2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #51713

The Role of Professional Learning Experiences in Equipping K-12 Teachers for Interdisciplinary Engineering Integration: A Case Study of One High School Engineering Project

Dorothy Decontee Gocol, Florida International University

Dorothy Decontee Gocol is a PhD student at Florida International University, College of Engineering. And a Graduate Research Assistant at the Department of Multidisciplinary Engineering and Computing Education, Systems and Management

Dr. Monica E. Cardella, Florida International University

Monica E. Cardella is the Chair of the Multidisciplinary Engineering and Computing Education, Systems and Management (ESM) department at Florida International University. She is also a Professor of Engineering and Computing Education in ESM and FIU's STEM Transformation Institute

Abstract

K-12 STEM instruction increasingly emphasizes interdisciplinary learning that integrates science, mathematics, and engineering to address real-world problems. This study examined how a structured professional learning experience influences high school teachers' beliefs, perceptions, and instructional practices related to engineering integration. Grounded in Constructivist Learning Theory and Social Cognitive Theory, the study draws on a qualitative case study of two marine science educators who participated in a professional learning experience workshop. Data were collected through semi-structured interviews and analyzed using thematic analysis to capture participants lived experiences. Findings indicate that sustained, hands-on professional learning enhanced participants' pedagogical innovation, increased their use of engineering design, and strengthened their self-efficacy in integrating engineering into science instruction. This indicates the importance of experiential and ongoing professional learning experiences in supporting teachers' capacity to implement interdisciplinary engineering instruction. These results suggest that well-designed professional development can serve as a catalyst for meaningful instructional change and more integrated STEM learning environments in K-12 education.

Keywords: Professional Learning / Professional Development (PD), Interdisciplinary Engineering Integration, K-12 STEM Education, Non-Engineering Educators

Introduction

In today's rapidly evolving educational landscape, K-12 education increasingly emphasizes learning that prepares students to apply knowledge across different subjects and engage with problems. Within this context, the integration of engineering concepts into K-12 classrooms has gained prominence to connect science, mathematics, and technology through problem-based learning experiences. However, for interdisciplinary engineering integration to be effective at the K-12 levels, teachers, many of whom do not have formal training in engineering, must be adequately prepared to teach beyond traditional disciplinary boundaries. Professional learning experiences (sometimes referred to as professional development) play a critical role in supporting K-12 teachers as they navigate this shift.

Teacher professional learning experiences include activities that help individuals build, update, and strengthen their knowledge, skills, and professional practice throughout their careers [12],[8]. Well-designed professional learning experiences can equip teachers with pedagogical tools, content understanding, and confidence needed to integrate engineering concepts into their instruction, foster interdisciplinary connections, and design meaningful learning experiences for students. Teacher's professional learning experiences can also create opportunities for teachers to collaborate, reflect on their practice, and adapt engineering ideas in ways that are developmentally appropriate and aligned with K-12 curricular goals. However, there are fewer studies that have examined how Professional development supports teachers in navigating interdisciplinary integration across engineering science, and contextualized learning environments [17],[22],[23]. Based on this, our study asks: How do professional learning experiences influence teachers' beliefs, perceptions, and reported practices regarding interdisciplinary engineering integration in high school classrooms?

While this study is grounded in existing literature, it moves beyond a traditional literature review by presenting an empirical qualitative analysis of teachers lived experiences within a professional learning context.

The section that follows begins with a review of relevant literature, methods, data analysis, findings, and recommendation. Through this structure, we share light on how structured professional learning experiences can equip educators to effectively implement interdisciplinary engineering practices, thereby fostering more

Literature Review

The growing emphasis on STEM education in K-12 settings has led to an increased integration of engineering concepts within science and mathematics curricula. This shift reflects broader educational goals aimed at preparing students to solve complex, real-world problems through interdisciplinary thinking. However, it also places new demands on teachers, many of whom have limited formal preparation in engineering and are expected to design and facilitate authentic engineering learning experiences.

Professional learning experiences have therefore become critical mechanisms for supporting teachers in this transition [8],[19]. Research suggests that effective PD not only strengthens teachers' content knowledge but also enhances pedagogical skills, instructional confidence, and the ability to integrate engineering concepts alongside science and mathematics [25],[26]. A range of PD approaches has been documented, including workshops, summer institutes, and sustained in-school coaching, all aimed at improving instructional practice and student learning outcomes [6],[16].

Despite this growing body of research, important gaps remain. Fewer studies have examined how professional learning experiences support teachers in navigating interdisciplinary integration, particularly in bridging engineering design, scientific principles, and contextualized learning experiences [6],[16]. In addition, limited attention has been given to how PD fosters teachers' collaborative practices, reflective capacity, and professional agency during the implementation of integrated engineering instruction [8],[19]. Addressing these gaps is critical for designing professional learning experiences that meaningfully support teachers without engineering backgrounds in delivering authentic, interdisciplinary K-12 engineering instruction.

The Importance of Professional Development in STEM and Engineering Education

Educators have direct influence over students' learning; therefore, it is important to invest the necessary resources to help them provide the best quality STEM education for their students.
This is attainable through professional learning experiences which serve as opportunities for teachers to gain tools that support instructional practices that create environments of confidence, and adaptability [7][39]. Teacher professional learning experiences can create opportunities for educators with no knowledge in certain fields to learn about the fields and effective ways to integrate various topics, including engineering design into their teaching and learning environments, which supports innovative, student-centered learning strategies [40]. For example, Brown and Bogiages [4] found that STEM professional development programs that go beyond one year, providing sustained training, support, and opportunities for practice, were effective in improving the knowledge, skills, and confidence of early-career secondary school science and mathematics teachers.

Integrating professional learning into consideration of school needs allows professional learning experiences to be designed in ways that meet the school culture and curricula [33]. Peer coaching and the opportunity to apply professional learning in the real world of the classroom while being supported by a mentor helps educators in applying their newfound learning in the classroom setting [28], [41], [34].

Interdisciplinary Teaching and the Need for Engineering Integration in K-12

To have an educational environment addressing problems relevant to everyday life requires learning that incorporates multiple disciplines. Incorporating engineering has gained momentum as a critical component of K-12 STEM education due to its impact in fostering problem-solving, critical thinking, and innovation among the STEM subjects [20].

The Next Generation Science Standards (NGSS) have made efforts in bringing engineering design into the K-12 classrooms, positioning engineering as a major practice alongside other traditional scientific inquiry [26]. Engineering can be integrated within the curricula of other subjects, particularly science and mathematics, through approaches such as engineering design challenges, project-based learning, and real-world problem solving. According to few studies, students who are exposed to integrated engineering instruction demonstrate increased engagement, enhanced collaboration, and stronger problem-solving skills [10],[17]. For example, two other studies documented middle and high school classrooms where students work collaboratively on engineering design projects that apply scientific and mathematical concepts to authentic problems, resulting in greater motivation and teamwork [3],[42]. These findings highlight the potential of interdisciplinary engineering integration to not only deepen content understanding but also develop critical 21st century skills in K-12 learners.

Despite these benefits, incorporating engineering into science and mathematics classrooms can be Challenging, especially when educators lack formal engineering pedagogical training and feel underprepared to teach engineering concepts and practices [14], [3]. Lack of confidence in how to incorporate engineering concepts, how to align them with standards, and how to assess student learning and uncertainty has been some of the issues expressed by many teachers [14]. These concerns indicate the importance of professional learning experiences in helping educators adopt interdisciplinary approaches.

This is a timely subject matter in education that aligns with the goals of interdisciplinary teaching. Interdisciplinary teaching aims to help students connect knowledge across disciplines and apply learning to real-world problems [38], [32].
However, realizing the full potential of engineering-focused professional learning experiences requires efforts to prepare and empower teachers to be able to build confidence needed to lead interdisciplinary learning experiences.

Challenges Faced by Educators in Integrating Engineering Concepts

Engineering historically has not been a part of teacher preparation programs like science or mathematics, especially for elementary and middle school educators [18]. While it is important to integrate engineering into K-12 education, educators face systemic and personal challenges in navigating this shift [16], [25]. For instance, a middle school science teacher may be required to integrate engineering design into their science class. Although the teacher possesses high content knowledge in science, they may lack formal training in engineering concepts and practices, such as the engineering design process, prototyping, and iterative problem-solving.

At the systemic level, limited access to sustained professional learning experiences, rigid curriculum structures, and the pressure to meet standardized testing requirements can further constrain meaningful integration. At the personal level, the teacher may experience low self-efficacy and uncertainty in facilitating engineering-based activities and assessing students' engineering thinking. Together, these Systemic and personal challenges complicate the effective integration of engineering into K-12 classrooms.

Addressing these challenges requires high-quality teacher professional learning experience. Engineering is frequently positioned as an add-on rather than an embedded component of science and mathematics curricula, which constrains teachers' ability to meaningfully integrate engineering concepts within existing instructional frameworks. At the personal level, many non-engineering educators report limited engineering content knowledge, low self-efficacy, and uncertainty about how to facilitate engineering design processes in age-appropriate ways [3],[6].

Teachers may also experience anxiety when teaching outside their disciplinary expertise and struggle to align engineering practices with their instructional goals. Without sustained and targeted professional development, these personal challenges can reduce teachers' confidence and willingness to incorporate engineering into classroom practice [8]. Together, these systemic and personal barriers underscore the importance of models for teacher professional learning that address both instructional capacity and the broader structural conditions shaping K-12 engineering integration.

Impact of Professional Learning on Teacher Self-Efficacy and Pedagogical Shifts

According to Bandura and Tschannen well-designed professional learning experiences can improve educator's self-efficacy (an educator's belief in their ability to organize and execute instructional strategies in achieving desired student outcomes) [1],[37]. This is a critical aspect for educators who lack confidence in their ability to teach engineering concepts. Professional learning experiences can drive positive shifts in teacher self-efficacy. For instance, engaging teachers in training that incorporate hands-on engineering design challenges, providing opportunities to reflect on their teaching, and offering feedback from facilitators are linked to increased confidence in integrating engineering [43], [44].

When teachers feel empowered and supported through sustained professional learning, access to resources, and collaborative professional communities, they are more likely to meaningfully adopt and integrate new content areas into their instruction. Research has shown that teacher self-efficacy and perceived support are critical predictors of instructional change and innovation, including the adoption of reform-oriented practices such as inquiry-based and STEM-integrated teaching [1], [37],[12]. Professional development that is ongoing, collaborative, and practice-based has been found to significantly increase teachers' willingness and ability to implement new disciplinary content in authentic and sustained ways [8], [7].

Within STEM education specifically, teachers who experience strong institutional and instructional support are more confident in integrating engineering and other STEM disciplines into their existing curricula [20]. Teachers who participate in engineering professional learning experiences often adopt design-based learning approaches in their classrooms, incorporate real-world problems into instruction, and create opportunities for students [45]. These shifts encourage deeper learning and transfer of knowledge. PD can be a driver of self-efficacy and prompt instructional change, especially among educators with non-engineering backgrounds.

While prior research provides important insights into professional learning experiences and engineering integration, this study builds on that foundation by examining how these dynamics are experienced and enacted by teachers in practice through qualitative inquiry.

Theoretical Framework

Constructivist Learning Theory and Social Cognitive Theory (SCT) guided the study, which together provides a foundation for understanding how PD equips educators to implement interdisciplinary engineering integration.

Constructivist Learning Theory posits that learners actively construct knowledge through experience, reflection, and interaction with their environment [46], [47]. Within this study, constructivism emphasizes that educators learn most effectively when engaged in meaningful, hands-on experiences-such as designing interdisciplinary engineering lessons- rather than passively receiving information. STC [48], [49] complement this perspective by highlighting the interplay of personal, behavioral, and environmental factors in learning. SCT emphasizes self-efficacy, suggesting that educators' belief in their ability to successfully implement interdisciplinary engineering strongly influences their engagement in classroom practices.

Through modeling, observation, feedback, and reflection, educators gain confidence in applying new instructional approaches, reinforcing their capacity to enact meaningful and sustained instructional change [1], [12], [8]. Together, these theories inform the research design by justifying the use of qualitative interviews and reflective practices to explore participants' experiences, perceptions, and behavioral changes over time [1], [5]. These two theories also guide data interpretation, enabling the study to link participants'professional learning experiences with self-reported changes in instructional practice, confidence, and interdisciplinary integration. By combining constructivism and social-cognitive perspectives, the framework captures both the experiential learning process and the psychological factors that shape teachers' agency and success in integrating engineering concepts into science and mathematics classrooms.

Method

The CREED project serves as the empirical context for examining how professional development supports interdisciplinary engineering integration (and is described more in a later paragraph). This paper presents a secondary data analysis of data collected for the CREED project. The CREED project team employed a qualitative research approach using interview data to move beyond theoretical discussions and explore how professional learning experiences equip mathematics and science educators to implement interdisciplinary engineering integration in practice.

A qualitative approach was employed. This allows for an in-depth understanding of participants' experiences, perceptions, and reflections, providing rich insights into the processes and impacts of the professional learning experience on teaching practices [5]. In the analysis presented in this paper, we included two marine science educators, Alan and Leo. These names are pseudonyms to protect confidentiality of the participants. The use of two participants is consistent with qualitative and phenomenological traditions that prioritize depth and richness of lived experience over generalizability [5], [21]. The small sample allowed for intensive engagement, and detailed thematic analysis, ensuring a nuanced understanding of the phenomenon [30],[36]. These two educators participated in workshops as part of CREED. Participants were selected purposefully, focusing on educators who had no prior engineering experience to capture their perspectives on professional learning experiences, challenges, and outcomes. Purposeful sampling is appropriate for qualitative case studies because it allows researchers to focus on individuals who have direct experience with the phenomenon under study and can provide detailed, contextually rich information [29].

Within the CREED project, the professional learning experiences provided participants with opportunities to experiment with engineering integration, collaborate with peers, and reflect on their teaching practice.

The professional learning experiences included a two-week summer workshop, coupled with monthly community meetings throughout the following two academic years, with opportunities for teachers to co-create lessons with undergraduate engineering students throughout the summer, over two academic year. These experiences facilitated the co-construction of knowledge, strengthened instructional skills, and empowered educators to implement interdisciplinary engineering learning in culturally relevant ways. Importantly, engaging in sustained, hands-on professional learning experiences also enhanced teachers' self-efficacy, allowing them to approach engineering instruction with greater confidence and adapt lessons to meet the needs of diverse learners [1], [8].

Through these mechanisms, CREED supports teacher development by supporting teachers in navigating interdisciplinary terrain (i.e. by bridging engineering design, science, and contextualized learning). The project highlights the role of teacher professional learning experience in fostering teacher competence, confidence, and collaborative practice.

Data Collection

Data were collected primarily through semi-structured interviews that occurred during the first semester following the summer workshops. The interviews provided participants with the opportunity to reflect on their experiences in the workshops, discussing how they applied interdisciplinary engineering concepts in their classrooms and share challenges and successes. Interviews were recorded and transcribed verbatim for analysis. While additional data were collected as part of the larger CREED project, this paper focuses specifically on one set of interviews because they provide means of understanding participants lived experiences,
beliefs, and reflections [5]. From a phenomenological perspective, interviews are important because they center the participants' own voices, providing insight into the meaning they ascribe to their experiences [5][50].

Data Analysis Procedure

We employed a thematic analysis approach. While we did not use rigid or predefined coding scheme at the outset, our coding process was both systematic and iterative. Initially, we engaged in open coding, carefully reading each interview transcript multiple times to identify meaningful segments related to participants' experiences with professional development and engineering integration. From this process, initial codes were generated inductively based on recurring ideas and patterns in the data. These codes were then reviewed, refined, and grouped into broader categories, leading to the development of key themes that captured shared patterns across participants' responses. Throughout this process, we continuously revisited the data to ensure that the themes accurately reflected participants' perspectives. This flexible yet structured approach allowed us to remain grounded in the data while identifying meaningful patterns relevant to the research question.

Trustworthiness

To ensure the credibility of the analysis, we read through each transcript four times, making sure that we have a clear understanding of Alan and Leo's responses. We selected and included quotes to support key interpretations, allowing Alan and Leo's own words to ground the analysis in authentic representation. Additionally, we provided explanations and quotes from the transcript to strengthen the connections between their statements and the broader themes that emerged. We also recognize the influence of our own perspective and experiences in the interpretation process, by acknowledging potential biases. This reflective approach helped ensure that the analysis remained as objective and accurate as possible.

This study focuses on two case studies and does not intend or attempt to represent the experiences of all educators, and the intent of this analysis is not to provide generalizable findings, but instead to provide richness and detail from a focus on a small number of cases.

Findings

The analysis of the interviews from the two participants of the study reveals how targeted professional learning experiences can enhance educators with non-engineering backgrounds to integrate engineering concepts into science lessons, foster student engagement, and address equity challenges in STEM. Four key themes emerged: (1) Growth in Pedagogical Innovation, (2) Engineering Integration through Hands-On Learning, (3) Building Inclusive Classrooms with a Gender Equity Lens, and (4) Lasting Impact on Student Engagement and Teacher-Student Relationships.

Growth in Pedagogical Innovation

Alan and Leo described how the CREED expanded their instructional capabilities in teaching engineering-related concepts despite their marine science backgrounds. Alan highlighted how the organization and delivery of CREED workshops inspired him to adopt new classroom management techniques: ***"Honestly, I thought it was just howyou guys ran the entirety ofthe process, and howyou organized100people, and made it made itfeel like a lot smaller ofa workshop than it was. And so Istruggle with something similar in my own classroom, whereI have 40 kids in nearly every single class. AndI took a bunch ofstuff fromyou guys So I took the speeddating, Idid that third day ofschool. And that's really helped me connect better with my students and be able to not only relate to them on a personal level, but be able to know okay, that person wants to be a marine biologist, thatperson wants to be a lawyer, thatperson wants to be a rapper, thatperson. And really, again, kind ofgoing back to what Iwas saying is really tailor as much ofmy class as Ican to help feed their interests."***

Leo also expressed a desire to broaden his teaching strategies to include interdisciplinary approaches. He saw CREED as an opportunity to overcome the challenges of bringing engineering into a science context: ***"But the infusion of engineering into a STEAMbased lesson, Ifindcan always be sometimes challenging. So Iwould say that that is something that I that I plan, or Ihope would broaden my horizon from this".*** This growth in desire to grow professionally demonstrates how professional learning experiences can empower educators to explore new teaching possibilities beyond their disciplinary boundaries.

Engineering Integration through Hands-On Learning

One central area mentioned by both participants was how CREED's problem-based learning approach supported the integration of engineering into their teaching. Alan shared how he used biomimicry-based lessons inspired by the CREED to build student problem-solving skills: ***"Absolutely. No, I'm actually so excited about this, like that,first, thatfirst lesson. To me, it was like, gold, I was so heartwarming to see some ofthe students. Like Isaid, Igave that example ofthe studentkind ofconnecting a Marine Science principle thatgiven him with engineering and like seeing the wholeprocess kindofwork together, and hopefully now seeing what they come up with, as theirproject. And after they've seen thepotential ofbiomimicry, and how a lot ofthe really innovativeprojects in the 21st century have actually comefrom engineers, quite literallyjustlooking at nature andsaying, How can Ibuild that? Andthen I go andbuild it."*** This demonstrates how professional learning experiences that center experiential learning can help nonengineering educators implement engineering design tasks.

Professional learning experiences that center experiential learning engages educators in active, hands-on, and reflective experiences, rather than relying solely on lectures or passive knowledge transfer. By participating in experiences, such as designing engineering lessons, modeling interdisciplinary activities, or experimenting with classroom strategies, teachers can directly experience the challenges and possibilities of integrating new content into their instruction.
This professional learning experience allows educators to test ideas, receive feedback, and reflect on outcomes, which supports the development of both practical skills and instructional confidence.

Building Inclusive Classrooms with a Gender Equity Lens

Leo's reflections brought attention to the gender imbalance in his classroom and the need for more inclusive STEM instruction. ***"AndIhave one this is a class of42 andIhave one girl with a possible interest in engineering. So to me right now that that's, that's a hope: thatIchange that number."*** The Project gave Leo strategies to engage more students but also increased his awareness of equality-related challenges. His intention to create supportive environments for girls in STEM highlights how professional learning experiences can spark teacher agency in addressing representation gaps.

Alan's approach to getting to know student interests also reflects a student-centered mindset that values inclusion:'***thatperson wants to be a marine biologist, thatperson wants to be a lawyer, that person wants to be a rapper, thatperson. Andreally, again, kind ofgoing back to whatIwas saying is really tailor as much ofmy class as Ican to helpfeedtheir interests.*** Such practices can drive inclusive and personalized learning experiences, particularly important when introducing content like engineering.

Lasting Impact on Student Engagement and Teacher-Student Relationships

Both educators stated a shift in their classroom dynamics after applying techniques learned through the CREED Project. Alan noticed that his students were more engaged, particularly when lessons allowed them to think creatively and engage real-world problems: "***Absolutely***. ***No, I'm actually so excited about this, like that,first, thatfirstlesson. To me, it was like, gold, I was so heartwarming to see some ofthe students. LikeIsaid, Igave thatexample ofthestudent kind ofconnecting a Marine Scienceprinciple thatgiven him with engineering and like seeing the wholeprocess kindofwork together,and hopefully now seeing whatthey come up with, as theirproject.***

Leo emphasized a deeper understanding of how his students think, which he used to adapt his instruction more effectively: ***"Um,well, yes, yes, in the sense that, that I, I didn't copy the activity, butI've done certain activities andhad discussions in the class to go to go toward that,you know,perspective. And soforth, was trying to get an idea ofhow people think and engage in the class. Not so much engage rather more think, because Ithink it's really revolving aroundthat".***

The professional development experience not only provided new teaching strategies but also enhanced educators' capacity to build stronger connections with their students, equipping them with tools, confidence, and mindset to bring engineering into their classrooms.

Conclusion

The analysis provided insight into some of the ways professional development can have a transformational impact in equipping K-12 educators to integrate engineering principles into nonengineering classrooms. The CREED project served as an agent of change to instructional innovation, empowering teachers like Alan and Leo to expand their teaching practices and bring engineering to life in new and engaging ways. Their experiences show how professional learning experiences can lead to: Increased confidence to teach interdisciplinary content, Practical strategies for classroom engagement, Personalized implementation of engineering principles, and Enhanced teacher- student connections through meaningful, applied learning.

Recommendations

Building opportunities for reflection and discussion helps educators internalize new approaches and recognize growth in their own practice. Conducting workshops frequently is helpful, and training can deepen and sustain the impact of professional development

Reference

[1]. Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York, NY: W. H. Freeman.

[2]. Beers, S. (2011). *Teaching 21st century skills: An ASCD action tool.* ASCD.

[3]. Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education, 97(3),* 369–387. https://doi.org/10.1002/j.2168-9830.2008.tb00985.x

[4]. Brown, R. E., & Bogiages, C. A. (2017). Professional Development Through STEM Integration: How Early Career Math and Science Teachers Respond to Experiencing Integrated STEM Tasks. *International Journal ofScience andMathematics Education, 17(1),* 111–128. https://doi.org/10.1007/s10763-017-9863-X

[5]. Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE.

[6]. Cunningham, C. M., & Carlsen, W. S. (2014). Teaching engineering practices. *Journal of Science TeacherEducation, 25(2),* 197–210. https://doi.org/10.1007/s10972-014-9380-5

[7]. Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). Effective teacher professional development. Learning Policy Institute. https://learningpolicyinstitute.org/product/effective-teacherprofessional-development-report

[8]. Desimone, L. M. (2009). Improving impact studies ofteachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38(3),* 181–199. https://doi.org/10.3102/0013189X08331140

[9]. *International Journal of STEM education, 3,* 11.https://doi.org/10.1186/s40594016- 0046-9

[10]. English, L. D. (2016). Advancing elementary and middle school STEM education. *International Journal of STEMEducation, 3(1),* 12. https://doi.org/10.1186/s40594-016-0040-3

[11]. English, L. D., King, D., & Smeed, J. (2017). Advancing integrated STEM learning through engineering design: Sixth-grade students' design and construction of earthquake resistant buildings. *The Journal ofEducationalResearch, 110(3),* 255-271.

[12]. Guskey, T. R. (2002). Professional development and teacher change. *Teachers and Teaching: Theory and Practice, 8(3),* 381-391. https://doi.org/10.1080/135406002100000512

[13]. Hammack, R., Ivey, T., Utley, J., & High, K. (2015). *Effect ofan Engineering Professional Development Program on Elementary Teachers'EngineeringInstruction.* Journal ofPre-College Engineering Education Research (J-PEER), 5(1), Article 4. https://doi.org/10.7771/2157- 9288.1090

[14]. Hsu, M. C., Purzer, S., & Cardella, M. E. (2011). Elementary teachers' views about teaching design, engineering, and technology. *Journal ofPre-College EngineeringEducation Research (J- PEER), 1(2),* 5.https://serc.carleton.edu/sp/library/interdisciplinary/index.html

[15]. Journal of Engineering Education, 102(1), 141–178. https://doi.org/10.1002/jee.20004

[16]. Katehi, L., Pearson, G., & Feder, M. (Eds.). (2009). *Engineering in K–12 education: Understanding the status and improving theprospects.* National Academies Press. https://doi.org/10.17226/12635

[17]. Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(11).

[18]. Lachapelle, C. P., & Cunningham, C. M. (2014). ENGINEERING IN ELEMENTARY SCHOOLS. *Engineering in Pre-College Settings, DOI: 10.2307/j.ctt6wq7bh.8,* 61–88. https://doi.org/10.2307/j.ctt6wq7bh.8

[19]. Loucks-Horsley, S., Stiles, K. E., Mundry, S., Love, N., & Hewson, P. W. (2010). *Designing professional development for teachers of science and mathematics* (3rd ed.). Corwin Press.

[20]. Moore, T. J., Miller, R. L., Lesh, R. A., Stohlmann, M. S., & Kim, Y. R. (2013). Modeling in Engineering: The Role of Representational Fluency in Students' Conceptual Understanding.

[21]. Moustakas, C. (1994). *Phenomenological research methods.* SAGE.

[22]. National Academy of Engineering & National Research Council. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. National Academies Press.

[23]

[24]

[25]. National Research Council. (2012). *Aframeworkfor K-12 science education: Practices, crosscutting concepts, andcore ideas.* National Academies Press. https://doi.org/10.17226/13165

[26]. NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States.* The National Academies Press. https://doi.org/10.17226/18290

[27]. NGSS Lead States. (2013). *Nextgeneration science standards: For states, by states.* National Academies Press.

[28]. Owens, D. C., Sadler, T. D., Murakami, C. D., & Tsai, C.-L. (2018). Teachers' views on and preferences for meeting their professional development needs in STEM. *School Science and Mathematics, 118(8),* 370–384. https://doi.org/10.1111/ssm.12306

[29]. Patton, K., Parker, M., & Tannehill, D. (2015). Helping teachers help themselves: Professional development that makes a difference. *NASSP bulletin, 99(1),* 26-42.

[30]. Patton, M. Q. (2015). *Qualitative research & evaluation methods* (4th ed.). SAGE.

[31]. Purzer, S., & Quintana-Cifuentes, J. P. (2019). Integrating engineering in K-12 science education: Spelling out the pedagogical, epistemological, and methodological arguments. *Disciplinary and Interdisciplinary Science Education Research, 1(13).* https://doi.org/10.1186/s43031-019-0010-0

[32]. Science Education Resource Center at Carleton College. (2010). Interdisciplinary approaches to teaching.

[33]. Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education, 4(1).* https://doi.org/10.1186/s40594-017- 0068-1

[34]. Showers, B., & Joyce, B. (1996). The evolution of peer coaching. *Educational leadership, 53,* 1216.

[35]. Smetana, L., & Nelson, C. B. (2023). Examining Pre-Service Elementary Teacher Self-Efficacy for

Engineering Education. *The Electronic Journal for Research in Science & Mathematics Education, 26(4),* 62-83.

[36]. Smith, J. A., Flowers, P., & Larkin, M. (2009). *Interpretativephenomenological analysis: Theory, method and research.* SAGE.

[37]. Tschannen-Moran, M., & Hoy, A. W. (2001). Teacher efficacy: capturing an elusive construct. *Teaching and Teacher Education, 17(7),* 783–805.

[38]. Wang, H.-H., Charoenmuang, M., Knobloch, N. A., & Tormoehlen, R. L. (2020). Defining interdisciplinary collaboration based on high school teachers' beliefs and practices ofSTEM integration using a complex designed system. https://doi.org/10.1186/s40594-019-0201-4

[39]. Zhou, X., Shu, L., Xu, Z., & Padrón, Y. (2023). The effect of professional development on inservice STEM teachers' self-efficacy: Ameta-analysis of experimental studies. International Journal of STEM Education, 10(37). https://doi.org/10.1186/s40594-023-00422-x

[40]. Engineering in K-12 Education: Understanding the Status and Improving the Prospects National Research Council. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press.

[41]. Parker, C. E., Stylinski, C. D., Bonney, C. R., Schillaci, R., & McAuliffe, C. (2015). *Examining the quality of technology implementation in STEM classrooms: Demonstration of an evaluative framework*. Journal of Research on Technology in Education, 47(2), 105

[42]. Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A., & Stohlmann, M. S. (2014). *Aframework for quality K-12 engineering education: Research and development*. Journal of Pre-College Engineering Education Research, 4(1), Article 2. https://doi.org/10.7771/2157-9288.1069

[43].Banilower, E. R., Cohen, K., Pasley, J. D., & Weiss, I. R. (2010). *Effective science instruction: What does research tell us?* (2nd ed.). Center on Instruction, RMC Research Corporation.

[44].Capobianco, B. M., Diefes-Dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. *Journal of Engineering Education, 100*(2), 304-328. https://doi.org/10.1002/j.2168-9830.2011.tb00015.x

[45]. Linda K. Smetana, L. K., & Charles B. Nelson, C. B. (2023). Teaching science in elementary and middle school: A cognitive and cultural approach. Teaching Science in Elementary and Middle School (6th ed.). SAGE Publications.

[46]. Piaget, J. (1952). The origins of intelligence in children. International Universities Press.

[47]. Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Harvard University Press.

[48]. Albert Bandura (1986). Social foundations of thought and action: A social cognitive theory. Prentice-Hall.

[49]. [1Albert Bandura (2001). Social cognitive theory: An agentic perspective. Annual Review of Psychology, 52, 1-26. https://doi.org/10.1146/annurev.psych.52.1.1

[50]. Sharan B. Merriam, S. B., & Elizabeth J. Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.

[51].Virginia Braun, V., & Victoria Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa