Board 170: STEM-ulating Change: Exploring Pre-Service Teachers' Perceptions of Integrated STEM Education (Work-in-Progress)

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Abstract

This article highlights the current focus on integrated STEM education, which is based on recognizing that the science, technology, engineering, and mathematics (STEM) disciplines are interrelated in real-world applications. The teaching practices of preservice teachers (PSTs) may be impacted by the perceptions they hold prior to entering the classroom. As a result, attention is needed to understand the perceptions of integrated STEM held by pre-service teachers (PSTs). Gaining a grasp understanding of these perceptions will enable educators to better prepare for teaching integrated STEM, potentially resulting in enhanced long-term teaching practices and student growth. Therefore, this paper employs the eight models of integrated STEM education proposed by Ring et al. (2017) to examine empirical studies and explore the factors that influence the perceptions of PSTs regarding integrated STEM education. Our paper follows the PRISMA guidelines and flow chart, which include a checklist with 27 items and a flowchart with four steps. The inclusion and exclusion criteria for this study required eligible papers to be empirically based, peer-reviewed, published in English between 2011 and 2023, and relevant to the research question. A content analysis method was applied to examine the articles (n = 27) that satisfied the inclusion criteria. PSTs' perceptions of integrated STEM education were influenced, according to preliminary findings, by the following variables: (a) prior knowledge and experiences with STEM education; (b) beliefs about STEM education; (c) perceived benefits and challenges of integrated STEM education; (d) available support and resources; and (e) professional development opportunities. The paper also addresses the theoretical and educational implications of the results for the planning and implementation of integrated STEM professional development programs for policymakers and stakeholders as well as teachers.

Keywords: Integrated STEM, STEM education, preservice teachers, perceptions

Introduction

STEM (science, technology, engineering, and mathematics) integration is a dynamic and innovative educational strategy (Li et al., 2020). Integrating STEM fields is essential for solving complex problems in the information age (Chai, 2018). In contrast to the tendency in K-12 education to treat S, T, E, and M as separate disciplines, integrated STEM education combines these subjects to represent real-world contexts (Aguirre-Muñoz et al., 2020; Baptista et al., 2023). This student-centered and integrative approach enables students to confront practical challenges by drawing insights and skills from both STEM and non-STEM fields. For instance, students can be helped to find inspiration in nature to solve engineering challenges by studying the biomimicry concept (Yeter et al., 2023). However, skilled educators are essential for successfully implementing this strategy (Dominic & Aik Ling, 2021). According to research, there is a complex correlation between student outcomes, teaching methods, and teachers' perceptions (Cope & Ward, 2002).

Therefore, understanding teachers' perspectives on integrated STEM education is necessary, as their views are likely to impact the motivation and involvement of students (Dominic & Aik Ling, 2021). However, there is a lack of study in this particular field, especially regarding the views of prospective teachers on STEM. Interestingly, pre-service and in-service teachers (PSTs and ISTs, respectively) differ in experience and skill sets, which could influence their approach when it comes to integrating STEM (Margot & Kettler, 2019). Consequently, this systematic literature review utilizes Ring et al.'s (2017) eight models of integrated STEM education as a framework to analyze empirical studies about PSTs' perceptions of STEM that were published between 2011 and 2023. The objective is to illuminate potential critical factors that may affect the STEM perceptions of PSTs. Additionally, the findings might provide insights into the design of effective integrated STEM professional development (PD) programs while contributing to wider conversations regarding educational practices and curriculum development.

Study Objectives

To thoroughly explore and synthesize the available research body related to PSTs' perceptions towards integrated STEM education, this study uses a systematic literature review methodology. This rigorous method enables the identification and comprehensive review of relevant studies that align with our research focus and research questions. To achieve an in-depth analysis, a multifaceted literature search will be conducted across academic databases and search engines. Relevant studies are identified through a rigorous screening process, and data extracted from the selected studies will be subjected to content analysis, with the findings reported in a narrative synthesis.

Research Questions

1. What factors influence PSTs' perceptions of integrated STEM education?
2. What potential implications might these perceptions of integrated STEM have on teacher education and PD programs?
3. To what extent do the findings correlate with the eight models of integrated STEM proposed by Ring et al. (2017)?

Methods

The basis of this systematic literature evaluation on PSTs' perceptions of integrated STEM is the framework (Table 1) developed by Ring et al. (2017). Originally, this framework was created to investigate experienced teachers' evolving conceptions of STEM education throughout PD. However, this framework exhibits significant promise for illuminating the distinct viewpoints that PSTs may have at the formative stage of their professional journeys. Unlike other approaches that adopt a single definition or rely solely on outcome measures, this framework outlines eight different models of integrated STEM education. The models encompass a spectrum of integration levels, from STEM as separate disciplines to meaningful integrated approaches. This range and variation compel and necessitate exploring the in-depthness of PSTs' perceptions and understandings of each model and may even find differences among them. Moreover, the framework's foundation in empirical research enhances its applicability to our current study, and this nuanced perspective fits more effectively with our current review's goals, which are to explore and gain further insights into PSTs' perceptions of integrated STEM education.

Table 1. *Eight Major Models of STEM Integration (Ring et al., 2017, p. 11)*

Model	***Definition***
Integrated disciplines	Teachers often used models with components that reflected the intersection of STEM teaching (e.g., Venn diagrams)
Science as context	Teachers portrayed STEM education as teaching scientific principles using technology, engineering, and mathematics as needed
Engineering design process as context	The iterative process of engineering design is frequently referred to by teachers as the technological means through which students acquire knowledge of scientific and mathematical concepts
Science and engineering design process as context	Teachers gave teaching science concepts and the engineering design process equal weight, integrating mathematical ideas and technology where applicable
Real-world problem solving as context	Teachers generally envisioned integrated STEM education as focusing on making STEM concepts as relevant as possible for students
STEM as separate disciplines	Teachers followed a model in which each discipline was isolated, sometimes indication some overlap in terms of support but not integrating the disciplines
STEM as an acronym	Teachers considered STEM as simply STEM
Engineering as context	Teachers displayed STEM education with a focus on engineering, using science, technology, and mathematics as needed

Eligibility Criteria

To ensure the inclusion of current and scrupulously developed research, only peer-reviewed articles that were published in academic journals between 2011 and 2023 were taken into account (see Table 2). This decision is consistent with the National Research Council's K-12 scientific Education Framework (NRC, 2012; NGSS Lead States, 2013), which was first released in 2011 and indicates a notable change in viewpoints on scientific education. Thus, by largely selecting studies conducted from this time period onwards, the potential for findings influenced by outmoded frameworks is minimized, and the usefulness of the current review's insights is maximized. Moreover, to ensure consistency in interpretation, it was essential that eligible studies were published in English and that PSTs were the principal participants to ensure direct relevance to our study questions. Furthermore, only empirical studies with extracted data that are relevant to the review's emphasis and address at least one of the research issues mentioned earlier in the paper were included. By meeting this criterion, the review's coherence is ensured, and it is confirmed that the included studies directly contribute to our objectives.

Table 2. *Inclusion and Exclusion Criteria*

Criteria	***Consideration***
Content Area	Include details with the key terms “Integrated STEM”, “Integrated Engineering”, “Pre-service teacher”, “Preservice teacher”, “Perception”, “Beliefs”, “Attitudes”
Language	Include only studies accessible in English
	Exclude all others
Date of Study	Include studies published between 2011-2023
	Exclude all others
Nature of Research	Include studies empirical in nature (qualitative, quantitative, mixed methods)
	Exclude all others
Location of Origin	Include all studies, regardless of origin
	Exclude none
Type of Publication	Include only empirically-based, peer-reviewed records from included informational sources
	Exclude all others

Data Sources

This study examined electronic databases that specialized in research regarding integrated STEM, education, and pedagogical studies. Eligible records were retrieved from the following databases during the summer of 2023: Academic Search Complete, Computers &

Applied Sciences Complete, EBSCOhost eBook Academic Collection, Education Research Complete, and ERIC. Notably, the current study used search parameters to explore the Academic Search Complete, Computers & Applied Sciences Complete, EBSCOhost eBook Academic Collection, and Education Research Complete databases simultaneously. Further, to guarantee a thorough search, Google Scholar was also used to ensure all pertinent records were located. It is crucial to note that Google Scholar's search parameters do not have the same limiting search terms, leading to 1280 results sorted by relevance. We adhered to Haddaway et al.'s (2015) suggestion to examine the initial 200 to 300 results from Google Scholar to identify any overlooked literature. Consequently, only the abstracts of the first 300 articles were examined, and 133 articles that had not been found in the other databases were revealed.

Search Strategy

The subsequent search terms were systematically employed to explore each database:

1. "Integrated STEM" AND "Pre-service teacher" AND "Perception"
2. "Integrated STEM" AND "preservice teacher" AND "Perception"
3. "Integrated engineering" AND "Pre-service teacher" AND "Perception"
4. "Integrated engineering" AND "preservice teacher" AND "Perception"

These searches were subsequently repeated for "Beliefs" and "Attitudes" (replacing "Perception") as well. Search limiters were implemented to align with the screening criteria, and terms had to be found in the title, abstract, or subject of the articles to be identified as eligible records (see Table 3).

Table 3. *Results of the initial search*

Search terms	Database	Search limiters	Results
"Integrated STEM OR integrated engineering" AND "pre-service teacher OR preservice teacher" AND "perception OR beliefs OR attitudes"	Academic Search Complete, Computers & Applied Sciences Complete, EBSCOhost eBook Academic Collection, and Education Research Complete	Scholarly (peer-reviewed) Journals in English Published: 2011-2023	49
	ERIC	Scholarly (peer-reviewed) Journals in English Published: 2011-2023	843

Selection Process

The initial search used the selected search terms and retrieved a large number of articles (n = 1413), of which 156 were identified as relevant to the study, confirming the efficacy of our search terms. Further analysis of the relevant articles yielded a final sample of 27 eligible studies.

Results and Discussion

Study Approach

While seven of the studies did not offer information on the future grade levels participants would teach (e.g., primary or secondary), the remaining studies revealed a notable distribution across educational stages. The largest group (14) focused on the primary/elementary level, followed by secondary/middle school (3), early childhood (1), and college/university (2). This trend showed that most studies occurred with elementary PSTs, while there is much room for investigating prospective early childhood educators' perceptions of STEM and STEM teaching (Radloff & McCormick, 2023).

There was also some geographical diversity in the places in which these studies occurred, Although the majority of studies originated from the United States (14), there was still global representation, with 4 studies from Europe, 4 from Asia, 1 from the Pacific region, and 1 from the Middle East. This finding appears to align with the ongoing US push to incorporate STEM education across pK-12 settings (Bryan & Guzey, 2020) and points to the need to consider PSTs' perceptions within more emergent STEM educational settings.

Concerning research design, there was a balanced distribution in the methodology employed across studies. Ten studies were quantitative, primarily utilizing surveys and questionnaires. Eight studies were qualitative, with these studies adopting interviews, focus groups, or observations for deeper insight. The remaining nine studies employed mixed methods that combined qualitative and quantitative approaches. This trend suggested a fairly equal distribution of the types of studies taking place, as well as the need to further explore each type (e.g., affordances, limitations, future directions).

Factors Influencing PSTs' STEM Perceptions

From the eligible studies, five key factors emerged that appear to shape PSTs' perceptions of integrated STEM. These include their *prior experiences*, *beliefs, perceived benefits* and *challenges of STEM teaching, available support,* and *teacher education*. These constructs have all been investigated separately at the level of preservice teacher education (e.g., Hammack et al., 2024; Dare et al., 2021; Radloff & Guzey, 2016). However, this review suggests they might also be considered 'linked' when considering PSTs' perceptions of STEM. As described previously by Bybee (2013), STEM perceptions are tied closely with stakeholder and context, and PSTs' reform-based needs (e.g., content and instructional support) are often very different than ISTs' (e.g., Capobianco & Radloff, 2022; Fantacone et al., 2024; Perkins-Coppola, 2019; Utley et al., 2019).

The findings of this review support and slightly extend upon current literature by providing a broader yet focused lens through which to explore the underlying mechanisms behind PSTs' STEM perceptions (Ring et al., 2017). The most straightforward direction forward would be to further define and investigate the intersections between these identified constructs. For example, how do PSTs' prior STEM experiences (e.g., schooling) and beliefs intersect with their perceived benefits and challenges of STEM teaching? How do their previous schooling and teacher education serve to shift their beliefs and challenges? Studies currently suggest the impactfulness of field experiences on these constructs (Hammack & Yeter, 2022), but are there other methods of supporting PSTs' conceptions? Other research points to the potential of engaging PSTs by analyzing videos of STEM lessons (Radloff & Guzey, 2017; Yeo et al., 2024) and virtual reality-based experiences (Silva-Diaz et al., 2023) as methods for supporting PSTs' STEM understandings. Research may also lean into each construct as it connects to educational psychology (Guzey et al., 2016). PSTs' STEM attitudes and interests may also impact their views of STEM (Savelsbergh et al., 2016).

Findings also point to reconsidering the affordances and limitations of established STEM conceptions (e.g., Bybee 2013; Lachapelle &Cunningham, 2017; Ring et al., 2017; Roehrig et al., 2021), as well as the nature of STEM (Akerson et al., 2018). STEM has been talked about as both an economic means of staying globally competitive and also as a means of reaching a more equitable world (Bryan & Guzey, 2020). These views may translate into a focus on STEM as a set of specialized careers (NSTA, 2020) or a way of solving global and culturally embedded STEM issues (Flanagan et al., 2022). Along the same lines, what are the implications of PSTs understanding STEM as 'interdisciplinary' (Van den Bogaard et al., 2021) versus 'transciplinary' (Bybee, 2013) on their lesson planning and enactment (Capobianco & Radloff, 2022)? For that matter, which conceptions are teacher education programs portraying to PSTs, and to what end are they doing so? Teacher educators' own STEM views and instruction can impact what approaches PSTs uptake as their own (Aydin-Gunbatar et al., 2018).

Conclusion, Implications, and Future Direction

This review identifies five key factors that shape PSTs' perceptions of integrated STEM: prior experiences, beliefs, perceived benefits and challenges, available support, and teacher education. Consequently, these findings call for teacher education programs to address PSTs' prior experiences and beliefs, which would help overcome negative perceptions and build their confidence in teaching integrated STEM (Hammack & Yeter, 2022). Concurrently, there should be readily available support for teacher educators, such as mentoring programs (Gresse Von Wangenheim et al., 2021) and resources provided (Yasar et al., 2016), which would aid in equipping PSTs with the knowledge and skills to navigate potential challenges. It also underscores the importance of high-quality PD, which focuses on integrated STEM, is relevant to differing grade levels of education, and aligns with addressing these identified key factors.

Future research should explore these factors in greater depth, particularly across different cultural contexts and subject areas. Additionally, investigating specific areas of content and pedagogical approaches to what makes an effective integrated STEM professional development program would provide valuable insights for future development and implementation within the field of academia. In doing so, we might address the current difficulties educators face with integrated STEM and empower future generations of teachers, equipping them with the knowledge, skills, and beliefs needed in a climate that increasingly demands STEM literacy and collaboration.

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