXCLUDE (SUBJAREA , "NEUR") OR EXCLUDE (SUBJAREA , "DENT") OR EXCLUDE (SUBJAREA , "ECON") OR EXCLUDE (SUBJAREA , "ENER") OR EXCLUDE (SUBJAREA , "IMMU") OR EXCLUDE (SUBJAREA , "NURS")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (LANGUAGE , "English")).

To ensure that more articles are included from the Scopus database, a second search which yielded 175 results was performed using the search term below:

> TITLE-ABS-KEY ("Online formative assessment" OR "online Evaluation" OR "online Feedback") AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011)) AND (LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "MATH") OR LIMIT-TO (SUBJAREA , "PHYS") OR LIMIT-TO (SUBJAREA , "CENG") OR LIMIT-TO (SUBJAREA , "CHEM") OR LIMIT-TO (SUBJAREA , "AGRI")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (EXACTKEYWORD , "Online Evaluation") OR LIMIT-TO (EXACTKEYWORD , "Online Feedback") OR LIMIT-TO (EXACTKEYWORD , "Online Formative Assessment")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "p") OR LIMIT-TO (SRCTYPE , "j"))

Furthermore, in the Web of Science database, 622 results were revealed using the first search term ((("Online formative assessment" Or "e-assessment" Or "Web-based formative assessment")), refined by:

> DOCUMENT TYPES: (PROCEEDINGS PAPER OR ARTICLE)
> Timespan: 2011-2020. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI.

To ensure that more results are captured through the database, a second search using the term "Formative AND assessment or Evaluation" yielded 432 results. Also, Google Scholar search yielded 16,300 results using the search term "online formative assessment in STEM higher education" but only 14 were imported for various inclusion and exclusion criteria processes due to relevancy. The search in google scholar continued until no relevant search was revealed after 10 pages of the displayed results.

All searches were done on the 31st of December, 2020. All identifications were limited to studies carried out within 2011 and 2020 with a focus on articles and conference papers published in the English language only. To ensure that the review is of quality, only peer-reviewed articles were considered relevant for this study. This review also focused only on experimental research articles and case studies which are believed to provide substantial findings that would relatively have less likelihood of bias and may provide valid and reliable information for this review. To extend more to the database search, hand search and consultation with experts in the field of assessment in STEM education yield additional 14 results to yield a total of 1299 results.

The Prisma Flow diagram provides the various identification, screening, eligibility and inclusion/exclusion criteria with the description of the number of articles excluded or retained in each case as presented in Figure 1.

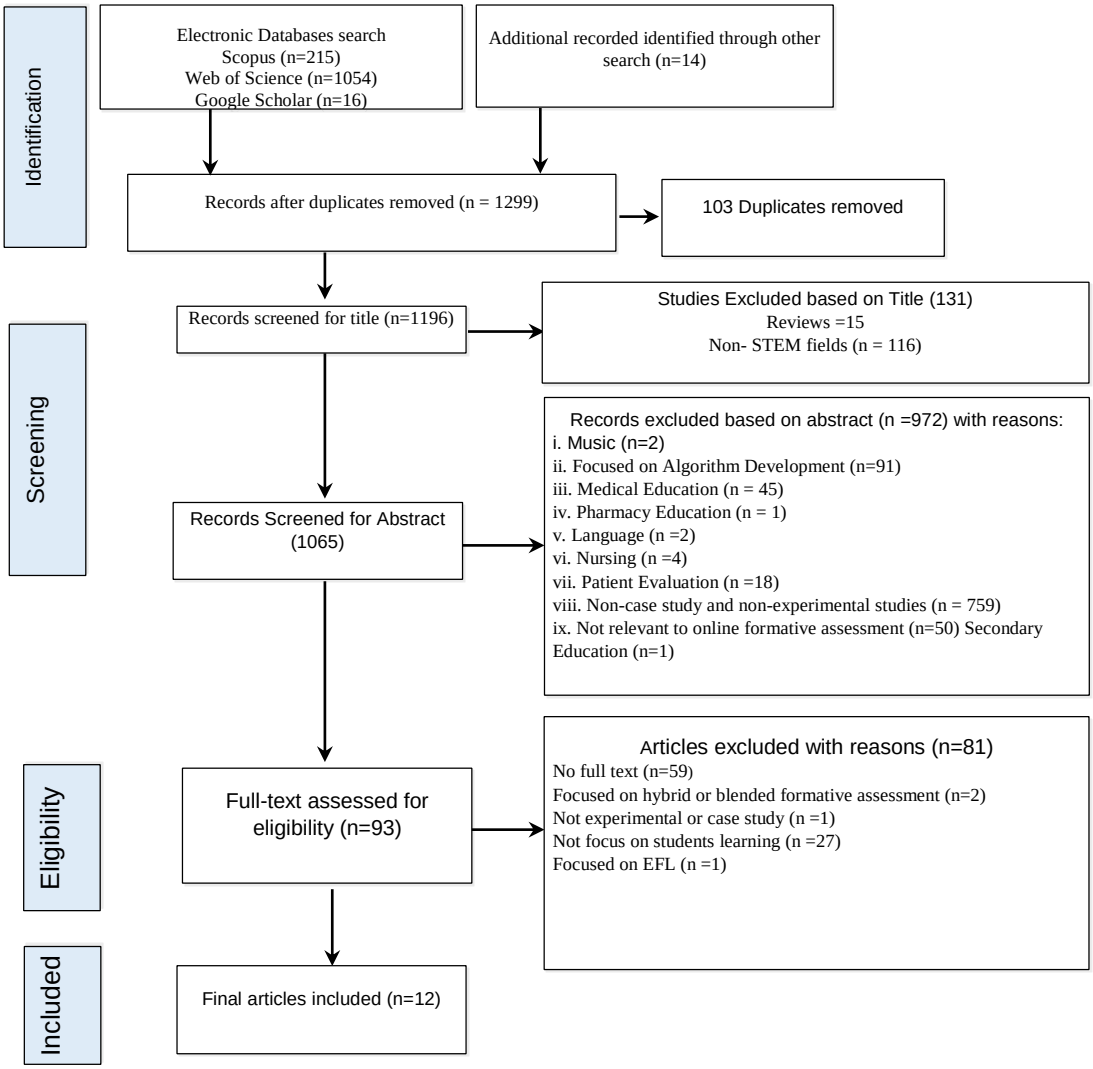

Figure 1. Prisma Flow Diagram for Literature Search (Moher et al., 2009) http://www.prisma-statement.org/

Screening, Eligibility and Inclusion

The screening was focused on higher STEM education having understood the fact that many tertiary institutions fully embraced online learning as an alternative to the suspended face-to-face learning during the COVID19 pandemic which extended up to the year 2021. From the total search, l103 duplicates were removed in which 1196 were screened for the title. All studies excluded at this stage were irrelevant because they were not carried out in Science Technology Engineering and Mathematics (STEM) fields and others were review studies. 1065 studies were screened for Abstract with a majority of them focusing on the design and development of an algorithm for formative assessment. 94 full text were assessed for eligibility which resorted to only 12 articles that were finally included for this review as shown in Fig 1; These articles captured at least major areas of interest which include learning domain, instructional strategies, hybridization of online formative assessment activities with games, usability, online formative assessment activities, online assessment tools, benefits, challenges.

Data Management

After the general search from the databases, the results of the search were exported to the endnote file format. Group and folders were opened in the endnote software where results of the search from each database were imported. A duplicate folder was created and was also copied to a new data file for

reference purposes. Exclusion based on title and abstract was systematically managed with the provided tabs in the endnote software. after this stage, a full-text search was carried out using the icon provided. The full text was found for some while for others, URL was found and lastly, no text was found for some. Those whose URL was found were searched through the publisher's websites and the text imported into the reference manager. The entire data management was carried out using the endnote reference manager.

Writing the Literature Review

This is where the key studies were analyzed. A table was developed to identify the aims, methodology, theories mentioned, study gap, findings, and the number of times cited for each key study under review which was based on the recommendation for a quality systematic literature review by (Galvan & Galvan, 2017). Therefore, Table 1 shows the key studies and their major findings. Furthermore, this review carefully examined the implications and recommendations from other reviewed articles to criticize and make deductions based on specific themes relevant to this review which provide some information utilized to develop the implication highlighted in this systematic review.

The Key Literatures

The key studies included in this review which are based on the exclusion/inclusion criteria are shown in Table 1. All the studies included were carried out in higher education and within the STEM field. 3 were in the physics course, 2 were in the Mathematics course, 5 were in computer technology, 1 was in general STEM course and the last was in Teacher education course. All of these studies focused on online/web-based formative assessment. the key studies selected were not limited to specific countries or locations. Table 1 shows the summary of the key studies included in this review. Some studies had an implicit description of the theory behind their research while others didn't show any. Three studies depicted Mastery learning as the theory underpinning their work. For example, Paiva et al. (2017), highlights that mastery learning is a pedagogical approach that is applied in tutoring systems whereby, a student can only be allowed to proceed further to the next modular unit after satisfying the mastery criterion of the present unit. The methodological approach of this literature was either experimental or case study as was one of the criteria of inclusion. Only 2 were case studies while the remaining were experimental and quasi-experimental.

MAIN TERMINOLOGIES

Several terms have been synonymously used by different authors without giving a distinct boundary to the definitions of these terms (Gikandi et al., 2011). To have a proper understanding of what this work entails, it is important to highlight the meaning of major terminologies used within the education context. First, let's understand the meaning of assessment. Assessment can be viewed in terms of program assessment such as curriculum assessment or in terms of student assessment. In this review, we are focused on student assessment which takes place during the teaching and learning process. According to Reeves and Hedberg (2006), assessment "refers to activities focused on measuring characteristics of human learners such as learning, motivation, attitudes, etc." Reeves and Hedberg attempted differentiating assessment from the evaluation. To them, the assessment focuses on measuring student's learning achievement while evaluation focuses on estimating the worth or outcome of a program after its implementation. Assessment can be classified into formative and summative (Gikandi et al., 2011; Clutterbuck et al., 2015). Though many other assessment types exist. Our focus is based on understanding the distinction between the two aforementioned assessments.

Summative Assessment

Summative assessment is also known as assessment of learning is the process "designed to confirm what students have learning or can do at the end of instruction" usually towards realizing the curricula outcome (Divall et al., 2014). According to Challis (2005), Summative assessment is more concerned about examinations where students demonstrate memorization without necessarily having a deep understanding of the subject. Students' assessment which is normally carried out for grading, award, or promoting students from one stage to another can be termed as summative assessment (Gikandi et al., 2011). It is important to highlight that both formative and summative assessments serve the purpose of assessing students' behavior or achievement. But extending the purpose can then differentiate them whereby summative is an assessment of learning while formative is for learning. The summative assessment covers a wider domain of students' learning compared with formative assessment.

Formative Assessment

Formative assessment can be seen as the process of obtaining evidence to make adjustments in subsequent steps during the teaching and learning process (Divall et al., 2014). According to them, what makes assessment formative is the purpose to which it is made. This means that, for adjustment to be made during the learning process, the teacher must provide feedback to students for them to reflect on their learning to make improvements in the subsequent assessment. From a review on online formative assessment, formative assessment was defined as "as the iterative processes of establishing what, how much and how well students are learning concerning the learning goals and expected outcomes to inform tailored formative feedback and support further learning" (Gikandi et al., 2011).

Divall et al. (2014b), consider it as a process, not a single action, aimed at improving learning, which entails shifting away from the focus from grades to learning processes, as well ass increasing self-efficacy and intrinsic motivation. Formative assessment can also be referred to as "assessment for learning" based on the purpose for which it is made. For this review, we consider formative assessment as a procedural activity that involves the collection and processing of students' academic achievement data to provide timely feedback to improve their learning.

Online formative assessment

Online formative assessment has been defined in different forms. Some of these include e-formative assessment or formative e-assessment, web-based assessment, web-based assessment for learning, online assessment for learning. All these terms involve the use of the web or internet and computer device. Gikandi et al. (2011) define online formative assessment as the "application of formative assessment within learning online and blended settings where the teacher and learners are separated by time and/or space and where a substantial proportion of learning/teaching activities are conducted through web-based ICT". Having seen the definition of online formative assessment by Gikandi et al., (2011) we, therefore, define it as all the processes involved in obtaining information about students' learning output to improve learning through giving timely feedback within a web-based learning environment. Our definition is based on the purpose of this review. We consider formative assessment in blended learning as a form of mixed learning approach which comprises of both web-based and face-to-face approach. Therefore, to have a pure context of web-based formative assessment, we overlooked formative assessment carried out within a blended learning environment as it is a unique learning approach that can be exclusively reviewed. At this point, we have to some extent shed light on the main terminologies involved in this review.

STEM Education

STEM education is a field that comprises four major areas of study which include Science, Technology, Engineering, and Mathematics. The acronym STEM was formerly described as SMET which was primarily to instill students at the ordinary school level with learning outcomes such as critical thinking

and effective problem solving to provide the opportunity for students who may opt not to further their studies with beneficial skills, and also provide more advantage for students who might continue with higher education within STEM courses (White, 2014). STEM education has gained more attention even in higher education recognizing that some concepts in specific subjects involve the use of multidisciplinary knowledge or multi-thought from other subjects within the STEM field (Taber, 2013).

FINDINGS

The findings of this review are navigated by the research questions.

What strategies are used during the online formative assessment?

The Strategies of teaching and learning may be considered as a set of methodologies employed during the instructional process. Online formative assessment is usually embedded into the teaching and learning process as it occurs. Therefore, we claim that the instructional strategy used might have an influence on the nature of how the online formative assessment is carried out, the perception of students on the assessment, and the expectation of the teacher in terms of students' response to the assessment and the logical pattern to which feedback can be obtained. For instance, if a project-based learning technique or problem-solving is used as the instructional strategy, the online formative assessment might involve different techniques of administering the formative test and as well different ways of collecting students' feedback. The procedure of implementing formative assessment in an online setting could be much more flexible in terms of guaranteeing effective communication between teacher and students when a particular learning strategy is adopted as compared with others.

Based on the articles reviewed, our findings reveal that little attention has been given to explaining the learning strategies used when an online formative assessment was carried out. However, a study by Harizah et al. (2020), applies a demonstration learning technique during the learning-formative assessment process in an online environment. A study by Yuliana et al. (2020), also shows the use of the 5E learning cycle which is only a model of instruction. This model cannot be seen as a learning technique that can independently be used during instruction but may require the use of other learning strategies such as inquiry, project, and problem-based learning. Furthermore, Kusairi et al. (2019), utilized an instructional modeling method of teaching and learning together with formative e-assessment which improved students understanding of motion in a straight line. Therefore, it would be better to understand the learning strategy adopted in which the online formative assessment was carried out to help teachers in implementing the most probable and effective way that can scaffold effective learning of STEM.

What is the promptness of getting feedback from an online formative assessment?

The nature of formative assessment is perhaps based on the expectation that lies within the purpose of its implementation. When learning is in progress, the instructional scheme has already been planned such that every segment of the instructional process requires efficient time management. Therefore, formative assessment is expected to provide immediate feedback that can be used to inform the teaching and learning process. our findings suggest that Online formative assessment provides immediate feedback that informs instructors on the treatment that should be considered to sustain or improve the learning progress of the students during an ongoing learning process. According to Wang and Han (2020), the use of the Learning Analytics Dashboard in terms of process-oriented feedback provides timely feedback which aided in improving the learning skill of students with little previous knowledge. This is undoubtedly one of the critical aspects that warrant a formative assessment, in general, to

become effective otherwise, it would lose its effectiveness and render no opportunity for instructors to better facilitate the learning that is expected.

What is the type of assessment involved during an online formative assessment?

This question is intended to find out whether or not the key studies engaged students in online formative assessment by using at least one particular form of the formative assessment. That is, whether more self-assessment, peer assessment, or teacher-based assessment was implemented. To figure out what these assessments are, we try to briefly highlight their meaning based on the context of this study.

Self-assessment

Self-assessment is a process where individual students examine the evidence of their learning progress and compares it with a set of achievement criteria provided by the teacher within the online learning environment. According to Sridharan and Boud (2019), self-assessment gives students the liberty to judge their performance. Self-assessment might not require the teacher to design the test items rather, individual or group of students are giving the opportunity to decide on what items which align with the achievement criteria, can enable them to reflect or produce learning evidence that can confirm that learning is taking place.

Peer assessment

Peer assessment can be seen as a process whereby a group of students collects learning evidence of each student within the group and assess it amongst themselves according to the already established learning outcome criteria (Nikolic et al., 2018; Sridharan & Boud, 2019). In this form of assessment, a student's learning evidence is usually assessed by another student within a particular group. According to Chang et al. (2020), peer assessment activities provide an opportunity for students to reflect on their learning progress to ascertain their areas of strength and shortcomings towards improving learning. It helps in completing both assessments for learning and assessment of learning (Panadero & Brown, 2017). This form of assessment might help reduce teacher's workload of trying to assess individual student's work, provide timely feedback, as well as save time most especially during the formative assessment (Chang et al., 2020).

Teacher-based assessment

This assessment can be described as a process in which a teacher engages in collecting, organizing and measuring students' learning evidence to promote learning. It requires students to only respond to the assessment items. It may be argued that these forms of assessment are usually implemented only during a summative assessment. We, however, opined that formative assessment can be structured to take the three various forms of assessment mentioned depending on the teacher's discretion to select which particular form that would be more suitable for the learning process.

Having highlighted the meaning of these three forms of assessment, we now examine the findings from the key reviewed studies. Based on question 4.2 revealed that the prevalent form of assessment was teacher-based assessment although other studies did not explicitly highlight the form of assessment used (Singh et al., 2011; Hooshyar et al., 2016; Lin & Wang, 2017). The teacher-based assessment involved the teacher administering the formative tests at various times (Cabrera & Villalon, 2013; Lu et al., 2018; Harizah et al., 2020;). This is important in identifying whether an online formative assessment is more effective when performed through a particular form of assessment. The ill-description of the exact form of assessment adopted during the online formative assessment does not provide a good basis for understanding the most probable form of assessment that is preferred in assessing students' learning progress through the online learning platform. This review would inform teachers and researchers in STEM education on the need to explore more online formative assessments to describe how different forms of assessment contribute towards effective formative assessment in

STEM education.

What are the domains of learning outcome assessed using online formative assessment?

From our findings, online formative assessment was more on assessing the cognitive domain of learning outcome (Cabrera & Villalon, 2013; Hooshyar et al., 2016; Lu et al., 2018; Harizah et al., 2020). Whereas, less assessment of affective and psychomotor domain was carried out through the online formative assessment. For example, Jeong et al. (2020), found that preservice teachers in STEM education had improved in their experimental STEM educational activities. The emphasis on assessing psychometric learning, that is, learning that deals with cognitive outcomes could be seen in line with the fact that, the importance attached to the promptness of an effective formative assessment might have a crucial role to play for an effective learning process. This could be based on the desire to utilize time required for the lesson efficiently as it can be easier to communicate cognitive learning outcomes as feedback to the teacher during the formative assessment and teaching or learning procedure than learning concerning psychomotor skills.

What are the online tools used in online formative assessment?

Firstly, it is important we highlight the description of what online formative assessment tools in this review mean. Even though it is difficult to provide one definition that best describes Online formative assessment tools, it can be seen as any form of software, application, or program that allows the teacher and students to determine whether or not learning is taking place within an online learning environment. These tools could be in the form of automated or non-automated programs that aid the formative assessment process and provides timely feedback to both the teacher and students. They also offers opportunity for students to do and redo self-assessments at their convenience (Tsai et al., 2015). Several online formative assessment tools used in different fields exist. For example, EvoGrader is an online formative assessment tool for assessing written explanations (Moharreri et al., 2014). Other tools include online quizzes (Kibble, 2007; Cohen & Sasson, 2016), and eQuip (Kerr et al., 2016).

Having described the meaning of online formative assessment tools, our finding shows that, the online tools used in the online formative assessment as highlighted by the key studies include online judge system (Lu et al., 2018); E-learning websites (Kusairi et al., 2019). Other studies were implicit about the online tools used and so indicated web, internet, web-based, or database as the tools used to perform the assessment (Kusairi et al., 2019). None of the recently used online assessment platforms such as Kahoot or Jamboard have been used in the studies reviewed. We suggest that this might be due to a fewer number of recent studies done on online formative assessment tools. Furthermore, the online tools used for formative assessment could sometimes be made by embedding game experiences to increase students' motivation or involvement. The findings concerning the game-based perspective of the online assessment tools still were not specified since the online formative assessment tools themselves were not explicitly described. If studies can be directed towards online learning and online formative assessment tools used in STEM education, it would be beneficial to both teachers and students so that they can find a variety of online tools available that can enhance their formative assessment through the online learning environment.

How are practical manipulative skills assessed formatively through an online platform?

One of the crucial concerns of this review is to examine how practical skills are formatively assessed because STEM fields consist of learning areas that may require students' use of their psychomotor skills. Perhaps more effort might be on the way to enhance students' practical skills even as there is increasing usage of online learning which is often outside the physical laboratories. However, based on recent studies, online formative assessment with respect to such domain of learning outcomes has not received much attention. Our findings on how manipulative skills are assessed formatively through the internet revealed that all reviewed studies were implicit about assessing learning through this domain and were only explicitly concern about cognitive aspects of learning outcomes. This being an area of concern, we can therefore suggest that special online means such as integrating virtual reality

technologies with platform that can formatively assess students while performing certain hands-on learning activities within the online platform should be explored.

DISCUSSION

It is evident from our finding that online formative assessment in STEM higher education plays important role in students learning of STEM disciplines. This review suggests that online formative assessments in STEM need to be given the necessary attention and treatments that can enable teachers to carry out formative assessments effectively while holistic learning takes place. Holistic learning is learning that encompasses both cognitive, affective, and psychomotor domains of learning outcomes. The first question outline which is on the prevalent form of online formative assessment provides us with the finding that, the assessment is mostly done by teachers with few instances where self-assessment was used and no instance where peer-assessment was used. The type of online formative assessment predominantly used can suggest for research into finding out why such type of assessment is preferred and thereby providing a possible means for improving or wide adoption and recommendation for formative assessments during online STEM learning in higher education. We argue that it might be more reasonable to consider the use of self-assessment or peer assessment compared with teacher-based assessment because adopting such can render much time saving during the ongoing online learning process than when a teacher-based assessment whereby a teacher would have to go through individual student's feedback before writing comments on the feedback as well.

The second question provides that, most of the domains of learning outcome assessed are the cognitive domain. STEM education requires learner engagement, practical problem-solving skills, application of knowledge to real-life. Focusing on facilitating only cognitive learning through the online formative assessment with little attention to facilitating other domains of learning outcomes might not suggest the realization of holistic learning in terms of STEM learning goals. For instance, students' understanding of motion in straight line (Kusairi et al., 2019) is a topic that would have require active learning where by students can handle tangible learning activities regarding this concept of motion rather than only observation of the phenomenon as it occurs through sets of models. It will be beneficial to have formative assessment cut across all domains of learning outcomes to give a better opportunity of determining the actual state of leaner's progress during an ongoing teaching and learning.

The third question is based on the online tools used during the online formative assessment. Having seen that only one study used an online judge system and others used the e-learning and web database platforms, the limited indication of different online tools used for the online formative assessment might suggest that there had been limited online tools especially in regards to STEM education or perhaps, studies on online formative assessment might have given little attention on the importance of online formative assessment tools based on their characteristics that may be suitable for learning STEM subjects. The use of online judge system by Lu et al. (2018), is an important step to exemplifying more adoption of these online formative assessment tools. Online tools are what provides the opportunity to implement online learning and formative assessment effectively. Even though there are drawbacks on using online platform to carry out learning and formative assessment as compared with the same processes carried out through face-to-face (f2f), the online tools are crucial to having a desirable formative assessment activity most especially in STEM.

The final question concerning the assessment of practical or manipulative skills is related to the second question which reveals the domain of learning outcomes formatively assessed via the online platform. The less consideration given to the online formative assessment of practical skills could suggest more effort on engaging students into learning STEM knowledge using the available learning materials at home. Since what is assessed is often based on what students have learned, then engaging students into practical learning experiences through the online medium may lead to finding strategies to assess the learning progress.

Table 1. Key Studies and their Findings

Title (Author)	Aim	Study Gap	Findings
Student's critical thinking skills in interactive demonstration learning with web-based formative assessment (Harizah et al., 2020)	Studying critical thinking skills after interactive demonstration learning with web-based formative assessment	Role of demonstration learning in enhancing critical thinking through web-based formative assessment	Increase in students critical thinking skills in a static fluid Handle a large number of students on formative assessments
Applying learning analytics dashboards based on process-oriented feedback to improve students' learning effectiveness (Wang & Han, 2020)	Development of learning analytic dashboard to offer process-oriented feedback to learners	Applying learning analytics dashboard based on process-oriented feedback across more STEM fields other than ICT course	Improvement of skill learning effectiveness of students with low-level prior knowledge. Provides personalized feedback through self-assessment to students
An Automated Course Feedback System using Opinion Mining (Singh et al., 2011)	Designing of an automated web-based course feedback system	the need to explore automated course feedback using sentence-based opinion mining	Provides complete feedback of students' performance score and students overall evaluation of a course based on their perception It is good as a means to provide teachers with feedback about the use of their methodologies and overall teaching and learning approach.
An adaptive interface for computer-assisted rubrics in an e-Marking tool using nearest neighbor (Cabrera & Villalon, 2013)	Designing of adaptive interface for e-marking tool	Use of different algorithm with an adaptive interface for testing the efficiency of e-marking tool	Evidence that suggests improvement in the efficiency of e-assessment tools
Data-Driven Analysis on the Effect of Online Judge System (Xudong Lu, Dongyu Zheng, Lei Liu 2018)	Analysis of data generated by the online judge system	Use of online judge system to tackle plagiarism and control of mechanical treatments . Also, the use of online judge to provide evaluation means to the knowledge points that needs mastery can be explored into	Improvement in programming abilities and promotes enthusiasm and knowledge
A solution-based intelligent tutoring system (ITS) integrated with an online game-based formative assessment: development and evaluation (Hooshyar et al., 2016)	Integration of solution-based intelligent tutoring systems with online game-based formative assessment	Examining the enjoyment of ITS integrated with online-game-based formative assessment compared with the offline game-based formative assessment is an area of interest.	Provision for the choice of selecting immediate elaborate feedback (IEF) or not immediate elaborate feedback (NIEF). Immediate elaborate feedback was more beneficial. The enjoyment of using IEF and NIEF was the same. Improvement in more knowledge acquisition

Title (Author)	Aim	Study Gap	Findings
Sustainable and Flipped STEM Education: Formative Assessment Online Interface for Observing Pre-Service Teachers' Performance and Motivation (Jeong et al., 2020)	To examine preservice teachers learning performance using formative assessment online interface	Examining adaptive assignment and feedback efficiency in more education groups	Positive learning performance and motivation for pre-service teachers. Enhance professionalization and use of formative adaptive feedback to students
Analysis of Students' Understanding of Motion in Straight Line Concepts: Modeling Instruction with Formative E-Assessment (Kusairi et al., 2019)	To analyze students' understanding of motion in a straight-line concept and their difficulties after the learning process	Not emphasized specifically on many roles of e-formative assessment in the study. Study indicators were more inclined on the learning strategy but not on e-formative assessment.	Increased students' understanding of motion in straight lines. Quick feedback
Diagnosing student errors in e-Assessment questions (Walker et al., 2015)	Demonstration of how re-marker and reporter facility of DEWIS e-assessment system facilitates the capture, analysis, and reporting of student error using two case studies	Trend analysis on mal-rules triggering in e-assessments tests	efficient capture and reporting of students' error and remarking students answers thereby making improved feedback available to students
An intelligent tutorial system based on a personalized system of instruction to teach or remind mathematical concepts (Paiva et al., 2017)	Description of the design, development, implementation, and evaluation of a tutoring system to improve students' engagement in mathematics	Improvement on tutoring systems and implementation in distance learning within other stem subjects other than higher education mathematics	Improvement in students' engagement and academic performance
The analysis of students' problem-solving ability in the 5E learning cycle with formative e-assessment (Yuliana et al., 2020)	To explore students' problem-solving abilities of heat and temperature through 5E learning model with formative e-assessment	Role of formative e-assessment in students' problem-solving abilities in STEM	Increase in students' problem-solving abilities
Facilitating student learning in distance education: a case study on the development and implementation of a multifaceted feedback system (Uribe & Vaughan, 2017)	Investigation of the role of feedback within a distance education environment	Experimentation on the proposed feedback model by Uribe and Vaughan, (2017).	Low knowledge about feedback by students may hinder timely and appropriate response to teacher's feedback

The recent adoption of home-based learning with the increasing use of online learning where students are only predisposed to purchased learning kits and available local materials might suggest that students would have to carry out their STEM learning activities in front of computers and cameras for teachers to observe how well they demonstrate their manipulative skills. Describing how this works out in regards to handling many students performing similar or different activities whether as individuals or small groups might be worrisome. Online formative assessment of learning outcomes such as degree of precision in measurements, tool grasping, and observational strategy about physical changes and other problem-solving abilities (Yuliana et al., 2020) during a STEM physical learning activity can be disturbing.

CONCLUSION

This review aimed at examining the use of online/web-based formative assessment in STEM higher education. Based on the insight drawn and the limitation of a study by Gikandi et al. (2011), this review qualitatively analyzed 12 studies based on the use of online formative assessment in learning STEM subjects. The studies show limited scope in terms of studying several issues concerning the use of online formative assessment whereby, information such as online tools used, assessment process, the domain of learning outcome assessed, assessment of practical skills, and form of assessment used were given little attention by most of the studies carried out in STEM education reviewed in this study.

RECOMMENDATION

This study is significant to practicing teachers and researchers on the need to give much attention to online formative assessment within STEM disciplines in higher education. Teachers can explore more online formative assessment tools that can aid in facilitating students learning in STEM. The learning tools can be classified based on the nature of their efficiency in assessing a particular kind of learning outcomes. Since STEM education comprises Science, Technology, Engineering, and Mathematics disciplines, certain learning areas within these disciplines might vary from others of another discipline. Therefore, explicating the exact online learning tool with its corresponding assessment potential would be beneficial in promoting effective online formative assessment in STEM higher education. In the same vein, researchers can broaden their scope when studying online formative assessment particularly for STEM higher education in which this study is based on to provide more evidence for future research and review studies. Finally, we can therefore suggest that provision for special online learning-assessment platform, such as integrating virtual reality technologies with platform that can formatively assess students while performing certain hands-on learning activities within the online platform should be explored.

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