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Board 167: Exploring Elementary Pre-service Teachers' Personal Engineering Efficacy and Engineering Teaching Efficacy in a Science Methods Course Incorporating Engineering Design Activities (Work in Progress)

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Abstract

The recent incorporation of engineering in state and national standards requires elementary teachers to teach engineering within their science curricula. However, few elementary pre-service teachers (PSTs) feel confident about incorporating engineering into their science curricula. Research on how to support effective engineering design instruction in PSTs' elementary education programs is sparse. The present study investigated the impact of engaging 170 elementary PSTs in a K-8 science methods course that incorporated several engineering design activities on their engineering design efficacy (EDE) and engineering design teaching efficacy (EDTE). Students completed pre and post surveys of the of the Engineering Design Self-Efficacy Instrument (EDSI) to measure their EDE. They also completed the M-EDSI (a modified version of the EDSI) to measure their EDTE. Results from the pre-test ($M = 49.6$, $SD = 22.9$) and post-test ($M = 82.0$, $SD = 13.1$) indicate that PSTs' participation in an engineering-focused K-8 science methods course significantly improved their EDE, $t(169) = 19.7$, $p < .05$. Similarly, there was a statistically significant increase in PSTs' EDTE after participating in the course ($M = 83.0$, $SD = 13.3$) compared to before ($M = 42.5$, $SD = 25.2$), $t(169) = 21.0$, $p < .05$. The findings suggest that exposing elementary PSTs to multiple engineering design activities within science methods courses improves their EDE and EDTE. Implications of the results and future research plans are discussed in the paper.

Introduction

The President's Council of Advisors on Science and Technology [1] stresses the importance of engineering in the United States. Over the past few decades, the need to promote and improve engineering education in the US has fueled several science education reforms. One of the latest significant reforms is the introduction of the Next Generation Science Standards (NGSS). The NGSS launched in 2013, and 88% of the states are now using the NGSS or other standards modeled on the NGSS. These states account for approximately 71% of the US students [2]. The NGSS requires students to learn engineering within their K-12 science curriculum [3]. Likewise, K-12 teachers are expected to teach engineering within K-12 science curricula [4]. However, most teacher preparation programs do not provide pre-service teachers (PSTs) with training focused on how to teach engineering [5-8]. Similarly, most elementary school teachers lack strong engineering backgrounds or degrees [7, 9], are unfamiliar with engineering [10], and have a limited understanding of engineering [11, 12]. Research has repeatedly shown that many elementary school teachers are unprepared to teach engineering [8, 13-15]. Teachers also lack engineering teaching efficacy [16, 17] and feel unprepared to teach or develop classroom activities incorporating engineering design [18]. Typically, college science education curricula do not cover engineering design [19]. Yet, it has several benefits, including students' enhanced learning resulting from their engagement [20]. If teachers are to implement science education reforms such as the NGSS, they need to have high engineering teaching efficacy.

Conceptual framework: Self-efficacy

Bandura [21] defined Self-efficacy as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" [21]. According to research, self-efficacy is one of the most powerful tools for predicting individuals' behaviors [22] and success [23] in completing specific tasks. Furthermore, individuals with high self-efficacy towards completing specific tasks tend to be persistent when faced with setbacks [24], expend significant efforts in completing tasks [24] and succeed [21, 25]. According to Bandura [21], there are four sources of self-efficacy: vicarious experiences; verbal persuasion; physiological and emotional states; and mastery experiences. The latter refers to an individual's prior experiences and is believed to be the most powerful of the four. Teaching efficacy is a "teacher's belief in his or her capability to organize and execute courses of action required to accomplish a specific teaching task in a particular context" [22]. Engineering efficacy is an individual's belief that they can successfully complete a specific engineering task. The NGSS requires K-12 teachers to teach engineering design processes (EDP) within science curricula [3]. Prior experiences with engineering significantly influence an individual's engineering design efficacy (EDE) [26]. Thus, scholars such as Perkins Coppola [27] and Wendell, et al. [28] stress the need to engage PSTs in EDP to prepare them to teach project-based engineering. Yesilyurt, et al. [29] found that engaging PSTs in an elementary science methods course involving engineering design challenges significantly improved their engineering teaching efficacy beliefs. Similarly, Webb and LoFaro [30] discovered that exposing elementary PSTs to an engineering methods course significantly boosted their confidence in teaching engineering practices. A study by Kaya, et al. [16] engaged 20 elementary PST who were enrolled in a science methods course in an engineering design process that utilized 3D printing. The results showed that their self-efficacy in teaching engineering improved as a result. Hammack and Yeter [31] engaged elementary PSTs in multiple engineering design activities throughout the semester and found significant improvements in their engineering teaching efficacies.

Research Questions

The present study sought to answer the following research questions: (1) What is the impact of engaging elementary PSTs in a K-8 science methods course incorporating elements of engineering on their engineering design teaching efficacy (EDTE) and engineering design efficacy (EDE)? and (2) Is there a statistically significant correlation between elementary PSTs' EDE and their EDTE?

Methods

Demographic information for the participants is shared in Table 1. Participants included 170 PSTs enrolled in a three-credit 15-week-long K-8 science methods course as part of an elementary teacher preparation program at a public university in the Western United States. All elementary PSTs are required to complete this course because it prepares them to teach K-8 science US school settings. The course incorporated several engineering design activities. These included (1) a 1.5-hour introduction to engineering design lesson utilizing the Tower Power activity from the Engineering is Elementary website; (2) a four-hour activity that challenged PSTs to design and build an efficient thermal insulator; (3) a two-hour activity that required PSTs to watch a series of videos showing engineering lessons being taught in elementary school settings and then analyze the engineering teaching techniques they observed; (4) an hour-long engineering lesson focused on designing shade structures with kindergarteners; and (5) readings focused on engineering design, engineering habits of mind, assessment of engineering lessons, and ways of linking engineering to other standards such as math and language arts. The course was taught by a science education professor and offered in multiple modalities, including (1) face-to-face, (2) hybrid, and (3) rapid shift to online instruction. Out of the 170 participants, 97 completed the course through face-to-face modality, 39 through hybrid, and 34 through rapid shift online.

Table 1.
Participant description (n=170)

	Gender		Race/Ethnicity					
	Female	Male	White (not Hispanic)	AIAN	API	Hispanic	Other (Multiracial)	Not Available
Frequency	153	17	153	3	2	3	4	5
Percent	90	10	90	1.7	1.1	1.7	2.3	2.9

Data collection

The researchers modified the self-efficacy subscale of the Engineering Design Self-Efficacy Instrument (EDSI) [32] to create the modified Engineering Design Self-Efficacy Instrument (M-EDSI). This was achieved by adjusting the items of the EDSI to include teaching. For example, the item, “How confident are you in your ability to conduct engineering design” was changed to “How confident are you in your ability to teach your students to conduct engineering design”. Participants completed the pre-survey of EDSI and M-EDSI at the start and the post-survey EDSI and M-EDSI at the end of the science methods course. The EDSI measured the participants’ confidence in their engineering design abilities, with ten items rated on a 100-point scale (100 being the most confident). The M-EDSI assessed participants’ confidence in teaching engineering design skills, with nine items rated on the same scale. The authors added the EDSI and M-EDSI subscale items and demographic questions to a Qualtrics survey. The university gave participants access to the survey through its online course management system.

Data analysis

PSTs’ survey data were exported to Microsoft Excel and cleaned before moving them to STATA version 17. The authors conducted 2-tailed paired samples t-tests at $\alpha = 0.05$ using the mean scores from the EDSI and M-EDSI. The tests generated results that the team used to assess the intervention’s effect on the response variable. In addition, the authors evaluated the Pearson correlation coefficients ($\alpha = 0.05$) between students’ EDE and their EDTE, first using pre-scores and then post-scores. This was followed by computing Cronbach’s reliability scores for the author-generated M-EDSI.

Findings

Engineering design teaching efficacy

As shown in Table 2, the participants' engineering design teaching efficacy (EDTE) showed remarkable improvement after completing the course, with the average teaching efficacy for engineering design rising 40 points (95.97%) from the pre to post.

Table 2

Paired sample t-test for elementary PSTs' pre and post EDTE

Variable	N	Mean	Std. err.	Std. dev.	[95% conf.interval]	
Pre-test	170	42.465	1.932	25.191	38.651	46.279
Post-test	170	83.082	1.019	13.292	81.070	85.095
t = 21.0409			df= 169			p=0.000

Engineering design efficacy

Table 3 shows participants' mean scores on engineering design efficacy (EDE) before and after participating in a K-8 science methods course. As seen in Table 3, the total mean of PSTs' scores from pre-test to post-test increased by 32 points (65.08%).

Table 3

Paired samples t-test for elementary PSTs' pre and post EDE

Variable	N	Mean	Std. err.	Std. dev.	[95% conf.interval]	
Pre-test	170	49.559	1.757	22.906	46.091	53.027
Post-test	170	82.024	1.003	13.076	80.044	84.003
t = 19.7143			df= 169			p =0.000

Correlation between EDE and EDTE

The research team computed Pearson correlation coefficients to assess the relationship between PSTs' EDE and EDTE, using their pre-test and post-test scores. The results showed a strong, positive correlation between PSTs' EDE and EDTE pre-scores ($r(169) = .908, p < .05$). A similar strong positive correlation was observed between PSTs' EDE and EDTE post-scores ($r(169) = 0.898, p < .05$). These findings provide evidence that elementary PSTs' EDE and EDTE are strongly associated.

Reliability of the M-EDSI

Findings indicate Cronbach's alpha values of .908 and .898 for the pre and post, respectively. Additionally, results show that deleting any of the nine items of the M-EDSI would still result in an overall Cronbach's alpha greater than .90. According to George and Mallery [33], Cronbach's alpha values greater than .90 are considered excellent [33]. Therefore, these results suggest that the M-EDSI is reliable for measuring students' EDTE.

Discussion

While previous research explores the topic of engineering teaching efficacy, the present study offers a novel perspective by specifically addressing Engineering Design Teaching Efficacy

(EDTE). This is important because engineering design is a major part of the NGSS [3] and is linked to students' enhanced learning [20]. The findings show that the intervention did not just significantly improve participants' EDTE but also their EDE. Mastery experiences is a primary source of self-efficacy development [21]. Therefore, PSTs' improved EDE could be attributed to their active engagement in multiple engineering design activities, which provided them with mastery experiences.

Research shows that vicarious experiences have a significant positive influence on the development of teachers teaching efficacy [30, 34]. Therefore, vicarious experiences obtained from watching and analyzing a series of videos showing engineering lessons being taught in elementary school settings could have increased PSTs' EDTE [21]. This study suggests that engaging elementary PSTs in science methods courses incorporating engineering design activities significantly improves their EDTE and EDE. These findings align with prior studies that found that engaging PSTs in engineering activities can enhance their engineering teaching efficacy [16, 29, 31].

In this study, participants were predominantly White (90%) and female (90%). Literature shows that gender and race are important variables that may affect individuals' science-related efficacies [35, 36]. Therefore, it is crucial to acknowledge that large differences between race and gender categories could have mediated the relationship between our intervention and dependent variables. These gender and racial disparities also imply that generalizations of these findings may only be made to PSTs with similar racial and gender distributions.

Furthermore, the findings revealed a positive correlation between PSTs' EDTE and their EDE, and this relationship was statistically significant. This means that an improvement in PSTs' EDTE is associated with a corresponding increase in their EDE and vice-versa [34, 37-41]. When an individual has a high level of efficacy in particular subjects, it can often translate to a higher level of efficacy in teaching that subject as well [42]. This is because when someone has a deep understanding and mastery of a subject, they are better prepared to explain complex concepts, answer questions, and provide effective feedback [42]. However, a statistically significant correlation does not infer causality [43], implying that this statistically significant correlation does not indicate a causal relationship between EDTE and EDE. Future studies should design and conduct studies exploring the causal relationship between PSTs' EDTE and EDE to understand the relationship between the two constructs better.

Finally, the research team analyzed the internal consistency of the M-EDSI by analyzing pre and post data from the same participants. The M-EDSI was reliable, with Cronbach's alpha values of .908 and .898, respectively. However, considering that this study is the first to use the M-EDSI, it will be worthwhile to test the M-EDSI across different sets of elementary PSTs to ascertain its reliability further, especially with larger sample sizes. Therefore, we recommend conducting additional studies using the M-EDSI to reinforce its reliability and gain a deeper understanding of its factors through exploratory and confirmatory factor analysis. We plan to continue collecting data using the M-EDSI and achieve a larger sample size from which we will reassess its reliability and determine its underlying factors. With a larger sample size, we may also be able to obtain a greater number of participants in the underrepresented gender and race categories. This could allow for further examination of race and gender as potential mediators of the causal relationship between students' participation in the science methods course and their EDTE and EDE.

Conclusion

The findings from the present study support engaging elementary PSTs in multiple engineering design activities within science methods courses to bolster their EDTE and EDE. Teacher educators wanting to help their PSTs develop their EDTE and EDE should consider providing them with multiple opportunities to engage with engineering design directly within science methods courses. The study also provides evidence that the M-EDSI is reliable for measuring PSTs' EDTE. However, there is a need to conduct studies to validate the instrument. Given that this study only employed quantitative data, in the future, qualitative data (i.e., focus group interviews) would be necessary to help explain particular components of the science methods course responsible for PSTs' changes in EDTE and EDE. This approach may also help explain how PSTs' EDTE and EDE change over time.

References

[1] The President's Council of Advisors on Science and Technology, "Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Mathematics (STEM)," 2010. [Online]. Available: https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-stem-ed-final.pdf.

[2] Carnegie Corporation of New York. "The Need to Align Teaching with Next Generation Science Standards." https://www.carnegie.org/our-work/article/need-curriculum-based-professional-learning-align-teacher-practice-next-generation-science-standards/ (accessed December 10th, 2022, 2022).

[3] NGSS Lead States, *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press (in English), 2013, p. 532.

[4] T. J. Moore, K. M. Tank, A. W. Glancy, and J. A. Kersten, "NGSS and the landscape of engineering in K-12 state science standards," *Journal of Research in Science Teaching,* vol. 52, no. 3, pp. 296-318, 2015.

[5] R. Hammack and T. Ivey, "Elementary teachers' perceptions of K-5 engineering education and perceived barriers to implementation," *Journal of Engineering Education,* vol. 108, no. 4, pp. 503-522, 2019.

[6] R. Hammack, P. Gannon, C. Foreman, and E. Meyer, "Impacts of professional development focused on teaching engineering applications of mathematics and science," *School Science and Mathematics,* vol. 120, no. 7, pp. 413-424, 2020, doi: 10.1111/ssm.12430.

[7] E. R. Banilower, P. S. Smith, K. A. Malzahn, C. L. Plumley, E. M. Gordon, and M. L. Hayes, "Report of the 2018 NSSME+," *Horizon Research, Inc.,* 2018.

[8] R. Hammack and T. Ivey, "Examining elementary teachers' engineering self-efficacy and engineering teacher efficacy," *School Science and Mathematics,* vol. 117, no. 1-2, pp. 52-62, 2017, doi: 10.1111/ssm.12205.

[9] E. J. Kang, C. Donovan, and M. J. McCarthy, "Exploring elementary teachers' pedagogical content knowledge and confidence in implementing the NGSS science and

engineering practices," *Journal of Science Teacher Education,* vol. 29, no. 1, pp. 9-29, 2018, doi: 1046560X.2019.1630794.

[10] Ş. Yaşar, D. Baker, S. Robinson-Kurpius, S. Krause, and C. Roberts, "Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology," *Journal of Engineering education,* vol. 95, no. 3, pp. 205-216, 2006.

[11] H. Deniz, E. Kaya, and E. Yesilyurt, "The differential impact of two engineering professional development programs on elementary teachers' engineering teaching efficacy beliefs," in *Annual meeting of National Association for Research in Science Teaching, Atlanta, GA*, 2018.

[12] H. Deniz, E. Yesilyurt, E. Kaya, and M. Trabia, "The influence of an authentic engineering design experience on elementary teachers' nature of engineering views," *Journal of Science Education and Technology,* 2017.

[13] E. R. Banilower, P. S. Smith, I. R. Weiss, K. A. Malzahn, K. M. Campbell, and A. M. Weis, "Report of the 2012 national survey of science and mathematics education," *Horizon Research, Inc.(NJ1),* 2013.

[14] P. J. Trygstad, P. S. Smith, E. R. Banilower, and M. M. Nelson, "The Status of Elementary Science Education: Are We Ready for the Next Generation Science Standards?," *Horizon Research, Inc.,* 2013.

[15] National Academies of Sciences, Engineering, and Medicine [NASEM],, "Call to action for science education: Building opportunity for the future," 2021, doi: 10.17226/26152.

[16] E. Kaya, A. Newley, E. Yesilyurt, and H. Deniz, "Improving preservice elementary teachers' engineering teaching efficacy beliefs with 3D design and printing," *Journal of College Science Teaching,* vol. 48, no. 5, pp. 76-83, 2019.

[17] J. L. Sargent, B. M. Holloway, S. R. Bayley, and A. V. Walter, "Investigation of Pre-Service Teacher Self-Efficacy for Teaching Engineering," in *2018 ASEE Annual Conference & Exposition*, 2018, doi: 10.18260/1-2--30729.

[18] K. L. Turner Jr, M. Kirby, and S. Bober, "Engineering design for engineering design: Benefits, models, and examples from practice," *IE: inquiry in Education,* vol. 8, no. 2, p. 5, 2016.

[19] N. G. Lederman and J. S. Lederman, "Next Generation Science Teacher Educators," *Journal of Science Teacher Education,* vol. 24, no. 6, pp. 929-932, 2013/10/01 2013, doi: 10.1007/s10972-013-9359-7.

[20] K. Heroux, K. Turner, and B. Pellegrini, "The MWM approach to technological design," *Journal of Materials Education,* vol. 32, no. 5, p. 231, 2010.

[21] A. Bandura, "Self-efficacy: toward a unifying theory of behavioral change," *Psychological review,* vol. 84, no. 2, p. 191, 1977, doi: 10.1037/0033-295X.84.2.191.

[22] M. Tschannen-Moran, A. W. Hoy, and W. K. Hoy, "Teacher efficacy: Its meaning and measure," *Review of educational research,* vol. 68, no. 2, pp. 202-248, 1998, doi: 10.3102/00346543068002202.

[23] M. Poulou, "Personal Teaching Efficacy and Its Sources: Student teachers' perceptions," *Educational Psychology,* vol. 27, no. 2, pp. 191-218, 2007/04/01 2007, doi: 10.1080/01443410601066693.

[24] D. H. Palmer, "Sources of self-efficacy in a science methods course for primary teacher education students," *Research in Science Education,* vol. 36, no. 4, pp. 337-353, 2006, doi: 10.1007/s11165-005-9007-0.

[25] A. Bandura, "Self-efficacy mechanism in human agency," *American psychologist,* vol. 37, no. 2, p. 122, 1982, doi: 10.1037/0003-066X.37.2.122.

[26] A. Carberry, M. Ohland, and H. S. Lee, "Developing an instrument to measure engineering design self-efficacy: A pilot study," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2009.

[27] M. Perkins Coppola, "Preparing preservice elementary teachers to teach engineering: Impact on self-efficacy and outcome expectancy," *School Science and Mathematics,* vol. 119, no. 3, pp. 161-170, 2019, doi: 10.1111/ssm.12327.

[28] K. B. Wendell, J. E. S. Swenson, and T. S. Dalvi, "Epistemological framing and novice elementary teachers' approaches to learning and teaching engineering design," *Journal of Research in Science Teaching,* vol. 56, no. 7, pp. 956-982, 2019, doi: 10.1002/tea.21541.

[29] E. Yesilyurt, H. Deniz, and E. Kaya, "Exploring sources of engineering teaching self-efficacy for pre-service elementary teachers," *International Journal of STEM Education,* vol. 8, no. 1, pp. 1-15, 2021.

[30] D. L. Webb and K. P. LoFaro, "Sources of engineering teaching self-efficacy in a STEAM methods course for elementary preservice teachers," *School Science and Mathematics,* vol. 120, no. 4, pp. 209-219, 2020, doi: 10.1111/ssm.12403.

[31] R. Hammack and I. H. Yeter, "Exploring pre-service elementary teachers' engineering teaching efficacy beliefs: A confirmatory analysis study (fundamental)," in *2022 ASEE Annual Conference & Exposition*, 2022. [Online]. Available: https://peer.asee.org/41231. [Online]. Available: https://peer.asee.org/41231

[32] A. R. Carberry, H. S. Lee, and M. W. Ohland, "Measuring engineering design self-efficacy," *Journal of Engineering Education,* vol. 99, no. 1, pp. 71-79, 2010, doi: 10.1002/j.2168-9830.2010.tb01043.x.

[33] D. George and M. Mallery, "Using SPSS for Windows step by step: a simple guide and reference," 2003.

[34] D. Menon and T. D. Sadler, "Preservice elementary teachers' science self-efficacy beliefs and science content knowledge," *Journal of Science Teacher Education,* vol. 27, no. 6, pp. 649-673, 2016, doi: 10.1007/s10972-016-9479-y.

[35] D. L. Witt-Rose, "Student self-efficacy in college science: An investigation of gender, age, and academic achievement," 2003.

[36] I. M. Riggs, "Gender Differences in Elementary Science Teacher Self-Efficacy," 1991.

[37] S. L. Britner and F. Pajares, "Sources of science self-efficacy beliefs of middle school students," *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching,* vol. 43, no. 5, pp. 485-499, 2006, doi: 10.1002/tea.20131.

[38] R. E. Bleicher and J. Lindgren, "Success in science learning and preservice science teaching self-efficacy," *Journal of science teacher education,* vol. 16, no. 3, pp. 205-225, 2005, doi: DOI:10.1007/s10972-005-4861-1.

[39] D. Palmer, "Sources of efficacy information in an inservice program for elementary teachers," *Science education,* vol. 95, no. 4, pp. 577-600, 2011, doi: 10.1002/sce.20434.

[40] J. Mulholland, J. P. Dorman, and B. M. Odgers, "Assessment of science teaching efficacy of preservice teachers in an Australian university," *Journal of science teacher education,* vol. 15, no. 4, pp. 313-331, 2004.

[41] O. S. Jarrett, "Science interest and confidence among preservice elementary teachers," *Journal of elementary science education,* vol. 11, no. 1, pp. 49-59, 1999, doi: 10.1007/BF03173790.

[42] A. Bandura, *Self-Efficacy: The Exercise of Control*. New York: W. H. Freeman and Company, 1997.

[43] C. L. Willett, "Why Correlation Doesn't Imply Causation: Improving Undergraduates Understanding of Research Design," University of Pittsburgh, 2023.