Science-Major Pre-Service Teachers' Experiences and Challenges in Teaching Integrated STEM (Science, Technology, Engineering, and Mathematics)

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ABSTRACT

Integrated science, technology, engineering, and mathematics (STEM) instruction asks teachers to connect ideas and practices across disciplines. For pre-service teachers whose preparation is concentrated in science, planning such lessons may be challenging. This descriptive qualitative study explored how science-major pre-service teachers understood integrated STEM and what difficulties they anticipated or experienced when planning and teaching it. Ten fourth-year science-major pre-service teachers from the College of Education at Nueva Ecija University of Science and Technology, selected through convenience sampling, completed a questionnaire containing seven five-point rating statements and five open-response questions. The researchers analyzed written answers through reflexive thematic analysis and summarized rating responses descriptively. Six participants described STEM as bringing the four disciplines together, and five connected integration with solving real-world problems; four responses reflected broad or incomplete understandings. The most frequently reported difficulty was connecting engineering and mathematics with science content (six participants). Other concerns included limited instructional time (two participants) and the possibility that students might become confused or lose interest (three participants). Mean ratings ranged from 3.40 to 4.20, with confidence in planning STEM lessons receiving the lowest mean. Four participants reported having taught or practiced teaching a STEM lesson, and two had completed STEM-specific training. Participants commonly requested further training, teaching resources, lesson examples, and mentoring. The findings suggest the value of giving future science teachers guided, practical opportunities to plan, teach, and reflect on lessons that meaningfully connect STEM disciplines. Because the sample was small and drawn from a single institution, the findings describe this group and are not generalizable.

Keywords: integrated STEM education; pre-service science teachers; teacher preparation; pedagogical content knowledge; qualitative study

INTRODUCTION

STEM education is often presented as an approach that brings science, technology, engineering, and mathematics into a shared learning experience. In practice, however, placing the four subjects in the same activity does not necessarily mean that they are meaningfully integrated. Kelley and Knowles (2016) proposed a framework for understanding how the disciplines can support one another, while Breiner et al. (2012) documented the range of meanings that educators and partners attach to STEM. The quality of integration can also vary. Roehrig et al. (2021), for example, identified curriculum units in which engineering design had only a loose relationship with science content alongside units with stronger disciplinary coherence.

Teachers therefore need more than accurate knowledge of their own subject. They must decide which concepts from other disciplines serve the learning goal and how students can use those concepts in a connected task. Shulman's (1986) account of pedagogical content knowledge (PCK) is relevant here because it emphasizes the transformation of subject matter into forms that learners can understand. Research on teacher knowledge continues to examine relationships among content knowledge, pedagogical knowledge, classroom practice, and

student learning (Gess-Newsome et al., 2019). In integrated STEM lessons, these demands extend across disciplinary boundaries.

Research has repeatedly identified barriers to STEM integration. Margot and Kettler's (2019) review grouped teachers' concerns around pedagogy, curriculum, school structures, student learning and assessment, and

access to support. Teachers have also reported interest in STEM approaches while feeling insufficiently prepared to implement them (Shernoff et al., 2017). Nadelson et al. (2013) found that inquiry-oriented professional development could strengthen teachers' confidence and efficacy. Classroom-based studies likewise describe challenges in deciding how science and engineering should work together and in sustaining student engagement (Dare et al., 2018). Teachers from different STEM backgrounds may also interpret integration differently and recognize the need to strengthen their knowledge beyond their original discipline (Wang et al., 2011).

These issues matter in teacher education, where pre-service teachers are still developing the knowledge and practical judgment needed for classroom instruction. Studies have examined pre-service teachers' conceptions of STEM and have found that their understanding of the disciplines does not always reflect a connected approach (Hacioglu & Yamak, 2016; Radloff & Guzey, 2016). Kurup et al. (2019) also reported that future primary teachers could express positive intentions toward STEM despite having an incomplete understanding of it. Professional learning may help shift these conceptions over time (Ring et al., 2017), but teacher educators first need to understand what future teachers currently know and where they need support.

The present study focuses on science-major pre-service teachers and their own descriptions of integrated STEM. It considers their definitions, experiences, concerns, confidence, and requests for support. The study was guided by two questions:

1. How do science-major pre-service teachers understand integrated STEM teaching?
2. What challenges do they encounter or anticipate when planning and teaching STEM lessons?

REVIEW OF RELATED LITERATURE

Understanding integration across STEM disciplines

Integrated STEM is intended to create purposeful connections among disciplines rather than simply placing separate activities beside one another. Kelley and Knowles (2016) emphasize the relationships among disciplines in addressing meaningful problems. Breiner et al. (2012), however, show that STEM does not have one universally shared interpretation. This matters for teacher preparation: if teachers define integration mainly by naming the four subjects, they may need additional support to explain how the disciplines contribute to a common learning goal.

Curriculum research reinforces this distinction. Roehrig et al. (2021) found different degrees of coherence across integrated STEM units, including examples where engineering design was weakly linked to science concepts. Such findings suggest that integration is not guaranteed by using a STEM label; lesson designers must deliberately connect the content, practices, and tasks.

Teacher knowledge, confidence, and professional support

Integrated teaching calls for teachers to select and explain content across subject areas while keeping the central learning objective clear. Shulman's (1986) concept of PCK provides a useful lens for understanding this work: teachers need to know both the subject matter and ways to make it accessible to learners. Gess-Newsome et al. (2019) further examine how teacher knowledge relates to practice and student achievement. For a science-major pre-service teacher, this can mean deciding when mathematical calculations or engineering design will deepen a science concept rather than distract from it.

Teachers' confidence and preparation are also shaped by opportunities to practice. Bandura (1997) identifies mastery experiences as an important source of self-efficacy. In teacher education, supervised planning,

teaching, feedback, and revision may provide such experiences. Nadelson et al. (2013) reported improved confidence and efficacy following inquiry-based STEM professional development. Effective professional learning also benefits from active engagement, a clear content focus, coherence, sufficient duration, and opportunities for collective participation (Desimone, 2009). These ideas help explain why participants may value training, ready-to-use materials, mentoring, and time to plan with colleagues.

Challenges reported by teachers and pre-service teachers

Studies of practicing teachers identify pedagogical and structural barriers, concerns about students, and a need for stronger curriculum resources and professional development (Margot & Kettler, 2019). Dare et al. (2018) describe difficulties with the extent of integration and with decisions about science and engineering during instruction. Among pre-service teachers, research has found that disciplinary knowledge may remain compartmentalized and that confidence or positive intentions do not always correspond to a detailed understanding of STEM (Hacıoğlu & Yamak, 2016; Kurup et al., 2019). The current study adds a small, context-specific account of how science-major pre-service teachers describe these issues.

METHODOLOGY

Research Design

A descriptive qualitative design was used to document participants' understandings and reported experiences. The questionnaire included open-ended questions as the primary source of qualitative information. Seven rating statements were also included to provide descriptive context for participants' views and confidence. These ratings were not used for inferential statistical testing.

Participants and Sampling

The study population consisted of 10 fourth-year Bachelor of Science students majoring in Science at the College of Education, Nueva Ecija University of Science and Technology, during SY 2026-2027, First Semester. Participants were selected through convenience sampling. Students who were currently deployed for field study in partner schools were invited by through the practicum coordinator. Inclusion criteria were (a) enrollment as a fourth-year science major, (b) participation in field-study deployment, and (c) willingness to give written informed consent. Ten agreed to take part, and all ten returned completed questionnaires.

Convenience sampling was chosen because these students were accessible and had direct experience with teacher preparation and classroom placement, which allowed them to speak to the research questions. Because participants were not selected to represent all pre-service science teachers, the findings are intended to describe this group in depth, not to be generalized to other institutions. The idea of information power offers one way to consider sample adequacy in qualitative work (Malterud et al., 2016): the study aim was narrow, and participants shared the characteristic of interest. At the same time, the brevity of the written answers reduced the information each participant could provide, a point addressed in the Limitations. Participants are identified as P1 through P10.

Data Collection

Data were collected from [September 7 to 14, 2026 using a questionnaire. Two yes/no items asked whether participants had taught or practiced teaching a STEM lesson and whether they had completed a course or training related to STEM teaching. Seven statements were rated from 1 (strongly disagree) to 5 (strongly agree) and addressed participants' understanding and confidence. Five open-response questions asked participants to (Q1) define integrated STEM; (Q2) describe a lesson they had planned, taught, or observed; (Q3) identify the hardest part of incorporating engineering and mathematics into a science lesson; (Q4) explain their role as a teacher during STEM activities; and (Q5) identify the support that would help them teach STEM more effectively.

Data Analysis

Responses to Q1 and Q2 were used to answer Research Question 1 (understanding of integrated STEM). Responses to Q2 through Q5 were used to answer Research Question 2 (challenges, anticipated difficulties, and support needs). Q2 contributed to both questions because lesson descriptions showed both what participants understood and what they had attempted.

The open-ended responses were analyzed using reflexive thematic analysis (Braun & Clarke, 2019) in six phases: (1) familiarization through repeated reading of all responses; (2) initial coding of each responses; (3) generating candidate themes by grouping related codes; (4) reviewing themes against the coded data and the full set of responses; (5) naming and defining themes; and (6) writing the analysis. Coding was inductive, so codes came from participants' wording and not from a preset list. Because answers were short, coding was applied at the level of a whole response or meaningful phrase, and unfinished or ambiguous answers were coded as incomplete and not interpreted beyond what was written.

Themes were not mutually exclusive: one participant's answer could contribute to more than one theme, so counts across themes exceed ten. Participant counts show how often an idea appeared and do not imply that more frequent themes are necessarily more important. Appendix A records the participant-level coding so readers can trace each theme to the responses that support it. Rating responses were summarized using counts, ranges, and means only; no inferential tests were performed, and subgroup means (with and without teaching practice) are reported for description.

Trustworthiness and Ethical Considerations

Several steps supported the trustworthiness of the analysis. The researchers kept a brief reflexive note about assumptions arising from their backgrounds as science educators. The coding record in Appendix A provides an audit trail linking responses to themes. Themes were checked against the full set of responses, and illustrative participant statements are given in the Results.

Participation was voluntary and did not affect course grades. Written informed consent was obtained, and participant codes replaced names. Questionnaire responses were stored and will be deleted after the study. The study received ethical clearance.

RESULTS AND DISCUSSION

Participant Background and Experience

Of the ten participants, four (P1, P5, P7, and P10) reported having taught or practiced teaching a STEM lesson. Two (P5 and P7) indicated that they had completed a course or training specifically related to STEM teaching. In the open-ended responses, seven described a lesson they had planned or used, two described observing a STEM-type lesson, and one reported no experience yet. The yes/no item and the lesson description were answered separately, so the two do not always match. P5 answered "yes" to teaching practice, but the lesson described in the written answer was observed. P2, P3, and P8 answered "no" to the yes/no item, yet described lessons in which students were engaged in activities; [explain from your records, for example, that these lessons were planned, used during practicum, or taught outside formal STEM teaching]. Subgroup results below follow the yes/no answers.

Table 1. Participants' background and experience

Participant	Taught/practiced STEM	STEM course/training	Lesson described
P1	Yes	No	Planned a bird-parts activity
P2	No	No	Students built and tested paper bridges in teams
P3	No	No	Electromagnetic waves; students were interested but confused

P4	No	No	Observed an experiment with full participation
P5	Yes	Yes	Observed a lesson using videos
P6	No	No	No experience yet
P7	Yes	Yes	Hands-on activities for exploration and problem-solving
P8	No	No	Hands-on lesson with active participation
P9	No	No	Planned a water-filtration prototype
P10	Yes	No	Lesson focused on science and technology

Research Question 1: How participants understood integrated STEM

Three themes were identified from the responses to Q1, with Q2 used to add context. Themes were not mutually exclusive, so counts total more than ten.

First, six participants described STEM as a combination of science, technology, engineering, and mathematics. Their answers showed awareness of the four subject areas, but they did not always explain how the disciplines would work together within a lesson. P4, for example, described STEM as learning the four areas together. P3 added that the combination could help students understand concepts and apply them to real-life situations.

Second, five participants connected STEM integration with solving everyday or real-world problems. P1 described the approach as using different subjects to address real-life problems, while P10 referred to it as a connected way of solving a problem. These answers suggest that some participants saw a practical purpose for integration beyond simply naming the four disciplines.

Third, four participants gave broad or incomplete definitions. P7 mentioned science, technology, and mathematics but omitted engineering, even though P7 was one of two participants who had completed STEM-specific training; with only two trained participants, this is an observation and not evidence that training does not help. P6's answer was unfinished and did not clarify how the subjects were connected. [Identify the remaining participants in this theme and, for P10, confirm that the Q1 definition itself, and not only the lesson described, was incomplete.] By contrast, P9 described integration as breaking down the traditional boundaries among the four disciplines, a more relational understanding of STEM. P10's lesson, which focused mainly on science and technology, is noted separately in Table 1 and was not used to judge P10's definition.

Taken together, the responses reflect the varied meanings of STEM reported by Breiner et al. (2012). They also resemble findings that pre-service teachers may have difficulty seeing the disciplines as connected areas of learning (Hacioglu & Yamak, 2016; Kurup et al., 2019). The results should not be interpreted as evidence that participants cannot teach integrated STEM; rather, their answers indicate areas where more explicit practice and discussion may be useful. Ring et al. (2017) found that teachers' conceptions can shift during professional development, suggesting that initial definitions can be developed through guided learning.

Research Question 2: Challenges in planning and teaching STEM

The most frequently reported challenge was connecting engineering and mathematics with science content, mentioned by six participants (P4, P5, P6, P7, P8, and P10). P4 described the difficulty as finding a simple way to connect engineering and mathematics to a science lesson. P7 referred to the challenge of fitting different formulas into an accessible lesson. Some responses were incomplete but still identified integration itself as a difficulty. Overall, participants appeared to be looking for practical ways to make cross-disciplinary connections without losing sight of the science concept.

This concern is consistent with the role of PCK described by Shulman (1986) and later work on teacher knowledge (Gess-Newsome et al., 2019). Planning an integrated lesson involves deciding which ideas and practices from other fields genuinely support the learning objective. The current study did not directly measure participants' content knowledge or PCK, so this interpretation should be treated as a possible explanation and not a demonstrated cause. The difficulty also echoes Wang et al. (2011), who noted teachers' awareness of the

need for additional knowledge when integrating STEM, and Dare et al. (2018), who documented challenges in balancing science and engineering.

A second challenge was limited classroom time, raised by two participants. P2 was concerned about fitting mathematical calculations and the design process into a lesson without rushing the science content. P9 similarly referred to having insufficient time to cover everything. Time was also reflected in participants' requests for more planning opportunities and collaboration. This aligns with research that identifies structural

and curriculum-related barriers to integrated STEM (Margot & Kettler, 2019).

The third theme concerned students' understanding and interest, raised by three participants. P1 emphasized explaining difficult concepts in simple terms, while P3 wanted activities that would help students become interested in a topic. P3's example of an electromagnetic-waves lesson captured the tension: students found it interesting but also confusing. P10 worried that including engineering and mathematics could create confusion. These concerns are consistent with Dare et al. (2018), whose participants discussed student engagement and motivation when implementing integrated STEM.

Support Needs and views of the Teacher's Role

Seven participants requested additional training, and seven asked for teaching resources, materials, or ready-made lesson plans. Four mentioned mentoring, guidance, or collaboration. Their responses indicate a preference for support that is both practical and connected to classroom work. Participants generally described the teacher's role as guiding or facilitating learning rather than simply delivering information. P9 called the teacher a guide and facilitator rather than a lecturer; P2 described a teacher who asks questions and allows students to work through problems.

These requests are broadly consistent with Margot and Kettler's (2019) review, which identified collaboration, quality curriculum resources, and professional development as useful forms of support. Desimone (2009) also highlights active learning and collective participation as features of effective professional development. From a self-efficacy perspective, opportunities to plan and teach lessons with feedback may be especially useful because mastery experiences can help build confidence (Bandura, 1997).

Comparison With Previous Studies

The present findings agree with previous work in several respects but differ in others. First, the finding that some participants named the four disciplines without explaining how they connect is consistent with studies of pre-service teachers whose understanding of STEM was compartmentalized or incomplete (Hacıoğlu & Yamak, 2016; Kurup et al., 2019). It also fits the broader observation that STEM has no single shared meaning (Breiner et al., 2012). However, P9's relational definition shows that not all participants held a narrow view, so the group should not be described as uniformly limited.

Second, the most common challenge, connecting engineering and mathematics to science, echoes the difficulty in deciding how science and engineering should work together reported by Dare et al. (2018). Their participants were practicing teachers implementing curriculum units, whereas ours were pre-service teachers anticipating or beginning to plan lessons, so the difficulty appears to be shared across career stages, though its source may differ. Because content knowledge and PCK were not measured, we cannot say whether the difficulty reflects limited knowledge of engineering and mathematics, limited experience designing integrated tasks, or both.

Third, time was raised by only two participants. Reviews of practicing teachers describe school structures and time as prominent barriers (Margot & Kettler, 2019). One possible explanation is that pre-service teachers have less responsibility for pacing and curriculum coverage than in-service teachers; another is that the open-ended question focused on engineering and mathematics and may not have prompted comments about time. Assessment, which is also a theme in the Margot and Kettler review, did not appear in the data, possibly for the same reason.

Fourth, participants' ratings were generally positive while their written definitions were sometimes incomplete. A similar gap between positive intentions and incomplete understanding was reported by Kurup et al. (2019). Self-reported ratings may overstate understanding, particularly when respondents have limited experience with the topic, and without interviews or observations it is not possible to determine which source better reflects participants' views.

Finally, participants' requests for training, resources, and mentoring match what teachers elsewhere report (Margot & Kettler, 2019; Shernoff et al., 2017). The contribution of this study is therefore not new categories of challenge but a small, context-specific account of how science majors in one teacher education setting describe them, which can inform local methods courses.

Questionnaire Ratings

Across the 70 ratings, responses ranged from 3 to 5; no participant selected a disagreement response. Comfort with allowing students to lead problem-solving received the highest mean (M = 4.20), with nine participants agreeing or strongly agreeing. Understanding the role of mathematics in a science lesson had a mean of 4.10, and all ten participants agreed or strongly agreed. By comparison, confidence in planning STEM lessons received the lowest mean (M = 3.40), with six participants selecting the neutral response. The ability to explain integrated STEM had a mean of 3.50, with five neutral responses. Understanding the role of engineering received a mean of 3.70.

Eight participants agreed that their teacher education program had prepared them for STEM teaching (M = 3.90), although seven still requested further training. This suggests that a positive view of general preparation can coexist with uncertainty about planning specific integrated lessons. Only two participants reported STEM-specific training, so their views of program preparation may have reflected teacher education more broadly; the questionnaire did not directly investigate this possibility.

Participants who reported having taught or practiced a STEM lesson (n = 4, including P5) had higher average confidence in planning (M = 3.75) and teaching (M = 4.00) than those without that experience (n = 6; M = 3.17 and M = 3.33, respectively). Because the groups were very small, this is a descriptive pattern only. It cannot establish that teaching practice caused greater confidence, and the groups may differ in other ways that were not measured. The pattern is nevertheless compatible with Bandura's (1997) emphasis on mastery experiences and with Nadelson et al.'s (2013) findings on confidence following inquiry-based STEM professional development.

Implications for Teacher Education

Three practical implications follow from the findings, with the caution that they rest on a small sample. First, science methods courses could give pre-service teachers repeated opportunities to design short engineering tasks and appropriate mathematical components that support specific science concepts. Second, teacher educators could provide sample lessons, adaptable teaching materials, and scheduled time for collaborative planning with peers or experienced teachers. Third, candidates could plan and teach integrated lessons under supervision, receive constructive feedback, and revise their plans. These activities address the challenges and support needs that participants described.

LIMITATIONS

Several limitations should be considered when interpreting the findings. First, the sample comprised ten fourth-year science majors from one university, selected by convenience. The findings describe this group and cannot be generalized to other pre-service teachers, programs, or regions; readers must judge transferability to similar contexts using the descriptions provided. Second, because the sample was small, participant counts should be read as descriptive, and subgroup comparisons are suggestive only. Third, data came from a single questionnaire at one point in time. Written answers were brief, some were unfinished, and no interviews were conducted to clarify them, so interpretations of meaning, especially for incomplete definitions, remain tentative. The questionnaire also did not capture changes in understanding or confidence over time. Fourth, all

data were self-reported. Ratings and descriptions reflect participants' perceptions and not observed teaching performance, and ratings sometimes appeared more positive than the completeness of written definitions. Fifth, the study did not measure participants' content knowledge or PCK, so explanations linking challenges to PCK are interpretive. Future studies could use interviews, lesson-plan analysis, classroom observation, or longitudinal designs with larger and more varied samples to compare stated understanding with demonstrated planning and teaching.

SUMMARY

This study examined how ten science-major pre-service teachers understood integrated STEM and what challenges they described in relation to planning and teaching STEM lessons. Participants most often defined integration as combining the four disciplines or using them to solve real-world problems. Some definitions remained general or incomplete. The most common difficulty was linking engineering and mathematics with science content, followed by concerns about lesson time and student understanding or interest. Participants requested training, resources, lesson plans, mentoring, and opportunities to collaborate. Ratings were generally positive, but confidence in planning integrated lessons was comparatively low. These findings describe a small, single-institution sample.

CONCLUSION AND RECOMMENDATION

The participants showed awareness of the purpose and disciplinary scope of integrated STEM, but their responses suggest that understanding how the disciplines connect remains a key area for development. Their concerns, as expressed in brief written responses, were practical: they wanted to know how to incorporate engineering and mathematics without making science lessons confusing or unrealistic within available class time. Although many viewed their teacher education program positively, their requests for further support suggest that general preparation may not be sufficient for these participants to feel confident in integrated lesson planning.

Teacher education programs should therefore consider combining conceptual discussion of STEM integration with hands-on lesson design, collaborative planning, supervised teaching, and feedback. Access to adaptable examples and mentoring may help pre-service teachers see how mathematics and engineering can contribute meaningfully to science learning. Further research should involve a larger and more varied sample and include interviews, classroom observations, and analysis of lesson plans. Following pre-service teachers through a STEM methods course could also help clarify how their definitions, planning skills, and confidence change over time.

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APPENDIX A. THEME-BY-PARTICIPANT CODING

A check mark indicates that the participant's response was coded under the corresponding theme or support category. RQ1: 1a = four disciplines combined; 1b = real-life problem-solving; 1c = general or incomplete understanding. RQ2: 2a = connecting engineering and mathematics to science; 2b = limited time; 2c = concern about students. Support: Tr = training; Ma = materials or lesson plans; Mn = mentoring, guidance, or collaboration.

Code	1a	1b	1c	2a	2b	2c	Tr	Ma	Mn
P1		✓	✓			✓	✓		✓
P2	✓	✓			✓		✓	✓	
P3	✓	✓				✓	✓	✓	
P4	✓			✓			✓	✓	
P5	✓			✓				✓	
P6				✓	✓			✓	
P7				✓	✓		✓		✓
P8	✓	✓		✓			✓	✓	✓
P9	✓				✓			✓	✓
P10		✓	✓	✓		✓	✓		