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Preservice Elementary Teachers Conceptions and Self-Efficacy for Integrated STEM

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Abstract: Educational reform efforts have emphasized preparing highly competent and confident preservice teachers to deliver effective K-12 Science, Technology, Engineering, and Mathematics (STEM) instruction. Self-efficacy is a key variable that influences motivation and performance, and therefore it is necessary to support the development of preservice teachers' integrated STEM teaching self-efficacy. This mixed-methods study investigates how preservice elementary teachers' integrated STEM teaching self-efficacy is shaped during their participation in a newly redesigned STEM semester consisting of three concurrent methods courses (science and engineering, mathematics, and technology methods courses). The quantitative data sources included the Self-efficacy for Teaching Integrated STEM instrument administered as a pre- and post-test, demographic, and open-ended questionnaire. The qualitative data sources included STEM identity letters, integrated STEM models, and STEM growth reflections. Quantitative results showed statistically significant positive gains in integrated STEM-teaching self-efficacy from the beginning to the end of the semester. The results from the content analysis also revealed positive shifts in PSTs' conceptions and attitudes about STEM. Notably, having a similar discourse across the three parallel-running methods courses provided a suitable context for preservice teachers to develop a shared understanding of integrated STEM. Implications for preservice STEM teacher preparation and research are discussed.

Keywords: integrated STEM; self-efficacy; preservice STEM courses

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1. Introduction

Numerous reform efforts across the globe in K-12 Science, Technology, Engineering, and Mathematics (i.e., STEM) education advocate restructuring curricula and programs emphasizing explicit integration of STEM disciplines [1–4]. Despite the calls, integrated STEM approaches are not necessarily designed for preservice teacher preparation courses [5,6]. Consequently, elementary teachers are under-prepared to design and deliver authentic, integrated STEM instruction to their students [7]. Reports from two large-scale national surveys in the United States suggest that elementary teachers are interested in teaching integrated STEM but lack sufficient training in STEM content and pedagogy [5,8]. Considering that interest in STEM fields begins at a young age [9–11], preparing a highly efficacious and competent next generation of elementary teachers is crucial to meeting the growing needs and demands of the future STEM workforce [12,13].

Integrated STEM instruction has shown several benefits among K-12 students, including increased motivation toward STEM-related fields [14], enhanced problem-solving skills [15], critical thinking and creativity [16], and increased interest and positive attitudes about STEM [17–19]. More recently, teacher professional development models have been developed with an increased focus on integrated STEM instruction [20–23]; however, such experiences are often short, so the effectiveness of such interventions for long-term changes in STEM instruction remains unclear. Studies have documented numerous challenges and barriers to STEM instruction in elementary classrooms. These challenges range widely, including a lack of STEM curriculum and activities for teachers to deliver meaningful STEM [24], time constraints [25], limited training in interdisciplinary pedagogical approaches [8], and school and administration support [26]. Different conceptions of the integrated STEM approach can cause additional confusion to teachers as they do not know how to design integrated STEM approaches when multiple perspectives are available [8,9].

Clearly, there is a need for redesigning preservice teacher preparation programs to enhance deeper interdisciplinary content and pedagogical knowledge related to integrated STEM [27,28], which, in turn, is likely to increase STEM teaching self-efficacy [13]. Self-efficacy has been an influential construct in teacher education and is positively associated with teachers' motivation [29], performance [30,31], and commitment to the teaching profession [32]. While a plethora of studies have consistently shown that elementary science and mathematics methods course experiences enhance self-efficacy beliefs [33,34], these courses are more often based on traditional siloed approaches rather than blending knowledge from different STEM fields [6,35]. Therefore, less is known about effectively supporting preservice teachers' knowledge, skills, and self-efficacy related to integrated STEM instruction. Prior studies have suggested links between self-efficacy and teachers' sense of competence and confidence in integrated STEM instruction [36,37]; however, significant gaps remain in the field's understanding of how preservice elementary teachers' (PSTs') integrated STEM teaching self-efficacy shapes during teacher preparation courses. The current study addresses the gap in the literature, and it contributes to the STEM preservice teacher education literature by investigating changes in PSTs' conceptions and self-efficacy related to integrated STEM as they participate in an intentionally redesigned STEM block (STEM semester hereafter) for PSTs.

2. Theoretical Underpinnings and Background Literature

2.1. Self-Efficacy in Teacher Preparation

Derived from Social Cognitive Theory, self-efficacy has emerged as an influential construct [38] in teacher education and has been linked to teachers' decision-making related to instructional activities, organization of lessons, and ability to handle challenging situations [39]. Consistent with Bandura's conceptualization of self-efficacy, in this study, STEM teaching self-efficacy refers to an individual's abilities to execute STEM instruction (teacher action) that they believe will increase students' knowledge and understanding of STEM topics (desired student outcome). Teacher self-efficacy consists of two dimensions; personal efficacy involves teachers' beliefs in their ability to teach effectively, and outcome expectancy relates to student outcomes as a consequence of their teaching. Self-efficacy beliefs that someone holds can promote effort [40] and commitment to teaching [41]; therefore, we posit that higher STEM teaching self-efficacy will positively influence PSTs' willingness to teach STEM in the future.

Research on preservice teacher self-efficacy has largely been conducted within the context of elementary science or mathematics methods as independent courses. Studies have consistently shown that experiences within the methods courses can foster self-efficacy by engaging preservice teachers in inquiry-based science [33,42,43] or mathematics instruction [44,45]. Bandura et al. [39] proposed four sources of self-efficacy: mastery experiences, vicarious experiences, verbal persuasion, and emotional arousal, and these sources seemed to impact self-efficacy within a variety of contexts. In general, mastery experiences, including first-hand teaching experience, have stood out as a powerful source of self-efficacy [46,47]. For instance, Menon [33] found that preservice teachers' science teaching self-efficacy increased after field experiences as they applied reform-based pedagogies learned in the science methods course, which helped them see what works and what does not within the classroom. Other studies found watching and reflecting on expert videos on STEM practices as positive vicarious experiences for developing positive conceptions of integrated STEM instruction [48].

More recently, there has been an increased focus on integrating engineering, technology, or STEM-focused activities within the science or mathematics methods courses; however, little research has been conducted on how these new interventions within the existing courses impact preservice teachers' self-efficacy for integrated STEM. Johnson et al. [37] explored PSTs' self-efficacy for integrated STEM teaching. They found that modeling integrated STEM instruction benefitted preservice teachers' perceived self-efficacy to teach science and mathematics within an integrated STEM framework. However, preservice teachers expressed concerns about their science and mathematics content knowledge, which stood out as one of the limiting factors towards the development of self-efficacy. Similarly, Ryu et al. [49] found that preservice teachers found developing and integrating STEM lessons beneficial to their perceptions of teaching STEM in the future but also felt challenged by their lack of interdisciplinary knowledge and understanding, school culture, and the absence of teacher role models in the classrooms. Careful planning, and designing methods courses that integrate STEM disciplines, can increase STEM teaching self-efficacy; however, time devoted to such experiences is often limited [50]. For instance, most studies exploring engineering teaching self-efficacy reported two weeks of engineering design interventions [51,52], making it difficult to claim whether the gains in self-efficacy are long-lasting. With a handful of studies on preservice STEM teaching self-efficacy, much remains unclear about how self-efficacy for integrated STEM instruction develops and what contextual factors may support or limit the development of long-term self-efficacy.

2.2. STEM Education

STEM education has been conceptualized in many ways, and there is a lack of consensus on what truly counts as STEM instruction [53,54]. Most models and definitions, however, called for disrupting traditional siloed approaches to teaching STEM [55,56] and shifting towards merging some or all of the STEM sub-disciplines [8]. For this study, we draw upon Nadelson and Seifert's [57] notion of integrated STEM as "the application of knowledge and practices from multiple disciplines to learn about or solve transdisciplinary problems" (p. 221). Similarly, Moore and Smith [58] defined STEM instruction as involving students participating in "engineering design as a means to develop relevant technologies that require the learning and use of appropriate science and/or mathematics content" (p. 5). STEM pedagogies must promote active learning that allows students to use hands-on, practical applications to solve real-world problems [24,59] and build knowledge via social discourse and teamwork [60,61].

Other approaches to STEM integration are the "content" and "context" integration of STEM. Content integration emphasizes knowledge from multiple content areas blended into a singular unit or used to advance the learning within one discipline, for instance, to enhance engineering learning while integrating knowledge from other disciplines [35]. On the other hand, context integration focuses on increasing the relevancy of the content topic from one discipline by using contexts from different disciplines [58]. Given a variety of models and conceptions about STEM, designing STEM instruction for preservice courses has been noted as a challenge due to a lack of a coherent framework [56,62] to help instructors redesign courses for a greater STEM focus. Designing educational experiences that build preservice teachers' specialized knowledge in STEM content and pedagogy is warranted to see the desired change in our current K-12 STEM education [55,63]. The onset of the Next Generation Science Standards amplified the need for deeper connections between various disciplines and for the use of a strategic approach to design instruction utilizing disciplinary core ideas, science and engineering practices, and crosscutting concepts [64].

In response to this pressing need to prepare a highly qualified and competent next generation of teachers to deliver effective STEM instruction, many teacher preparation programs in the United States have attempted to make programmatic changes to focus on integrated STEM. A wide variety of models for restructuring preservice teacher preparation courses is becoming popular, ranging from either combining existing methods courses to move towards interdisciplinary approaches to STEM teaching and learning or adding STEM learning opportunities to an existing course to enhance preservice teachers' pedagogical skills for future STEM teaching [9]. For instance, Rose et al. [65] conducted a study to explore programmatic features of elementary teacher education programs across the United States, and they found that more than 44 institutions included technology and engineering experiences within their programs or as part of existing science or mathematics methods courses, or separate methods courses were developed on technology integration. Regardless of the design, the emphasis is on explicit and intentional integration of STEM disciplines to support preservice teachers' abilities to effectively deliver integrated STEM in future classrooms [48].

2.3. Preservice STEM Education

With increased attempts to redesign preservice teacher preparation programs to include STEM integration, the research on preservice STEM teacher education is also growing; however, much remains unclear about the underlying factors that support or hinder integrated STEM teaching self-efficacy. Despite a paucity of research on STEM teaching self-efficacy, emerging studies [37,48,59] suggest that courses that cut across multiple contexts and are positioned to advance interdisciplinary knowledge using approaches that involve problem-solving by formulating questions, communicating, participating in scientific inquiry and engineering, and designing solutions to complex real-world problems [58,66], and instructor STEM modeling [37] are pivotal to enhancing PSTs' confidence and self-efficacy in teaching integrated STEM. Research by [59] investigated the impact of a newly designed STEM block that combined two traditional mathematics and science methods courses. When comparing the self-efficacy outcomes from the two groups of preservice teachers, i.e., those enrolled in the STEM block and others in traditional methods courses, they found that the STEM block group showed higher gains in STEM teaching self-efficacy than the group who received traditional instruction. In the Johnson et al. [37] study, the collaborative effort between mathematics and science educators resulted in redesigning existing methods courses to include STEM model lessons. The co-teaching approach significantly increased PSTs' self-efficacy for integrated STEM.

Given the growing attempts toward STEM teacher education, one body of research claims that investigating preservice teachers' conceptions of STEM is central to understanding the challenges that exist [24,67] and determining the supports needed to design best practices intended for bringing a long-lasting positive change [68]. Teacher conceptions about STEM may include but are not limited to: teacher beliefs and perceptions regarding STEM curriculum and pedagogy [24], values they hold regarding STEM teaching [28], and how one positions oneself to learn and develop as a STEM educator [69]. Holincheck and Galanti [70] explored STEM conceptions of practicing elementary teachers enrolled in an online STEM education course using visual representations (concept maps). Participants' concept maps revealed two perspectives about STEM education: disciplinary interpretation (STEM teaching with knowledge from distinct content areas) and an integrative interpretation of STEM (knowledge and skills from across disciplines).

Similarly, [28] utilized an open-ended survey consisting of textual and visual responses to capture preservice teachers' conceptions of STEM. Both textual and visual representations showed variations in how preservice teachers conceptualize STEM. At the same time, misconceptions and misunderstandings about STEM they carried from prior experiences were also visible. Video reflections on integrated STEM teaching were also helpful in building PSTs' awareness and appreciation for integrated STEM teaching [48]. In another study conducted within the context of an engineering-focused methods course [71], preservice teachers developed perceptions of engineering at the end of the course. Their shifts in perceptions included (1) a conceptual understanding of engineering design situated within the elementary science classroom, (2) a pedagogical understanding related to instructional and assessment tools, and (3) an attitudinal change related to overall confidence in implementing engineering-based science lessons in their future classrooms.

Unsurprisingly, other studies report contrary results. In the study conducted by Ryu and colleagues [49], preservice teachers' disciplinary backgrounds influenced their decision-making during lesson planning, as many lesson plans were not situated within the notion of integrated STEM but rather within one discipline. Others realize that developing a sophisticated understanding of integrated STEM is an ambitious goal considering preservice teachers often bring varied views and conceptions about STEM disciplines originating from their prior experiences in science or mathematics [27,37]. Empirical studies found that a lack of solid content background in science, mathematics, and engineering [53,72] was critical in developing preservice teachers' understanding of STEM integration. For instance, the study by Kurup and colleagues [68] revealed that preservice teachers had limited confidence in teaching STEM. Preservice teachers reported that STEM initiatives were not necessarily emphasized at schools [68] and the lack of STEM role models had an impact on preservice teachers' interest and intentions to teach STEM in the future [49,68]. Often, time devoted to STEM instruction is short and not enough to challenge preservice teachers' "ill-informed or surface-level conceptions" [63] or their negative dispositions toward STEM disciplines [73]. Because results from prior studies on preservice STEM teacher education are inconclusive and render conflicting results, additional studies are needed to investigate preservice teachers' conceptions and self-efficacy for integrated STEM.

3. Focus of This Study and Research Questions

Given the empirical findings and gaps in the literature on preservice STEM teacher education, we focused on exploring changes in PSTs' conceptions of STEM and we integrated STEM teaching self-efficacy during their participation in the redesigned STEM block (STEM semester hereafter). We contend that building a strong STEM foundation within preservice methods courses can potentially support the development of integrated STEM teaching self-efficacy and cultivate positive conceptions of STEM teaching and learning. The following research questions guide this investigation:

1. How does preservice elementary teachers' integrated STEM teaching self-efficacy change after participating in the STEM semester?
2. How do preservice elementary teachers conceptualize integrated STEM instruction at the beginning and end of the STEM semester?

4. Methodology

4.1. Research Design

In this mixed-methods research, we utilized a triangulation convergent design approach (see Figure 1) to converge and corroborate quantitative results with qualitative findings [74]. The design was well-suited to the study considering that self-efficacy is a complex construct and understanding one's conceptions about STEM further requires deeper investigation into the processes that are in place within the research context [75]. We draw upon pragmatism as our philosophical stance to utilize common elements from two distinct worldviews: post-positivism, or deductive approach, and constructivism or inductive approach [76]. The ontological (singular and multiple realities exist), epistemological (research question is of primary importance), axiological (multiple stances), and methodological (combining and converging quantitative and qualitative methods) assumptions of the pragmatic approach further inform our research questions, methods used, and reporting of the data [74,77].

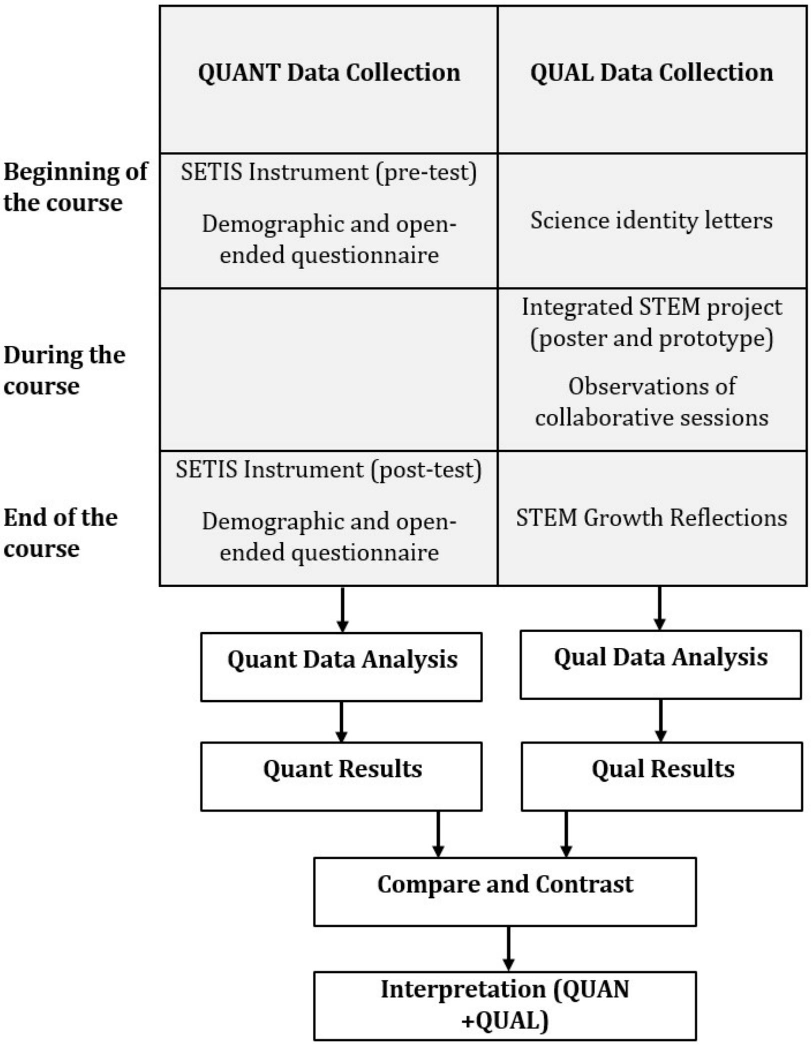

Figure 1. A Mixed-methods approach, with a triangulation convergent design.

While the quantitative findings were targeted to explore the changes in preservice teachers' STEM teaching self-efficacy beliefs, the qualitative analysis provided rich data to understand their beliefs and perceptions about STEM at the beginning and end of the STEM semester. The quantitative and qualitative data were collected and analyzed separately, and the findings from the two data sets were triangulated, i.e., compared, converged, and synthesized to present the results.

4.2. Research Context

This study was conducted in a newly redesigned elementary STEM semester at a large, research-intensive university in the Midwestern region of the United States. In response to the calls for reforms in teacher preparation programs, the integrated STEM curriculum design efforts were led by a multi-disciplinary team of STEM educators and researchers, including four faculty and four graduate students from various disciplines: science and engineering education (one faculty and two graduate students), mathematics education (two faculty and one graduate student), and technology education (one faculty and one graduate student). Within the STEM semester, three concurrent courses center on integrated STEM connections: mathematics, science and engineering, and technology or Innovative Learning Technologies (ILT) methods (see Table 1 for more details on the content within the three methods courses). The science and mathematics methods courses are 3-credit, semester-long, and meet for 15–16 weeks, while the ILT methods course is a

2-credit course. The other two courses that preservice teachers are enrolled in include a mathematics content course and a 2-day practicum per week in a local elementary school.

Table 1. STEM Semester Methods Course Overview.

	Science Methods	Mathematics Methods	ILT Methods
Course Description	Role, trends, content, and materials of science in childhood education. Development of science experiences for use with children.	Scope, content, and organization of the mathematics curriculum; development, use, and sources of instructional materials; teaching procedures.	Development of strategies for using technology to support K-12 classroom instruction. Internet resources, applications software, and authoring programs.
Focus Topics	5E lesson planning [7], Engineering Design Process [78], Science and engineering practices and sense-making [79].	Principles and teaching practices for teaching mathematics aligned with Principles to Actions [80].	Overview of technology education standards [81,82]. Introduction to online math and science tools and applications, educational robotics, and AI, and their potential uses in elementary education.

The design of the STEM curriculum and STEM pathways across multiple methods courses were based on our conceptual framework (refer to [83] for more details on the framework for STEM curricular reform) (see Figure 2) that position scientific inquiry processes and pedagogies that are fundamental to conceptualizing STEM learning and are highly promoted in the Next Generation Science Standards [64]. We draw upon existing models of STEM integration [56,58] that emphasize problem-based learning that involves scientific inquiry (using science and engineering practices), engineering design process to solve a problem, and integrating technology and mathematics to design solutions. While PSTs were engaged in discipline-specific instructional approaches for STEM within each specific methods course (e.g., science and engineering practices, engineering design, 5E lesson planning, mathematical modeling, and robotics/coding), there were STEM-themed pathways and shared projects across multiple courses (see Table 2 for the structure and format of the shared assignments). Each course used a multi-disciplinary approach to focus on content areas relevant for PSTs to see and indulge with the topics to experience STEM connections across disciplines and, in the end, solve an engineering design challenge using the STEM knowledge and skills learned from different fields.

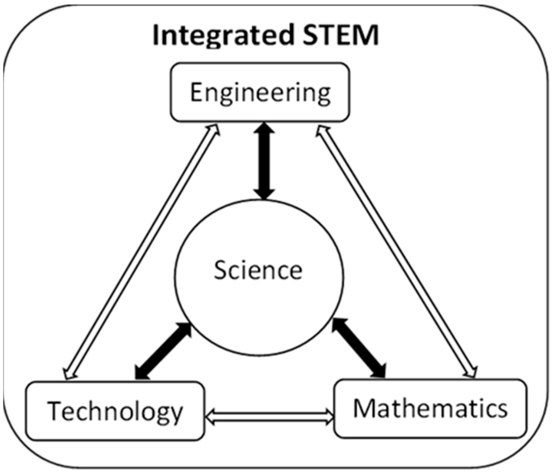

Figure 2. Framework for Integrated STEM Curriculum Reform.

Table 2. Shared Assignments for Integrated STEM.

	STEM Identity Letters	Integrated STEM Project	STEM Growth Reflections
Time of the Semester	Beginning of the semester (first week)	Mid-semester, developed over a course of four classes in each methods course (a total of 12 classes), spread over a month	End of the semester (introduced two weeks before the conclusion of the semester)
Format and Structure	Individual story writing, online submission to the course site	Poster/slide making, poster/slide presentation, creating a prototype/model, collaborative group project (3–4 PSTs per group)	Individual story writing, offline, pictures of artifacts to show growth, online submission to the course site
Connection to Integrated STEM Self-efficacy	Analyze, reflect, and write about identity as a learner of science and mathematics (and experiences with engineering and technology), perceptions about STEM teaching	Work in collaborative teams, engage in engineering design to create a solution to the problem, use scientific content and mathematical and technological tools to build prototypes and testing solutions, and enhance creativity by making a poster.	Builds on reflective practice, reflect on perceptions about integrated STEM teaching and draws on examples from the three methods coursework to illustrate their learning.

Each semester, the STEM Curriculum Reform team meets regularly to discuss the successes and challenges within the STEM semester and consequently revise the shared assignments. This study was carried out in the third and fourth iterations of the STEM semester. Based on the challenges that STEM instructors faced and PSTs' feedback, changes to the structure of the STEM semester were considered. Noting that the process of re-designing and implementing the STEM semester posed numerous challenges, the onset of the COVID-19 pandemic brought additional complications that forced the adoption of a hybrid teaching model. The COVID-19 pandemic challenged STEM instructors to navigate conditions described as volatile, uncertain, complex, and ambiguous (VUCA)—a term used to describe circumstances that call for re-envisioning education for a VUCA world [84,85]. The notion of VUCA has been previously popular in other fields (e.g., business, and leadership); however, the COVID-19 crisis led practitioners and policymakers to expand this term to education. Purposeful and persistent efforts by our STEM team led to continuously trying to improvise, experiment, and innovate the existing STEM semester model to a hybrid (synchronous, asynchronous, in-person) model. For instance, PSTs continued to observe and work with elementary students in a practicum setting but adapted to participating via web conferencing and visiting only two weeks inside the physical classroom (compared to 12–14 weeks in prior semesters).

As with many institutions, several courses adapted to synchronous online formats. For hands-on courses in the STEM semester, this challenge was addressed through the use of manipulatives and resource kits that allowed PSTs to engage from home. To engage PSTs with creating integrated STEM learning experiences, they were asked to work virtually in teams and create an integrated STEM project focused on the food chain. PSTs created interactive slides to engage children in the activities they designed and hands-on projects that children could create using materials children would be likely to have in their homes. Therefore, the two STEM semesters during the pandemic era are of particular interest for the present study and provide authentic contexts to explore preservice elementary teachers' conceptions and self-efficacy for integrated STEM. The online and in-person classes were held in alternate weeks. The science methods course met once a week for three hours. Regarding the other two methods courses, mathematics met twice weekly for about 1.25 h each, and ILT methods met once weekly for about 1.5 h.

4.3. STEM-Themed Pathways

4.3.1. Sustainability

We describe one of the cross-course themes, "sustainability", designed in response to a university-wide Sustainability Curriculum initiative. As part of this initiative to infuse sustainability into the existing course curriculum, members of the instructor team first developed a Sustainability Module for STEM Block courses in the Fall of 2020. The module, implemented the following semester, focused on a phenomenon of regional importance: flooding. In the science methods course, PSTs learned about the hydrologic cycle in the context of creating 5E lesson plans. The parallel math methods course completed and adapted tasks focused on flow rate, definitions of 100- and 500-year floods, and relating floodplain maps with line graphs [86]. After this multidisciplinary approach to modeling and building PSTs' background knowledge, the technology course challenged PSTs to 3D-print a model house [87] to place on a real-world floodplain model. Teams then used the engineering design process to develop flood mitigation strategies for their assigned location on the floodplain. The project culminated with a guest speaker from the College of Engineering whose focus was on water and flooding. Teams of PSTs tested their mitigation strategies by pouring water over the floodplain model and discussing which ones withstood the flooding and why others did not. This iteration of the module included a follow-up challenge for PSTs to adapt the flooding activities for children in the elementary grade levels corresponding with their practicum placements. Subsequent iterations of the project have transitioned toward using sustainability as an overarching theme for the integrated STEM projects that PSTs create for use with elementary students. For instance, integrated STEM projects created during hybrid instruction focused on the food chain within a context of sustainable ecosystems in the region.

4.3.2. Robotics and Coding

A second cross-course theme was educational robotics [88]. In the ILT methods course, PSTs first learn about puzzle-piece programming in Scratch during week 2 of the semester. They are then introduced to a variety of robotics appropriate for use with elementary students. These include BeeBots, Edison bots, Dash bots, Sphero, and Cubelets. After initial opportunities to explore how these bots work and how they might be incorporated in elementary classrooms, PSTs engage in integrated STEM experiences with robotics in other methods courses. For example, PSTs engage in a modified version of the Fraction Path [89] as they design a 120 cm path with a specific science context (e.g., solar system, hydrologic cycle). They then program Dash bots to act as tour guides along the path, announcing the distance traveled, fractional lengths of 120 cm, and key science ideas at each of the 5 stops along the path. In their mathematics methods course, PSTs design tasks focused on connecting multiple mathematical representations and using BeeBots to navigate among matching representations (e.g., story problems, pictorial representations, equations, and images of manipulatives). At the end of the semester, PSTs present their own ideas for incorporating educational robotics in a math or science lesson.

4.3.3. Participants

The participants of this study included 132 PSTs enrolled in the elementary education program at a large Midwestern research-intensive public university. Undergraduates interested in the program are generally enrolled in their junior year, and the STEM semester marks the beginning of their methods coursework. Table 3 presents the demographic information and prior science courses (high school and college) taken by participants before participating in this study. The data were collected from six distinct cohorts during Fall 2021 (three cohorts, 74 students enrolled, and all consented to participate) and Spring 2022 (three cohorts, out of 69 students enrolled, 58 students agreed to participate) semesters. The enrollment in each cohort typically ranges from 22–28 PSTs. The course instructors of the three methods courses, consisting of faculty and graduate students, read the recruitment script that outlined the goals and purpose of the study on the first day of the course session. All participants who volunteered to participate signed the university-approved Informed Consent forms. Each participant was given a unique identifier, and pseudonyms were used in the files shared within the research team during the analysis and correspondence of the results.

Table 3. Demographic information of participants (n = 132).

Age (Years)	No. of Science Courses Taken in High School	Gender	Year (in 4-Year Program)	Race
19–21 (n = 109)	Two (n = 5)	Male (n = 9)	Year 2 (n = 45),	African American/Black (n = 2)
22–25 (n = 18)	Three (n = 38)	Female (n = 120)	Year 3 (n = 83)	White/Caucasian (n = 112)
>25 (n = 5)	Four (n = 57)	Prefer to not say (3)	Year 4 (n = 4)	Asian (n = 4)
	Five (n = 19)			Hispanic (n = 11)
	Six (n = 11)			Prefer to not say (3)
	Eight (n = 2)			

4.4. Data Collection

Data were collected in two distinct phases: a quantitative phase and a qualitative phase. The quantitative data sources included the Self-efficacy for Teaching Integrated STEM (SETIS) instrument [90], a demographic and open-ended questionnaire. The qualitative data sources included STEM identity letters, integrated STEM models, and STEM growth reflections.

4.5. Quantitative Data Sources

The SETIS instrument [90] was used as a pretest and a post-test, administered at the beginning and end of the semester. The SETIS survey consists of 30 items on a 4-point Likert scale ranging from 1 representing "cannot do at all", 2 as "would have difficulty doing this", 3 as "most confident I can do this", to 4 representing "very confident that I can do this". The instrument measures teacher confidence in their ability to perform teaching tasks related to integrated STEM teaching and learning. Scores on the SETIS could vary between 30 and 120, with higher scores corresponding to higher self-efficacy. The instrument's reliability for the current sample was explored using Cronbach's alpha (α) for the pre- and post-test data. Cronbach's α values show that the internal consistency of measurement for pre- and post-SETIS is 0.963 and 0.955, respectively, thus suggesting strong reliability estimates [91]. At the beginning of the semester, participants were provided with a secured link to access the survey online a week before the first session via the course management site. They were given two weeks to complete the survey. Similarly, participants completed the post-survey online towards the end of the semester within a two-week period.

Similar procedures were followed to administer the open-ended questionnaire as a pre- and post-test (same link as the SETIS survey) with two questions for which participants provided text responses. The open-ended questions centered on participants' perceptions of STEM at the beginning and end of the semester; the questions were: "How would you define STEM?" and "What do you think about STEM teaching in elementary classrooms?" The demographic data were collected only once at the beginning of the semester, along with the pre-SETIS instrument.

4.6. Qualitative Data Sources

The primary data sources included written STEM identity letters and STEM growth reflections. Secondary data sources included Integrated STEM models (poster and the prototype, and observations of the in-class sessions) where PSTs worked together to create and present their Integrated STEM posters and models. The details of the qualitative data sources (format, structure, and nature of data sources) are available in Figure 1. The STEM identity letter prompts were designed to reveal PSTs' pre-existing views, attitudes, and beliefs about each STEM discipline related to their K-12 experiences as learners of science and mathematics and other past informal experiences in STEM. Given that early experiences in science, mathematics, and engineering play a significant role in shaping their beliefs and interests in STEM subjects [33], the STEM letters allowed PSTs to critically reflect on their memories of experiences as learners as well as interactions with their science or mathematics teachers from early years through college or university. For instance, in one of the prompts, PSTs were asked about "general characteristics of science and engineering experiences that have been meaningful (or a turn-off) for them". There were prompts to understand how their prior science experiences have shaped their "definitions of science and attitude towards science and science teaching". We contend that critical reflection on past experiences [92] sets the stage for interpreting the meanings of STEM teaching presented in this course.

The second primary data source was the set of written STEM growth reflections, also based on reflective practice, allowing PSTs to reflect on and analyze their STEM experiences and write how these experiences impacted their development as learners and future teachers of integrated STEM. The STEM growth reflections were purposefully positioned at the end of the semester, allowing PSTs to select episodes from all the different methods courses and showcase their learning on integrated STEM using those artifacts. We asked: "How have you grown with respect to integrating across STEM subjects (Refer back to your beliefs/perceptions about STEM integration from the beginning of the semester)?" They were also prompted to reflect on their strengths and areas they would like to continue to focus on in the future to enhance their knowledge and skills related to integrated STEM teaching; we asked: "How will you continue to grow in your understanding and beliefs about STEM integration in the future?" The secondary data sources included observations of integrated STEM sessions where a researcher took field notes on PSTs' interactions. At the same time, they made decisions on creating a prototype/model as a solution to the problem (see the Sustainability STEM-themed pathway description above). The poster and model presentation sessions were also observed, and field notes were recorded.

4.7. Data Analysis

The research team conducted data analysis in two distinct phases, including (1) a quantitative phase and (2) a qualitative phase. Both phases occurred after the conclusion of the data collection. Below is the description of each of the two phases of data analysis. Three of the researchers are experts in qualitative research; one is a faculty member in science education, two others are advanced doctoral candidates (final year at the time of the study) in mathematics education, and one is a doctoral student in learning technologies in education.

4.7.1. Quantitative Data Analysis

The quantitative data were analyzed using IBM Statistical Package of Social Science (SPSS) software. The pre–post repeated measures design was used to determine the change in integrated STEM teaching self-efficacy beliefs for the preservice teachers (n = 121) from the pre- to post-test (two time points). The t statistic was used to test the null hypothesis that there were no significant differences between the pre- and post-self-efficacy mean scores for the SETIS scale. Cohen's D estimates the effect size to provide information about the magnitude of the change from pre- to post-test.

4.7.2. Qualitative Data Analysis

We utilized content analysis [93,94] to analyze the qualitative data iteratively. The content analysis aims to "provide knowledge and understanding of the phenomenon under study" [95] (p. 314) and is well-suited to analyze text data that appears in verbal, print, or electronic format collected from multiple sources such as open-ended surveys, narrative responses, and observations [96]. Therefore, content analysis is particularly suitable for this study as it allowed opportunities for an in-depth analysis of the text responses from the open-ended questionnaire, STEM identity letters, STEM growth reflections, and classroom observations. The analytical framework (see Figure 3) by [93] guided our analysis in a four-step process, including (1) decontextualization, (2) recontextualization, (3) categorization, and (4) the compilation of the data. The research team (two faculty experts in quantitative and qualitative analysis, one in science education and the other in mathematics education, and three doctoral students, one in the 5th year of science education Ph.D. program, and the other two in the 2nd year of science education and innovative learning technologies Ph.D. programs) revisited the data at each of the four stages to ensure the validity, reliability, and trustworthiness of the analysis. Below, we describe the four stages in detail.

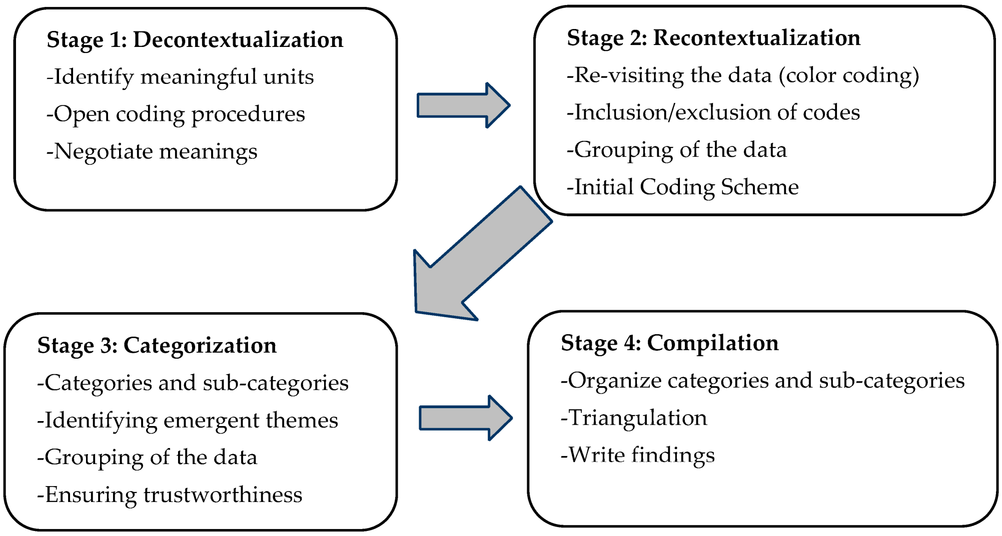

Figure 3. Analytical Framework for Data Analysis.

Decontextualization. At this stage, the team of five researchers independently visited the data, selected randomly by the team, several times to break the data into meaningful units [97]. Each unit was assigned a code emerging from the data using open coding procedures. The researchers then met to discuss the codes and alternative interpretations until we reached a consensus. We ensured the interpretations' analytical rigor and reliability procedures were consistent with the qualitative techniques used in science education for agreement between codes [98]. Each unit and code were discussed to allow researchers to describe the code without presuming the correctness of their descriptions. We revisited the sample of the data to negotiate meanings and multiple interpretations if they existed until an agreement was reached.

Recontextualization. The research team revisited the data to capture additional units and label and color-code the codes that provide meaningful information about preservice teachers' conceptions and self-efficacy for integrated STEM. While original data files were preserved, the color coding allowed for the selection and exclusion of the codes. Then, the research team met to condense the codes while grouping the raw data and developing an initial coding scheme. Each researcher independently and thoroughly revisited the data and used the coding scheme to re-code the data.

Categorization. At this stage, codes were examined for emerging patterns and sorted into categories. The categories and sub-categories were then reassembled into emergent themes. At this point, we revisited the data to draw relevant links between the codes and identify any additional category or sub-category. We particularly paid attention to cues that provided further details on confirming or disconfirming evidence supporting each theme related to understanding PSTs' conceptions about integrated STEM. Throughout, we employed multiple procedures to ensure data trustworthiness and analytical rigor, including constant comparison for consistency between coders and analyzing refutational texts [99] in the data, as these phrases were particularly interesting to understanding participants' alternate conceptions about integrated STEM, and the use of tables (see Table 4 for an example of the coding scheme).

Table 4. Sample Coding Scheme.

Meaningful Unit (Sample Excerpt)	Initial Code	Category/ Subcategory	Themes
At the beginning of the semester			
I do not recall much about science in the classroom.	No recollection of science	Negative dispositions	Low affinity for STEM
I think about how STEM is only for guys or how rare it is to see a woman in STEM.	Only guys Scarcity of woman in STEM	Gender differences in STEM	STEM stereotypes
The idea of STEM scares me. I never took a STEM class in my high school because I thought it was complicated.	Scary, complicated, no STEM class in high school	STEM seems scary Lack of prior knowledge in STEM	STEM is new and complicated
At the end of the semester			
I learned so much and have realized that I also have so much more to learn. So, I am now open-minded to new technology, and new ways of teaching science.	Open-minded, new ways to teach science, more to learn—technology	Positive change after the semester	Positive attitudes about STEM
I wasn't so sure about how I would incorporate so many different components into one lesson. After completing my integrated STEM lesson plan, I realized how easy it can be.	Easy, Incorporate STEM components	More confidence for STEM integration	Increased confidence in planning and designing integrated STEM lessons
STEM is critical for all students, not just left-brain individuals and males	Critical for all students	Importance of STEM for students	Importance of Integrated STEM for all K-5 learners

Compilation. At this stage, we organize our categories and sub-categories to make sense of the data and write emergent findings. Each qualitative data source was analyzed using the analytical framework described here. Then, we employed triangulation [100] to converge and corroborate findings from the quantitative and qualitative data sources to understand the changes in PSTs' conceptions and self-efficacy for integrated STEM.

4.7.3. Findings

In this section, we first present the findings from the quantitative analysis of the changes in PSTs' self-efficacy from the SETIS survey. Then, we discuss qualitative trends from the STEM identity letters and STEM growth reflections. In reporting the excerpts, "IL" indicates identity letter, "GR" represents written growth reflections, and "OR" represents open-ended responses.

4.8. Changes in Self-Efficacy for Integrated STEM

The study explored changes in PSTs' self-efficacy beliefs for integrated STEM during their participation in the STEM semester. The data from the survey were tested for the normality of the distribution of scores, skewness ($<\pm 2.0$), and kurtosis ($<\pm 2.0$). Descriptive statistics for pre- and post-SETIS are presented in Table 5. The mean score significantly increased from the pretest (M = 88.77, SD = 13.96) to the post-test (M = 105.12, SD = 10.14).

Table 5. Descriptive statistics on variables for self-efficacy.

Variable	Mean	SD	Min	Max	Skewness	Kurtosis
SETIS						
Pre-Survey	88.77	13.96	48	120	−0.39	0.38
Post-Survey	105.12	10.14	82	120	−0.22	−1.01

Maximum possible score: SETIS = 120.

The dependent-paired sample t-test showed significant differences between the pre- and post-scores at $p < 0.001$. (See Table 6). Using [101]'s suggested norms, we found a large effect size (d = 0.967) for the changes in integrated STEM teaching self-efficacy.

Table 6. Paired Samples *t*-test.

	Mean	Std. Deviation	Std. Error Mean	*t*	df	Sig. (2-Tailed)
Pair 1 Pre-Survey—Post-Survey	16.350	16.899	1.470	11.2 *	131	0.000

* Significant at $p < 0.001$.

4.9. Qualitative Themes

The trends from the open-ended responses and written reflections supported the quantitative results that showed positive shifts in participants' conceptions and confidence in integrated STEM teaching and learning. In the next section, we present the results in two parts, including (1) three initial themes from the pre-open-ended responses and STEM identity letters that PSTs wrote at the beginning of the semester documenting their personal and professional experiences with science and STEM and their perceptions about STEM teaching and learning and (2) three emergent themes from the STEM growth reflections and post-open-ended responses towards the end of the semester.

4.10. Beginning of the Semester Themes

4.10.1. Low Affinity for STEM

At the beginning of the semester, most participants' ($n = 84$) responses indicated low affinity and interest in teaching STEM. Participants' prior experiences in individual STEM subjects, particularly science or mathematics, seemed to impact their current beliefs about STEM. For example, one participant shared, "I do not have that strong of a relationship with science or engineering. Thinking back on my time, I barely came across real, meaningful science teachers =" (IL, Participant 16). Negative dispositions in science seemed to influence their views about STEM teaching:

> I would say that my personal definition of science is boring, confusing, difficult, and time-consuming. Since I have not had very positive experiences with science in the past years, I would say this has definitely affected my definition of science... I think that when teaching STEM, it is easy for students to give up because the material is too hard or confusing for them. This causes them to lose confidence in their STEM abilities and feel as though math, science, or technology is too hard. (IL, Participant 12)

One of the prompts in the open-ended response was about what they think STEM means and the importance of STEM in elementary teaching. Most participants knew what the abbreviation STEM stands for but indicated a lack of exposure to STEM in prior coursework. As one PST mentioned, "Growing up, we didn't learn much of STEM specifically... I believe today's curriculum is more based on equal science, technology, engineering, and math. For example, in my technology class this semester, we get to work with robots. I do not have any memory of working with robots or much with computers, except specials" (IL, Participant 22). Participants perceived STEM as a new concept gaining popularity in the school curriculum nowadays; as one PST mentioned, "I think it is so great that schools are focusing more on STEM-based learning. I never got to experience science much in elementary school" (pre-OR, Participant 6). Similarly, another participant mentioned that "science, technology, engineering, and mathematics (STEM) are a part of an educational discipline in elementary schools" (pre-OR, Participant 16).

4.10.2. STEM Stereotypes

Another trend that stood out from participants' responses at the beginning of the semester was that they associated STEM with various stereotypes. For instance, one participant reported, “when I think of STEM, I think of a lot of stereotypes and stigmas. I think about how STEM is “only for guys”, or how rare it is to see a woman in STEM. (IL, Participant 4). Another participant mentioned that “the first things that come to my mind is I think of “left brain” people succeeding in STEM” (IL-Participant 26). We also noted that participants expressed the desire to help their students stay away from such biases. The quote for participant 4 expressed this tendency:

> As a future science teacher, I want to break the stigma. Anyone can be a part of STEM, especially if you work hard and put your mind to it. When teaching elementary students about STEM, I want them to know that if they enjoy STEM, they are good enough to go for it. STEM is for anybody, and I really want to stress that to kids. It’s damaging to say that STEM isn’t for everyone to impressionable kids. (IL, Participant 4)

Participants strongly emphasized that “STEM is really important for all students, but especially for girls and young women, who are disproportionately represented in STEM majors in college” (IL, Participant 13). Another participant shared the importance of outside-of-class activities for encouraging girls in STEM: “I believe that it is important to encourage young girls to take part in STEM activities outside of class. . . to be engaged and curious, and STEM can achieve that for them” (IL, Participant 16).

4.10.3. STEM Is New and Complicated

Another theme that appeared in participants’ responses at the beginning of the semester was that they seemed to perceive STEM as a relatively new concept and something that is being pushed in elementary schools more recently. The excerpt below expresses this tendency:

> When it comes to teaching STEM in grade school, I think it is a relatively “new” concept. I know elementary students have been learning math and science for ages and that they themselves are not new, but the idea that technology, math, and science are now an integral part of succeeding in the world after school is newer in schools. (IL, Participant 12)

Participants also expressed that STEM teaching and learning is complicated as it involves four disciplines, and they do not know how to teach it. As one participant posed in a question in response to the questionnaire about what STEM means, “how to teach science, technology, engineering, and math to a constant ever-growing culture” (pre-OR, Participant 34). The participant further elaborated that “we live in a country that is growing every single day, the way I teach science or technology, will be different from how teachers taught me when I was in elementary school” (pre-OR, Participant 34). Another participant expressed how STEM is challenging: “My own definition of STEM would be a way to figure out the more challenging side of things in a meaningful, thought-out way. I say this because STEM is a hard thing to wrap our heads around. (IL, Participant 2).

Participants who did not find one or more individual STEM disciplines as their strong suit tended to believe that STEM needs more time and effort: “STEM would be for some of my weakest skills. STEM to me is something that I have to put lots of work into to understand, but it’s something that is useful to know which is why I’m always determined to do my best to understand STEM subjects” (IL, Participant 8). Another participant mentioned that “the idea of STEM scared me. I never took a STEM class in my high school because I thought it was complicated and out of my brain capacity” (IL, Participant 4).

4.11. End of the Semester: Themes

4.11.1. Positive Attitudes about STEM

At the end of the semester, participants wrote STEM growth reflections where they were asked to reflect on their understanding of STEM while referring to their perceptions of STEM from the beginning of the semester (STEM identity letters). A majority of participants’ responses in growth reflections, as well as post-open-ended responses, indicated positive shifts in their attitudes toward STEM. Participants developed a positive affinity towards STEM, as one participant noted that STEM is "challenging but attainable. It [Integrated STEM] is something I have grown to like" (post-OR, Participant 9). Participants' reports of positive STEM attitudes and values most often cited experiences within the methods courses. As one participant mentioned, "Overall, in the STEM block, I learned so much and have realized that I also have so much more to learn. So, I am now open-minded to new technology, and new ways of teaching science" (GR, Participant 35). Further, participants often reflected and compared their perceptions of STEM from the beginning of the semester to suggest an improved understanding of STEM, as a participant mentioned, "At the beginning of the semester, I wasn't aware how closely they all [referring to four disciplines] worked together. At the end of the semester, I quickly learned that they can easily be incorporated into one big group" (GR, Participant 23).

Participants realized the value of integration across disciplines rather than teaching the four disciplines as silos. As one student mentioned:

> "First, I thought STEM was just science, technology, engineering, and math as a separate but as the semester went on that changed quickly. STEM is a curriculum based on an interdisciplinary and applied approach rather than teaching the four disciplines as separate and discrete subjects. STEM integrates them into one cohesive learning model based on real-world applications, so they are intertwined, they aren't their own separate". (GR, Participant 8)

Participants considered STEM experience built on hands-on as beneficial for elementary students, as one participant mentioned, "the hands-on approach is effective for students because it created those problem-solving skills and gets them thinking" (GR, Participant 28). Another participant stressed the importance of STEM "so that students can firsthand see the connections between the things they are learning" (GR, Participant 11). Realizing the value of STEM as a foundation, one participant shared that the "aspects of STEM interconnect with each other through various ways and hold a foundation needed for further, advanced STEM skills" (Participant 2).

4.11.2. Increased Confidence in Planning and Designing Integrated STEM Lessons

Participants indicated increased confidence in planning and designing Integrated STEM lessons, as evident in the growth reflections and post-open-ended responses. As one participant wrote, "I didn't realize how easy it is to incorporate different parts of STEM into a lesson plan or activity that is understandable to students" (Participant 3). Several participants credited experiences within the STEM Block for enhancing their understanding of how different subjects are integrated into one lesson, as one participant mentioned,

> Before this semester, STEM classes were individual and lived on their own, separately. Math was math, and science was science, and they just stayed that way. This semester really taught me that these classes can join forces to create a really successful lesson. I feel confident in my ability to integrate all of these subjects into one lesson effectively, more so than before". (GR, Participant 13)

Initially, participants viewed STEM teaching as difficult and something that involves expensive materials. At the end of the semester, many participants mentioned that the Integrated STEM project was an eye-opener that changed their attitude about designing a STEM lesson. As Participant 7 mentioned, "Before doing this project, I had no idea how to integrate STEM all together into a lesson and this project really opened my eyes. I think this project made me realize that integrating these subjects together isn't as difficult as I thought it would be" (GF).

The participant further elaborated how their group collaboration led to integrating the four STEM disciplines to problem-solve using an engineering design to create a roller coaster, using scientific and mathematical skills to calculate the speed of the marble, and utilizing robotic technology (rolling robots). As the participant wrote, "For example, when we were trying to figure out how to find the speed of the marble going down the rollercoaster I made, I had to use my problem-solving skills to find what math equation I needed to use to find the speed of the marble. One of my ideas was using a little rolling robot to collect data to find our speed" (GR, Participant 7). Contrary to the beginning of the semester, participants realized that there are resources to support designing effective STEM instruction in the future, most of which can come in handy to engage students in STEM. As one participant shared, "It [designing STEM activity] does not cost more, there are a lot of resources out there that can be used or can be modified. I think with engineering you can use a lot of household appliances or stuff you have laying around the house. Or, even if you were to go outside for something, you could look through the dollar section or you can get it for very cheap" (GR, Participant 5).

4.11.3. Importance of Integrated STEM for ALL Learners

At the beginning of the semester and as noted in the previous section, some participants had a stereotypical view of STEM being a privilege for some and not accessible to all. After engaging with the integrated STEM semester, a positive shift in participants' perceptions was noted, as the participant wrote, "STEM is critical for all students, not just left-brain individuals and males" (Participant 26). Another participant shared: "[STEM is] especially important for all students, but especially young girls and racially diverse students who may feel excluded" (Participant 8). A similar notion was expressed by another participant suggesting the importance of STEM for women:

> Considering I am a woman and women make up the minority in STEM, it is important to emphasize, even for girls who doubt due to societal norms, STEM isn't a scary thought that should turn you away but a fun challenge, easy to implement into a classroom. (Participant 4)

Positive experiences within the STEM semester allowed participants to value Integrated STEM for K-5 teaching and "see" themselves in that role in the future, as one participant wrote, "combining these [STEM] topics allows for an even richer learning experience for students. One of my goals as an educator is to seize the opportunity to integrate STEM topics in order to make learning more engaging and impactful for my students" (Participant 6). Another participant explicitly talked about the importance of and emphasis on real-world STEM connections, and that STEM lessons can provide young children "a variety of learning opportunities put together to teach new perspectives" (Participant 7). Participants shared that STEM helps students build skill sets for the future as STEM allows "students and educators to get creative with their work. They get to think, build, be a leader, try new things, and learn" (Participant 11). Another participant emphasized the integration of STEM when the "four different pillars [referring to Science, Technology, Engineering, and Mathematics] need to come together and be integrated so that students can develop skills and an interest in STEM that can help them understand how our world works and how to adapt to it" (Participant 14).

5. Discussions

This study contributes to the field's understanding of how PSTs can be supported in teacher preparation programs to develop the necessary knowledge and skills on integrated STEM teaching and learning. The primary goals of this study were to investigate (1) PSTs' integrated STEM teaching self-efficacy and (2) conceptions of STEM teaching and learning during their participation in three concurrent methods courses that are part of the STEM semester. The results of the study strongly suggest significant positive gains in integrated STEM self-efficacy from the beginning to the end of the semester. The trends from the qualitative analysis also provide evidence of positive shifts in PSTs' conceptions and attitudes about STEM from the beginning to the end of the semester. Prior studies have suggested the impact of disciplinary backgrounds on preservice teachers' views and conceptions about STEM [27,49]. Unsurprisingly, we found that participants' prior experiences influenced their initial perceptions of STEM at the beginning of the semester.

Given that many PSTs' prior exposure to STEM learning was limited, it makes sense that several PSTs had naïve conceptions of STEM at the start of the STEM semester [102].

Evidence suggests that course experiences within the STEM semester helped participants to become more comfortable and confident in planning and designing STEM lessons, as well as increased intentions to teach STEM topics in the future. These findings concur with other studies in the field that suggest improved preservice teachers' conceptions of STEM in teacher preparation programs [28,37,48,59]. Notably, exposure to STEM experiences within the three concurrent methods courses helped preservice teachers reach a better understanding of how different disciplines work together in an integrated STEM lesson. We adhered to [57]'s notion that integrated STEM should promote "the application of knowledge and practices from multiple disciplines to learn about or solve transdisciplinary problems" (p. 221). That said, we realize that it may have been difficult for preservice teachers to conceptualize STEM in one semester, especially when methods courses might be their first exposure to explicitly integrated STEM teaching and learning.

For this present study, it is important to note that the team of STEM educators came together on a regular basis to discuss and co-design the STEM pathways and curriculum across the three methods courses (science, mathematics, and technology). It appears that having a similar discourse about integrated STEM across the three parallel-running methods courses provided a suitable context to bring positive changes in conceptions and self-efficacy for integrated STEM. As [103] asserted that STEM integration is complex, it is important that preservice teachers engage in the discourse surrounding STEM pedagogies across multiple courses to understand the interconnectedness between disciplines. Discourse could also focus on "agency and shifts in power structures" [83] inherent to implementing STEM in elementary classrooms. Based on the findings, we strongly recommend establishing strong partnerships between multi-disciplinary STEM education faculty, as such an approach could be fruitful in designing authentic STEM experiences. That said, we also acknowledge the challenges associated with developing partnerships among experts from multiple STEM education disciplines, including but not limited to constraints such as time investment, scheduling conflicts, varied departmental culture and norms, availability of resources, and administrative support [22,83,104].

While the results indicating positive changes in integrated STEM teaching efficacy are promising, it is important to note that participants did not teach their STEM lessons in formal settings (K-6 classrooms). However, based on the results, we contend that improved levels of self-efficacy may support PSTs' smooth transition into their student teaching the following semester. With more established ideas about the importance and value of integrated STEM teaching and learning in K-6 classrooms, PSTs are more likely to translate their knowledge and skills learned in the STEM semester into future classroom practices. Considering prior studies have noted various challenges that teachers face during the implementation of STEM within classrooms [49,105], longitudinal studies are needed to explore whether and how integrated STEM teaching self-efficacy is maintained during field experiences and early years of teaching. Possibilities for further research could also include studies that continue to explore factors that influence PSTs' integrated STEM teaching self-efficacy, especially during field experiences (for example, mentor teacher support and role modeling STEM, school STEM culture, time, and resources).

One interesting finding from the study was that at the beginning of the semester, PSTs considered STEM as a "privilege" and believed that boys in general are more successful in STEM-related careers than girls. Other studies have also noted various stereotypes associated with STEM such as gender equity and other biases related to STEM including negative perceptions about women in the engineering profession [19,105,106]. Towards the end of the semester, we found positive changes in PSTs' perspectives about STEM learning including more positive attitudes towards encouraging young girls in STEM. While the results may imply that positive STEM experiences allowed for perceptions to change, more research is needed to understand how these beliefs translate to practice. In other words, longitudinal research is warranted to understand how PSTs support young learners, especially girls, in their future classrooms. An important implication is that PSTs need additional practice and support before they feel equipped with strategies for equitable STEM teaching [19]. We also recommend developing partnerships with schools where field experiences could be part of the integrated STEM semester. Vicarious experiences such as observing positive role models (such as classroom teacher mentors) supporting young learners in STEM could be important contributors towards PSTs' STEM teaching self-efficacy.

6. Limitations

This study has limitations. First, the structure of the STEM semester is unique, and we acknowledge that not all institutions may have a similar design. Therefore, the findings of this study are specific to our STEM semester and may not be replicable in programs with different contexts and structures for supporting PSTs' STEM teaching and learning. Other major limitations relate to the instrument used in this study. Prior to this study, we had investigated PSTs' self-efficacy, beliefs, and knowledge for technology [107], science [108], and mathematics [109]. While published validity and reliability studies exist for these instruments, they did not capture PSTs' self-efficacy for integrated STEM. Fewer instruments currently exist for measuring this construct, with SETIS being one of the only options with published validity and reliability studies. However, the SETIS scale was validated using exploratory factor analysis, and coefficient alpha values for the pre- and post-test of the SETIS instrument were reported as greater than 0.90 [90], suggesting possible item redundancy. Additional research on the SETIS scale's validity and reliability that employs confirmatory factor analysis or item response theory is not yet available but would strengthen what is currently a limitation of this study. The possibility of testing effects from the pretest–post-test design in this study is an additional limitation. Since all participants in this study were required to complete the same coursework in the STEM Semester structure, a control group design was not practical. While findings from this study suggest positive gains in integrated STEM self-efficacy throughout the semester, future research using a counter-balanced research design to compare across multiple programs would strengthen this study's findings.

7. Conclusions and Implications

The results from this study provide evidence of positive shifts in PSTs' self-efficacy and attitudes regarding integrated STEM after their participation in the STEM semester. The findings of the study suggest the importance of explicit STEM instruction in an integrated way, unlike the traditional silo approach. The study has important implications for preservice teacher preparation programs and future research. First, considering the increasing demand for integrated STEM instruction, it is vital that STEM educators realign their programs to include explicit learning opportunities to promote PSTs' knowledge, skills, and dispositions in STEM. Second, in order to ensure a desired change in perceptions about STEM, it is important that PSTs observe integrated STEM instruction and practice teaching it during field experiences. It is not uncommon that preservice teachers may consider STEM as a "paradigm shift" and may be reluctant to teach it unless they "see" authentic integrated STEM instruction in classrooms. Realizing that it could be challenging and may depend on school culture, teacher educators must involve PSTs in explicit discussion around the current status of integrated STEM and the associated challenges. Third, while significant positive shifts in this study seem promising, future research may consider investigating self-efficacy in the long term over multiple semesters. A majority of our participants were homogeneous (young white women); future research could include a more heterogeneous group of participants to understand how varied backgrounds and other demographics impact self-efficacy development.

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Informed Consent Statement: All participants gave their informed consent for inclusion before their participation in the study.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

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