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A Systematic Literature Review on the Perceptions of Teachers of STEM Integration

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Abstract

Low academic performance of students has always been a challenge in science and mathematics education despite the introduction of different constructivist approaches, like STEM integration, to promote student learning. The beliefs and perceptions of teachers about a certain approach were believed to shape curriculum implementation. This necessitates a review of the perceptions of teachers of STEM integration. PRISMA 27-item components of reporting systematic literature review were employed to extract patterns relevant to the benefits, challenges, and recommendations identified by K-12 teachers. From n=721, only five research articles were left for final review after a four-phase screening process. Teachers generally view STEM integration as promoting student achievement (problem-solving skills) and motivation or interest. There is an emerging view that science integration in mathematics instruction is stronger than mathematics integration in science instruction. Interestingly, a misperception was identified about technology education integration. This implies incorporation of STEM integration concepts in the undergraduate curriculum as teacher preparation was identified as one of the main problems on which improvements may be focused. The lack of equipment to support technology education integration as well as the appropriate skills needed to deliver the lesson was another emerging theme. In turn, the need for upskilling programmes to support the teachers in delivering 21st-century learning approaches is emphasised. Content knowledge is a prerequisite to pedagogical knowledge. To implement STEM integration, teachers need to know the contents of the different disciplines integrated.

Keywords: Science and Mathematics Integration, STEM Integration, Teacher beliefs, Teacher perception

Introduction

In the Programme for Student Assessment (PISA), the Philippines was ranked second lowest in mathematics and science among 79 countries that participated in the assessment. This prompted the Department of Education (DepEd) to provide additional policies to address this concern (Haw *et al.,* 2021). Golla and Reyes (2020) revealed in their analysis of Grade 7 to10 mathematics curriculum vis-à-vis the PISA mathematics literacy framework that there was a misalignment, especially in terms of competencies related to interpretation, evaluation, and higher-level reasoning skills. It was emphasised that applications to real-life and practical situations must be expanded in the curriculum. In the introduction section, the authors did not state the objectives of the work at the end of the section. In addition, the authors did not provide an adequate background and very short literature survey to record the existing solutions/methods, to show the best of previous research, the main limitation of the previous studies, the outcomes (to solve the limitation), and the scientific merit or novelties of the paper.

In another study, the alignment between the mathematics teacher education curriculum in the Philippines and the 2021 PISA mathematics literacy framework was examined. There was an observed alignment of PISA mathematics literacy standards with those of programme outcomes, performance educators, and course descriptions of the mathematics teacher education curriculum (graduates before SY 2021 to 2022). However, some of the performance outcomes and indicators of the mathematics teacher education curriculum are too broad to target the specific standards of PISA. In addition, there are concerns with the standards involving applications in different contexts. In general, this may indicate that the CHED-mandated courses do not fully satisfy the standards of PISA; hence, TEIs cannot fully produce the desired quality of mathematics teachers (Balagtas, 2021). This only articulates the need to review the preparation of pre-service and in-service teachers in terms of content and pedagogical knowledge in mathematics education to meet such international standards.

Based on the Trends in International Mathematics and Science Study (TIMSS), another international assessment, Balagtas et al. (2019) and Mullis et al. (2020) revealed that the results of all assessments indicate poor performance in mathematics and science competencies. In their examination of the alignment of the mathematics and science competencies in the current curriculum assessed in TIMMS, they found out that grade 4 mathematics and science curricula are more aligned with the TIMSS 2015 assessment framework than the grade 8 mathematics and science curriculum (95% alignment and 88% alignment versus 85% alignment and 61% alignment, respectively). The mathematics curriculum is generally more aligned with the said framework than the science curriculum. This gap in the curriculum needs to be addressed, and this could offshoot into another concern in the educational scene.

Mathematics and science curricula are intertwined because computational skills that are needed in their science subject (i.e., physics that is written in the DepEd curriculum guide as Force and Motion) are acquired in the students' mathematics subjects. Moreover, to concretize abstract concepts in their mathematics subject, teachers can anchor them on scientific information that can be taken up in their science lessons. Another constructivist approach to integrate these topics is through STEM integration which considers Science, Technology, Engineering, and Mathematics disciplines.

Science and mathematics integration has been reviewed for decades driven by the movement to integrate curricula from the discipline-based curriculum. There is a need for science and mathematics integration. Mathematics is an abstract subject, and the sciences can provide realistic examples to concretise these mathematics concepts. They both share the goal of promoting problem-solving skills (Basista & Mathews, 2002).

Kiray (2012) developed a model that integrates science and mathematics that is suited to the context of the teachers in Turkey, which is called the Balance Model. There are five integration approaches that can be derived from this model summarised in Figure 1.

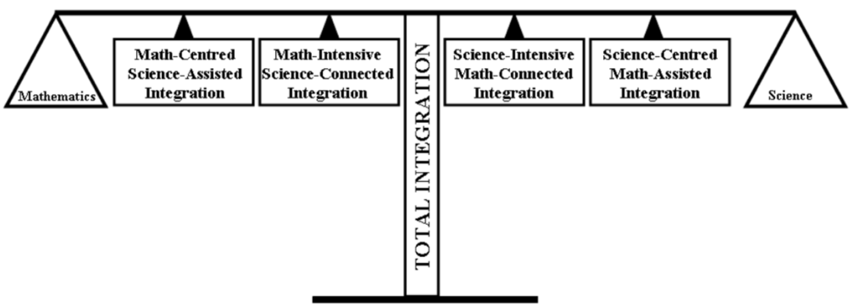

Figure 1. Mathematics and science content knowledge integration for each approach.

Several studies say that mathematics and science learning complement each other with the goal of increasing student achievement. Satchwell and Loepp (2002) reported that mathematical content and skills promote students' understanding of their science courses. Moreover, in two separate studies, Koirala and Bowman (2010) and Berlin and White (2010) point out in their empirical work that scientific content can reinforce out-of-mathematics applications to make learning in this subject more meaningful. Conflicting ideas concerning the sequence of science and mathematics content in the integration of these two subjects, there are studies stating that mathematics concepts must be presented before science. There are also those indicating that science and mathematics content is to be presented simultaneously. Kiray and Kaptan (2012) investigated the effectiveness of Science-Intensive Mathematics-Connected Integration to students and found out that achievement level is increased with the use of the experimental approach. No other studies were conducted to examine the effectiveness of other approaches in the balance model.

The study sought to review existing literature about the perceptions of elementary and high school teachers about STEM integration. The following questions were answered to evaluate the literature:

1. What do the teachers believe as the benefits and challenges of STEM integration in the classroom?
2. What are the recommendations needed by these teachers to implement STEM integration in their classrooms?

Methodology

This study was guided by the 27-item components of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic literature studies. To be selected for review, the research articles must be peer-reviewed empirical research studies. The most recent systematic literature review was conducted by Margot and Kettler (2017) and published in the International Journal of STEM Education. With this, the criteria for the timeframe of the review will start from 2016 to 2022. The research article should also include information that could at least answer one of the research questions identified. Academic Search Complete and Education Resources Information Center (ERIC) databases were searched via Elton B. Stephens Company Host (EBSCOhost).

To ensure thoroughness, articles found were rechecked in Google Scholar. Through the suggestion of Haddawayet et al. (2015), the first 300 results in Google Scholar will be considered. One research article that is unique to Google Scholar was added to the review. The last search was done on 9 August 2022.

Table 1. Inclusion and Exclusion Criteria

Parameters	Inclusion Criteria	Exclusion Criteria
Timeframe	Research articles published from 2016-2022	Research articles published before 2016-2022
Type of Research	Primary research articles that are published in peer-reviewed journal publications	Systematic reviews, editorials, books, and other non-primary research documents
Participants	Study participants included teachers in the K-12 levels	Study participants included teachers who are not in the K-12 levels

Research Design	Empirical Studies (includes qualitative, quantitative, mixed-methods, and meta-analysis)	Studies that are not empirical
Language	Research articles published in English	Research articles that are not published in English
Database	Research articles in Academic Search Complete and ERIC via EBSCO	Research articles that are not in Academic Search Complete and ERIC via EBSCO

The search terms that were placed via the advanced search setting of EBSCOHost are “teachers, perceptions, beliefs, or attitudes,” and “STEM education or science, technology, engineering, and mathematics education”. Restrictions were placed, such as the availability of the complete text, the article must be peer-reviewed, and others that align with the inclusion and exclusion criteria presented in Table 1.

Nine articles were retained after the screening process as shown in Figure 2. Consider that the previous systematic literature conducted by Margot and Kettler (2017) was undertaken only five years ago and reviewed 29 articles in the timeframe inclusion criteria of 2000-2016.

Considering the article-to-number-of-year ratio, this study and the previously shown systematic literature review are almost proportionate. The quality of the research articles was evaluated with the use of a rubric that was introduced by Margot and Keller (2017), cited from the work of Mullet (2006). This led the researcher to retain five research articles for review.

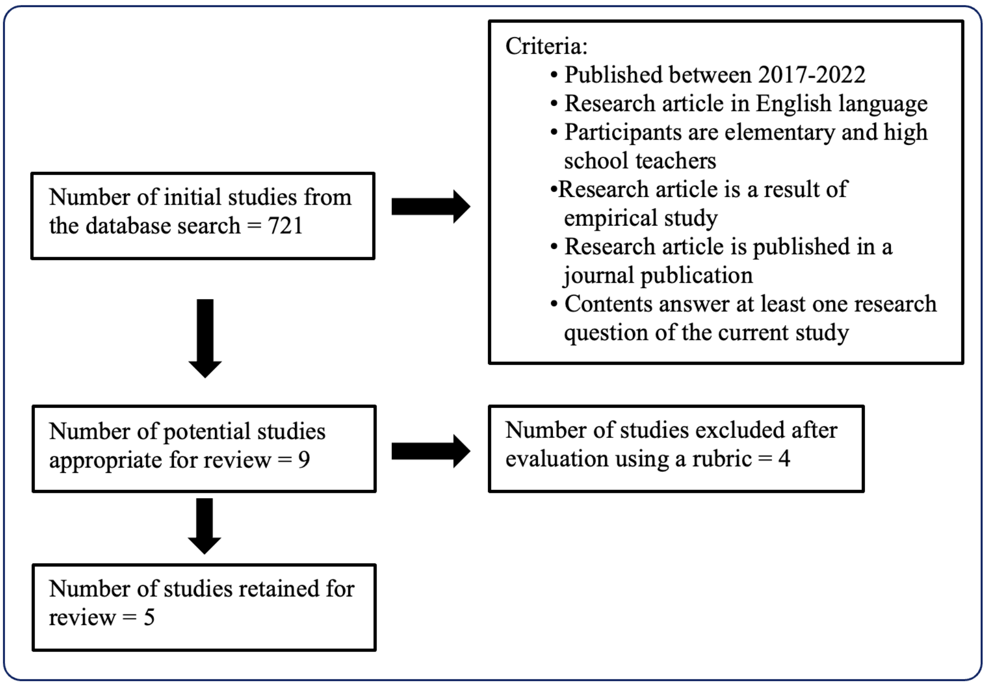

Figure 2. Research Article Screening Process

Thematic analysis was utilised as a method of reporting the different patterns formed from the data. Six phases of thematic analysis suggested by Braun and Clarke (2006) were used in data analysis.

Results and Discussion

1. Perception of Teachers on STEM Integration

1.1. Positive Impacts of STEM Integration on Learners

Reviewed articles reveal that teachers perceive STEM integration to benefit student learning. Two prevailing themes are related to this perception. First, STEM integration promotes academic achievement, as all articles point out that problem-solving skills are developed by providing real-life and concrete examples through this integrative approach. AlMuraie et al. (2021) added that STEM integration is perceived as a way to provide a conducive learning environment for these cognitive skills to be acquired. Sen and Ay (2017) and Fırat (2020) further explained that higher-order thinking skills are targeted through this integrated approach because it concretises the ideas by giving real-world examples and also improves the attention of the learners; hence, enhancing the retention of concepts.

Second, teachers perceive STEM integration to have a positive effect on student motivation. Participants in the study of Stubbs and Myers (2016) have provided examples such as having more students venture into STEM-related (agriculture) courses and careers in the future. Since models are given in this integrative approach, it may be due to the concept that it is more hands-on (Fırat, 2020) and real-world problems and applications are presented, making it more relevant to the learners.

1.2. Weaker Mathematics Integration

Teachers generally view that STEM integration is possible, although there are other contradictory views revealed in some of the responses of the teachers. One of the participants in the study of Sen and Ay (2017) said that Mathematics is unrelated to any other discipline, considering that it is a part of their undergraduate preparation. Also, in Fırat's (2020) work, one of the partakers mentioned the inapplicability of STEM integration in every subject. Although, all of the studies reviewed point out that Mathematics and Science are easily integrated.

It is noteworthy that the integration of mathematics and engineering concepts is viewed to be weaker compared to others; that is, there is more integration of science in mathematics instruction versus mathematics in science education. Hence, Sen and Ay (2017) said that the integration process weakens teaching. This also led the researchers to recommend the inclusion of integration practices in the undergraduate curriculum to solve this. In Kiray's (2012) Balance Model that presents how content knowledge in science and mathematics integration is introduced, their results point out that Science-Centered Mathematics-Assisted Integration (SCMAI) is more observed than Mathematics-Centered Science-Assisted Integration (MCSAI). The other reviewed articles further supplemented this finding. Asli and Zsoldos-Marchis (2021) stated that physics is the discipline where most mathematics applications are introduced. Moreover, Sen and Ay (2017) said that most of their teacher respondents believed that Mathematics is related chiefly to science compared to other disciplines.

1.3. Misperception of Technology Education Integration in Mathematics

Another important component of STEM integration is technology education. It is important to take note of the distinction between technology education and technology-assisted instruction. Stubbs and Myers (2016) found a misperception in the teachers' responses that technology integration in instruction is included as part of STEM education. STEM education concerns learning about the use of technology. Interestingly, Sen and Ay (2017) reported that most participants have a positive view of technology integration in mathematics. They view technology integration in coded responses as "solving mathematics problems," "visualising the geometric objects," "watching the video," "simulation," and "homework". It can be observed that the idea of the teachers of technology integration is in instruction. It is supported by the last codes they were able to form which is about integrating technology to make mathematics instruction effective. This misperception may be further supported by the findings of AlMuraie et al. (2021). The teachers' least common interpretation of the definition of STEM is that it is about using simulation software to predict engineering design performance and developing engineering practices for creating engineering designs as well as testing them with scientific problem-solving skills.

2. Recommendations for the Improvement of STEM Integration

2.1. Teacher Preparation Programmes

It was acknowledged in all of the reviewed articles the significant role of teacher preparation in implementing STEM integration. In the study of AlMuraie et al. (2021), a difficulty in teacher preparation is identified, leading them to recommend stronger programmes that target the professional development of the teachers. In addition, Fırat (2020) suggested that pre-service training can be provided using engineering and technology-based learning because the participants identified them as the areas in which they need support. Moreover, Sen and Ay (2017) said that the participants did not receive an education that prepared them to integrate science into mathematics instruction. It is then suggested that they be trained through in-service training programmes. Furthermore, Asli and Zsoldos-Marchis (2021) found a significant difference in teaching mathematics applications when the respondents are compared according to their computer user skills. Teachers with higher computer skills integrate more mathematics applications. The respondents requested that teaching mathematics applications be included in the Israeli curriculum.

2.2. Lack of Equipment and Appropriateness of the Curriculum

Concerning the results of Asli and Zsoldos-Marchis (2021) about the importance of equipping teachers to increase integration in mathematics instruction, physical facilities are required. The lack of equipment is the most frequently mentioned reason for not integrating mathematics applications. AlMuraie et al. (2021) found out that the teachers' least common interpretation of the definition of STEM is that it is about using simulation software in the prediction of engineering design performance and the development of engineering practices for creating engineering designs as well as testing them with the use of scientific problem-solving skills. This further supports the need for more facilities to be provided for teachers to strengthen their integration mechanisms.

Another emerging need identified was the call for curriculum review to make it fit into STEM integration. For example, Sen and Ay (2017) revealed that most participants believed that the curriculum is not appropriate for integrating science and technology into mathematics instruction. Additionally, Fırat (2020) reported that STEM integration may have a negative impact on learners when it is related to the preparedness of the curriculum they currently have.

Conclusion

The systematic literature review revealed a generally positive view of STEM integration benefiting the learners. They believe that STEM integration can promote student achievement, specifically in acquiring problem-solving skills, as STEM integration requires using real-world and real-life situations as a springboard or application of the lessons. Furthermore, the teachers believe it motivates the students more and increases their interest in STEM careers. However, on their side, as teachers, several challenges were identified. The teachers feel that it is easier to integrate scientific concepts into mathematics instruction than integrate mathematics concepts into science instruction. This research gap may be addressed by introducing a model, such as Kiray's (2012) Balance Model, to fully integrate lessons from the disciplines. However, this requires teachers to have content knowledge in both disciplines, as content knowledge is a prerequisite to pedagogical knowledge. In addition, a theme that emerged was the misperception of teachers on technology education integration. The lack of equipment to support them in technology education integration was common in all the research reviewed. This suggests enough adequate facilities be in place coupled with upskilling programmes. The researchers also call for constant curriculum review to ensure that STEM integration fits into the curriculum currently followed by the teachers. Lastly, all of the research articles reviewed acknowledge the importance of teacher preparation in the process, which is the basis in the recommendation for a review of the undergraduate curriculum that education majors are having, as well as more focused pre-service and in-service programmes, training, and workshops about STEM integration.

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