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STEM Pedagogical Content Knowledge of Preservice Teachers

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ABSTRACT

The United States needs to produce more graduates with the required 21st-century skills such as critical thinking, problem-solving, collaboration and cross-cultural awareness to remain a top competitor in a global marketplace. Science, technology, engineering, and mathematics, commonly referred to as STEM, is a transdisciplinary approach to learning through real-world application. The fastest growing occupations require STEM skills and STEM education and can be effective in promoting desired 21st-century capacities. To successfully teach STEM, educators need pedagogical content knowledge. Students can be greatly impacted by their teachers and K-12 public school may be the first-time students are exposed to STEM education. Even if students do not pursue careers in STEM, they benefit from the communication, collaboration, critical thinking, and problem-solving skills gained from STEM education. The purpose of the correlational quantitative study was to determine the STEM pedagogical content knowledge of preservice teachers and to consider any gaps in STEM pedagogical content knowledge. Recommendations include adding an explicit STEM course into preservice teacher preparation programs and future research.

Keywords: STEM education; 21st-century skills; preservice teachers; teacher preparation; STEM workforce

Introduction

The demand for employees qualified to perform in STEM careers continues to proliferate and the United States needs to contend in a global marketplace to remain in a position of global leadership (National Academies of Sciences, Engineering, and Medicine [NASEM], 2019). Research claims 75% of the fastest-growing occupations will require STEM skills, and STEM careers have the most considerable projected growth (Du Plessis, 2020; Holian & Kelly, 2020). Between 2007 and 2017, employment in the STEM fields grew 24.4% compared to just 4.0% for all other occupations, and this growth is expected to continue and increase by 8.9% between 2014 and 2024 (Noonan, 2017). To remain relevant in a highly competitive global marketplace, the United States needs to produce more STEM graduates (Perna et al., 2010). One of the reasons for an emphasis on STEM education is the globalization of the workforce. Due to the global nature of economics, technology and innovation have become vital to economic success (Casto & Williams III, 2020; Du Plessis, 2020).

While STEM education does not have the same importance in K-12 education as literacy, it may be just as significant in ensuring that more students are retained in STEM careers and build critical skills required even outside of STEM disciplines (Bybee, 2010; Jenlink, 2013). Still, many teacher preparation programs forgo STEM requirements while students pursue state teaching certifications (Garrett, 2008). As such, preservice teachers may lack exposure to explicit STEM education and instructional practices simply because they have not been exposed to the content and pedagogy (Ryu et al., 2019). This could result in gaps in knowledge and skills that can be passed on to students. Therefore, we sought to provide an initial assessment of preservice teachers' pedagogical content knowledge (PCK) in STEM to better inform preservice programs as whether explicit STEM education is needed in teacher preparation programs.

Literature Review

The United States needs to produce more STEM graduates to remain competitive in a global marketplace (Deniz et al., 2021). Currently, research suggests that there are significant gaps in science, technology, engineering and math, or STEMeducation and this negatively impacts the United States in a global marketplace (Bartlett & Bos, 2018). The gap in education may be responsible for the lack of progress in mathematics for fourth and eighth-grade students between 2007 and 2009 (National Science Board, 2022a). Although the United States ranks high in science, 7th place among 37 active OECD countries (Rotermund et al., 2021), the ranking for mathematics is much lower. Currently, the United States ranks 25th of 37 countries in mathematics (Rotermund et al., 2021).

STEM education is important beyond just preparing students for STEM careers. STEM competencies have been shown to support general economic growth within countries competing in a global marketplace (Park et al., 2020). Even if students do not pursue careers in STEM, they benefit from the communication, collaboration, critical thinking, and problem-solving skills gained from STEM education. These skills are crucial to success in an international economy and can be gained through effective STEM instruction (NASEM, 2018).

STEM education is an essential aspect of education for the future success of our students (Stohlman et al., 2012). STEM education inspires creativity, engages innovation, promotes problem-solving and critical thinking skills (Siekmann, 2016). According to Aydin (2020), while some students may pursue STEM careers, others still benefit from STEM education by becoming technologically and scientifically literate. Korucu and Kabak (2021) found that classrooms in 21 different countries using STEM positively influenced student motivation, attitude, and academic achievement.

Studies have shown that introducing STEM to young students positively impacts their future career aspirations in the STEM fields (Bagiati et al., 2010; Dejarnette, 2016; Huang, 2017; Jenlink, 2013). Kindergarten through 12th grade (K-12) schools are some of the first places that young students are exposed to formal education. The focus of STEM at the elementary level is less about achievement and more about engaging students in their learning, thus developing an interest in further STEM studies (Aydin, 2020). However, successful STEM learning depends on quality STEM teaching. A framework for understanding teaching is that of pedagogical content knowledge. Historically teacher preparation programs focused exclusively on the teacher's content knowledge (Mishra & Koehler, 2006). In recent years, more teacher preparation programs in higher education have shifted their focus toward general pedagogical knowledge separately and often at the expense of content knowledge (Mishra & Koehler, 2006). Shulman's contributions defining CK and PK lead teacher preparation programs to focus on either one concept or the other independently (Mishra & Koehler, 2006). However, Shulman proposes pedagogical content knowledge (PCK) as a way of unifying pedagogy and content (Mishra & Koehler, 2006). Shulman suggests that PCK is the most significant component of successful teaching practices (Krepf et al., 2018).

For over thirty years, there has been discussion and debate regarding the definition and meaning of the term pedagogical content knowledge (Krepf et al., 2018). While this study utilizes a sample from the United States, issues regarding STEM education are part of discussions globally including researchers from Germany (Krepf et al., 2018), Jamaica (Mayne, 2019), Mayalisa (Gholami et al., 2021), Turkey (Aydin, 2020), and Taiwan (Chen et al., 2021). There are two main approaches to this ongoing debate. The first primarily elaborates on Shulman's concept of PCK and adds new components (Krepf et al., 2018). The second approach focuses on the interconnectedness among Shulman's knowledge of teaching: dimensions of knowledge (Krepf et al., 2018). Many other theorists have researched PCK and its elements, but a common theme throughout most research is that PCK is a blend of CK and instructional strategies (Gholami et al., 2021). PCK is the basic, context-specific knowledge that teachers activate when reflecting on practice and executing instruction that cultivates the greatest experiences for student learning (Mayne, 2019). This theory is developed from the works of Shulman (1986).

Current Study

Providing quality STEM education is dependent on the knowledge and skills of those teaching it to students. However, as noted earlier, many teacher preparation programs do include specific STEM requirements (Garrett, 2008) and these may leave teachers unprepared to teach STEM. As such, the purpose of this study was to determine preservice teachers' STEM pedagogical content knowledge. The research was guided by two overarching research questions:

1. What is the current level of STEM pedagogical content knowledge among pre-service teachers on the STEM Pedagogical Content Knowledge Scale?
2. Are pre-service teachers' levels of STEM pedagogical knowledge significantly higher or lower than neutral when using the STEM Pedagogical Content Knowledge Scale?

Methodology

Participants

A total of N=64 preservice teachers participated. The survey participants were predominantly White (84%) and female (92%) between the ages of 18-24 (97%). Most students were enrolled in their sophomore year (38%) at the time of the survey. The most frequency program represented was Pre-K-4 (Early Grades) Teacher Preparation program with 56% of the sample enrolled in this teacher certification program.

Instrumentation

The STEM Pedagogical Content Knowledge Scale (STEMPCK Scale; Yildirim & Şahin-Topalcengiz, 2018) was used. The scale includes an introduction that informs participants the purpose to "evaluate your thoughts regarding STEM pedagogical knowledge." Participants are then reminded that their responses are confidential and encouraged to answer all items. They are asked to provide their age, gender, department and class, with the latter two being specific to their program of study and university. The scale present 56 items broken up into six individual tables. Each table provides items corresponding to one of six categories and make up the subscales for PK (12 items), science (8 items), technology (7 items), engineering (7 items), mathematics (8 items), and 21st-century skills (13 items).

The PK subscale items measure teachers' agreement regarding their pedagogical skills including use of different teaching strategies, their ability to create effective learning environments, communicate with students, and evaluate student performance. The five subject specific subscales measure whether teachers agreed to having "enough knowledge" in the subject to teach it. They rate how strongly they agree with being knowledgeable of current trends and tools in the subject, whether they could engage students in the subject through discussion or by combining course material across subjects.

Items are rated on a five-point Likert scale ranging from 1= "strongly disagree" to 5= "strongly agree". Higher agreement indicates stronger pedagogical knowledge. Acceptable reliability has been shown for each subscale, αs ≥.78 (Yildirim & Şahin-Topalcengiz, 2018).

Procedures

The STEM Pedagogical Content Knowledge Scale was administered to preservice teachers via an anonymous online format. Faculty in the preservice education programs at three universities in Pennsylvania distributed the survey via email to their students. All participants had to be currently enrolled in the education program and seeking one of the following certifications: Early Grades (PreK-4), Middle Grades (4-8), Secondary Education (7-12) and Special Education (Pre-K-12). The participants were notified that the survey was voluntary, anonymous, and unrelated to any coursework or other institutional requirements. Participation took place online and all procedures related to the study were approved by the authors' University Institutional Review Board.

Data were analyzed using JASP (JASP Team, 2022). The overall score for the STEMPCK and each of the six subscales were calculated and used in all analysis. To determine pre-service teachers' overall levels of STEMPCK, descriptive statistics were calculated to determine the average scores for the STEMPCK and each subscale along with standard deviation, minimum and maximum scores. To determine whether teachers' scores were significantly higher or lower than neutral, a series of one-sample t-tests were conducted that compared the average score for each subscale to a neutral scale score of 3.00. Given the multiple tests, a Bonferroni corrected alpha value of α=.007 was used. Cohen's d was used to determine effect size. We considered an effect size of less than .20 to be small, .20-.49 to be moderate and .50 and above to be large.

Results

Descriptive statistics for the overall STEMPCK and the six subsections on the STEM Pedagogical Content Knowledge Scale are presented in Table 1. The overall STEMPCK score showed that on average pre-service teachers agreed with items on the scale (M=3.76). However, when examining the average scores for the six subsections, differences appeared. Pre-service teachers had the strongest agreement with items on the pedagogical knowledge scale (PK; M=4.26) and 21st century skills subscale (M=4.43). Pre-service teachers also agreed with items on the math subscale (M=3.73) and the technology subscale (M=3.62). Pre-service teachers did not agree with items on the science (M=2.93) or engineering subscales (M=2.90).

Table 1.
STEMPCK Survey Subscale Scores (N=64)

	Mean	SD	Minimum	Maximum	Cohen's *d*
STEMPCK	3.76	0.43	2.84	4.57	8.71***
PK	4.26	0.40	3.25	5.00	10.56***
Science	2.93	0.78	1.22	4.44	3.76***
Technology	3.62	0.75	1.71	5.00	4.78***
Engineering	2.90	0.71	1.57	5.00	4.08***
Mathematics	3.73	0.78	2.00	5.00	4.74***
21st-Century	4.43	0.40	3.57	5.00	11.08***

Note: STEMPCK is an abbreviation for STEM pedagogical content knowledge and PK is an abbreviation for pedagogical knowledge. A one-sample t-test was conducted for each subscale to compare the mean score to a neutral score of 3.00 using a Bonferroni corrected alpha value of $\alpha=.007$.
***$p<.001$

Pre-service teachers' agreement with items corresponds with stronger STEM pedagogical content knowledge specifically in the areas of pedagogical knowledge, 21st century skills, math and technology. The lack of agreement on items in the science and engineering subscales illustrates weaker pedagogical content knowledge in those areas.

Pre-service teachers' average score on each subscale was significantly different from neutral, $p<.001$. In addition, the effect sizes ranged from $d=3.76$ to 11.08 indicating that these differences were large in magnitude. In line with the descriptive statistics, students had agreement with statements measuring their overall pedagogical knowledge, $t(63)=25.09$, $p<.001$, 21st-century skills, $t(63)=28.74$, $p<.001$, PCK in the areas of technology, $t(63)=6.62$, $p<.001$, and mathematics, $t(63)=7.43$, $p<.001$. Their agreement was significantly more than neutral. In contrast, they disagreed with having PCK in the areas of science, $t(63)0.63$, $p<.001$ and engineering, $t(63)1.06$, $p<.001$, and this disagreement was significantly lower than neutral.

Discussion

The purpose of this study was to assess preservice teachers' scores in STEMPCK. Having strong PKC can benefit student learning in STEM, and in turn better prepare our workforce. Pedagogical knowledge includes teachers' instructional strategies to deliver content to their students in engaging ways. According to Shulman (1986), pedagogical knowledge is a part of the knowledge teachers need to have to be successful and believes content knowledge is just as significant. Preservice teachers here reported higher than neutral scores in 21st-century skills and the pedagogical knowledge subscales. This included students feeling prepared to utilize multiple instructional strategies, create effective learning environments and having strong communication skills. The 21st-century skills subscale included understanding the role of empathy and respect in teaching and being an effective communicator. These skills will benefit teachers in the classroom. Importantly, they will be modeling the critical 21-st century skills that are needed for a productive STEM workforce.

Preservice teachers had the highest scores in the subject scales of technology and mathematics. In technology, preservice teachers agreed that they had knowledge regarding the subject of technology, have the ability to integrate technology into their teaching, and will use technology tools with students. In mathematics, preservice teachers agreed that they had knowledge of mathematics and possessing effective teaching strategies for mathematics.

Preservice teachers in this study reported low scores in their content knowledge in the subscales of science and engineering. This is concerning as teachers focus more on content they are most comfortable teaching (Chen et al., 2021; Sterling, 2006). Therefore, if we want to increase the likelihood that teachers will focus thoroughly on science and engineering, it is important that teachers have high levels of content knowledge in these areas. In the subscale of engineering, preservice teachers did report that they understand that engineering is based on science and mathematics. However, they scored below neutral in five of the seven indicators related to engineering demonstrating substantial gaps in their engineering PCK. This included a lack of attention to trends in engineering and low enjoyment with engineering. Participants also indicated that they were less confident in integrating engineering into the curriculum and helping students to learn about engineering.

Preservice teachers had low scores in the science subscale. Participants did not score above neutral on any survey items in science subscale. They reported limited knowledge in scientific content knowledge and indicated that they do not follow trends in science and advanced scientific studies. It was concerning that they disagreed with their ability to be an effective science teacher, and their familiarity with trends and advanced scientific studies.

Implications

Shulman (1986) notes the importance of content knowledge and pedagogical knowledge in preservice teachers. Given that teachers spend more instructional time in content areas in which they have the most content knowledge, it is essential preservice teachers are prepared to teach all content, including STEM (Chen et al., 2021; Sterling, 2006). If preservice teachers have lower than average content knowledge in STEM subjects, it may impact the amount of instructional time teachers devote to this content (Thomson et al., 2018). This would in turn impact students' interest in and preparation for the STEM workforce.

Preservice teachers had scores above neutral in overall STEM pedagogical content knowledge**,** 21st-century skills, and the subjects of technology, and mathematics. However, in science and engineering, preservice teachers' knowledge fell below neutral. This is less than ideal for preservice teachers. As a result, preservice teachers enrolled in teaching preparation programs may not have the knowledge both schools and society want them to have to utilize STEM education to promote 21st-century skills in their classrooms. This might include principals and other educational leaders who are seeking teachers that are capable of helping students become STEM literate. Society at large is also in need of a workforce that is STEM literate and needs knowledgeable teachers in order to produce students for this.

Preservice education programs can address these gaps. For example, education programs could include courses that help to build students' knowledge in science and engineering. These courses might include a focus on current trends in science and engineering and reviewing advanced studies in science, as students themselves low on both of these items. The courses might also address how to teach about trends and scientific findings and ways to integrate this with other STEM subjects.

For example, preservice teachers felt confident in teach math, which suggests they may spend more time teaching math to their students. Incorporating math examples from engineering or science studies could increase their comfort with and also time spent in teaching science and engineering. This would have the secondary benefit of allowing their students to see the interdisciplinary nature of STEM subjects and ways in which they are applied in the real world.

This study is not without limitations. The sample came from one geographical area and was limited in size. The students were largely female and in their sophomore year. The survey used relies on one time point of self-report knowledge. It would be beneficial for future research to explore ways to directly measure this knowledge over time. It may be that preservice teachers' evaluations of their STEM PCK is not accurate, it could also change over time. Future research should seek to replicate the findings here with a larger national sample that includes more advanced preservice teachers. Nonetheless, the large effect sizes observed in this study increase the trustworthiness of the results suggesting that a closer look at preservice teachers' preparation to teach STEM is warranted.

Conclusion

It is clear from the body of research in the literature review of this study that preservice teachers need content knowledge, pedagogical knowledge and therefore STEMPCK is needed to be the most successful in the classroom (Taylan et al., 2022). Based on the results of this study, it can be suggested that teacher preparation programs should be reevaluated to implement explicit STEM course requirements to promote higher levels of self-efficacy in preservice teachers utilizing STEM education and to promote 21st-century skills in their classrooms.

References

Aydin, G. (2020). Prerequisites for elementary school teachers before practicing STEM education with students: A case study. *Eurasian Journal of Educational Research (EJER)*, (88), 1-39. https://dergipark.org.tr/en/pub/ejer/issue/57483/815278

Bagiati, A., Yoon, S. Y., Evangelou, D., & Ngambeki, I. (2010). Engineering curricula in early education: Describing the landscape of open resources. *Early Childhood Research & Practice, 12*(2). https://eric.ed.gov/?id=EJ910909

Bartlett, C., & Bos, L. (2018). STEAM around the world: Successfully incorporating hands-on learning and diversity into children's programming. *Journal of Library Administration*, *58*(2), 174–182. https://doi-org.libproxy.gmercyu.edu/10.1080/01930826.2017.1392223

Berube, C. T. (2014). *STEM and the city: A report on STEM education in the great American urban public school system*. Information Age Publishing.

Bybee, R. W. (2010). What is STEM education? *Science*, *329*(5995), 996-996. http://doi: 10.1126/science.1194998

Casto, A. R., & Williams III, J. A. (2020). Seeking proportionality in the North Carolina STEM pipeline. *High School Journal, 103*(2), 77-98.
https://www-jstor-org.libproxy.gmercyu.edu/stable/26986615

Chen, Y.-L., Huang, L.-F., & Wu, P.-C. (2021). Preservice preschool teachers' self-efficacy in and need for STEM education professional development: STEM pedagogical belief as a mediator. *Early Childhood Education Journal*, *49*(2), 137–147. https://doi-org.libproxy.gmercyu.edu/10.1007/s10643-020-01055-3.

Dailey, D., Cotabish, A., & Jackson, N. (2018). Increasing early opportunities in engineering for advanced learners in elementary classrooms: A review of recent literature. *Journal for the Education of the Gifted*, *41*(1), 93–105. http://dx.doi.org.libproxy.gmercyu.edu/10.1177/0162353217745157

Dejarnette, N. K. (2016). America's children: Providing early exposure to stem (science, technology, engineering and math) initiatives. *Reading Improvement*, *53(*4), 181–187. https://www.ingentaconnect.com/content/prin/rimp/2016/00000053/00000004/art00004

Deniz, H., Kaya, E., Yesilyurt, E., Newley, A., & Lin, E. (2021). Integrating engineering, science, reading, and robotics across grades 3-8 in a STEM education era. *Journal of Learning and Teaching in Digital Age*, *6*(1), 40-45. https://eric.ed.gov/?id=EJ1285529

Du Plessis, A. E. (2020). The lived experience of out-of-field STEM teachers: A quandary for strategizing quality teaching in

STEM? *Research in Science Education*, *50*(4), 1465-1499. https://doi.org/10.1007/s11165-018-9740-9

Ganley, C. M., George, C. E., Cimpian, J. R., & Makowski, M. B. (2018). Gender equity in college majors: Looking beyond the STEM/Non-STEM dichotomy for answers regarding female participation. *American Educational Research Journal*, *55*(3), 453-487. https://www-jstor-org.libproxy.gmercyu.edu/stable/26643520

Garrett, J. L. (2008). STEM: The 21st century sputnik. *Kappa Delta Pi Record*, *44*(4), 152-153. https://doi.org/10.1080/00228958.2008.10516514

Gholami, H., Md Yunus, A. S., & Mohd Ayub, A. F. (2021). Improving mathematics lecturers' pedagogical content knowledge through lesson study. *International Journal of Science, Mathematics & Technology Learning*, *28*(2), 53–71. https://doi.org/10.18848/2327-7971/CGP/v28i02/53-71

Holian, L., Kelly, E., & National Center for Education Statistics (ED). (2020). STEM occupational intentions stability and change through high school. Stats in Brief. NCES 2020-167. *National Center for Education Statistics*. https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2020167

Huang, S. (2017). Implement stem literacy in the elementary school curriculum. *Journal of Education Research, 11*(4), 389-402. https://libproxy.gmercyu.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=eue&AN=135961237&site=eds-live

Hutton, C. (2019). Using role models to increase diversity in STEM. *Technology and Engineering Teacher, 79*(3), 16-19. https://www.iteea.org/Publications/Journals/TET/TETNov2019.aspx

JASP Team (2022). JASP (Version 0.16.3)[Computer software].

Jenlink, P. M. (2013). STEM teacher preparation and practice-capturing a "Sputnik moment". [Editorial]. *Teacher Education & Practice, 26*(2), 173-180. https://link.gale.com/apps/doc/A514683029/AONE?u=anon~634300a4&sid=googleScholar&xid=ad77f643

Kennedy, B., Fry, R., & Funk, C. (2021). 6 Facts about America's STEM workforce and those training for it. *Pew Research Center*. https://www.pewresearch.org/fact-tank/2021/04/14/6-facts-about-americas-stem-workforce-and-those-training-for-it/

Korucu, A. T., & Kabak, K. (2021). The effects of STEM and other innovative interdisciplinary practices on academic success, attitude, career awareness: A meta-synthesis study. *Journal of Learning and Teaching in Digital Age, 6*(1), 27-39. https://dergipark.org.tr/en/pub/joltida/issue/59433/854103

Krepf, M., Plöger, W., Scholl, D., & Seifert, A. (2018). Pedagogical content knowledge of experts and novices-what knowledge do they activate when analyzing science lessons? *Journal of Research in Science Teaching, 55*(1), 44-67. https://doi.org/10.1002/tea.21410

Mayne, H. (2019). Pedagogical content knowledge and social justice pedagogical knowledge: Re-envisioning a model for teacher practice. *Research in Educational Administration & Leadership, 4*(3), 701-718. https://doi.org/10.30828/real/2019.3.9

McCullough, L. (2020). Proportions of women in STEM leadership in the academy in the USA. *Education Sciences,* 10. https://doi.org/10.3390/educsci10010001

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054. https://www.learntechlib.org/p/99246/

National Academies of Sciences, Engineering, and Medicine. (2018). *Indicators for monitoring undergraduate STEM education*. National Academies Press.

National Academies of Sciences, Engineering, and Medicine, Policy and, G. A., Board on Higher Education, and Workforce, Committee on Closing the Equity Gap: Securing Our STEM Education and Workforce Readiness Infrastructure in the Nation's Minor, Leigh, M. J., McGuire, K., Espinosa, L. L. (2019). *Minority serving institutions: America's underutilized resource for strengthening the STEM workforce*. Washington, D.C.: National Academies Press. https://peer.asee.org/33114

National Science Board, National Science Foundation. (2022a). Science and engineering indicators 2022: *The State of U.S. Science and Engineering*. NSB-2022-1. Alexandria, VA. https://ncses.nsf.gov/pubs/nsb20221

Noonan, R., & Economics and Statistics Administration (DOC), Office of the Chief Economist (OCE). (2017). STEM jobs: 2017 update. ESA issue brief #02-17. *US Department of Commerce.* https://eric.ed.gov/?id=ED594354

Park, W., Wu, J.-Y., & Erduran, S. (2020). The nature of STEM disciplines in the science education standards documents from the USA, Korea and Taiwan: Focusing on disciplinary aims, values and practices. *Science & Education*, *29*(4), 899–927. https://doi.org/10.1007/s11191-020-00139-1

Perna, L. W., Gasman, M., Gary, S., Lundy-Wagner, V., & Drezner, N. D. (2010). Identifying strategies for increasing degree attainment in STEM: Lessons from minority-serving institutions. *New Directions for Institutional Research*, (148), 41-51. https://doi.org/10.1002/ir.360

Peters-Burton, E., & Johnson, T. (2018). Cross-case analysis of engineering education experiences in inclusive STEM-focused high schools in the United States. *International Journal of Education in Mathematics, Science and Technology*, *6*(4), 320–342. https://eric.ed.gov/?id=EJ1193468

Rotermund, S., Burke, A., & National Science Foundation, N. S. B. (2021). Elementary and secondary STEM education. Science & engineering indicators 2022. NSB-2021-1. Alexandria, VA. https://ncses.nsf.gov/pubs/nsb20211/

Ryu, M., Mentzer, N., & Knobloch, N. (2019). Preservice teachers' experiences of STEM integration: Challenges and implications for integrated stem teacher preparation. *International Journal of Technology and Design Education*, *29*(3), 493–512. https://doi.org/10.1007/s10798-018-9440-9

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14. https://doi.org/10.3102/0013189X015002004

Siekmann, G., & National Centre for Vocational Education Research (NCVER) (Australia). (2016). What is STEM? The need for unpacking its definitions and applications. *In National Centre for Vocational Education Research (NCVER).* National Centre for Vocational Education Research (NCVER). https://eric.ed.gov/?id=ED570651

Sterling, H. A. (2006). *Beginning elementary school teachers' perceptions of structural and cultural context factors impacting their science teaching*. Northern Arizona University.

Stohlmann, M., Moore, T. J., Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College*

Engineering Education Research 2:1, 28-34. https://doi.org/10.5703/1288284314653
Taylan, R. D., Tunç-Pekkan, Z., Aydın, U., & Birgili, B. (2022). Teacher educators in k-12 classrooms: How to nurture professional development and research. *Journal of Higher Education Theory & Practice*, *22*(1), 175–188. https://doi-org/10.33423/jhetp.v22i1.4974
Thomson, M. M., DiFrancesca, D., Carrier, S., Lee, C., & Walkowiak, T. A. (2018). Changes in teaching efficacy beliefs among elementary preservice teachers from a STEM-focused program: Case study analysis. *Journal of Interdisciplinary Teacher Leadership*, 2(1), 29–43. https://doi.org/10.46767/kfp.2016-0022
Yildirim, B., & Sahin-Topalcengiz, E. (2018). STEM pedagogical content knowledge scale (STEMPCK): A validity and reliability study. *Journal of STEM Teacher Education*, *53*(2), 3-22. https://eric.ed.gov/?id=ED593112

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