Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #46721

BOARD # 352: DRK-12 Examining Changes in Elementary Teachers' Engineering Self-Efficacy Across a Year-Long Professional Learning Program

Prof. Ryan G. Summers, University of North Dakota

Ryan Summers is an Associate Professor of Science Education in the Department of Teaching, Leadership, and Professional Practice. He is the principal investigator of "Investigating how combining intensive professional development and modest support affects rural, elementary teachers' science and engineering practice" (NSF Award 2201249).

Dr. Rebekah J Hammack, Purdue University at West Lafayette (PPI)

Rebekah Hammack is an Assistant Professor of K-8 Science Education at Purdue University. She served as an Albert Einstein Distinguished Educator Fellow in the Division of Research on Learning in Formal and Informal Learning. Dr. Hammack's research focuses on the connection of local contexts to STEM interest and identity development in youth, particularly rural youth in elementary and middle grades, as well as how elementary teachers develop teaching efficacy and identity as STEM educators. Through her research, Dr. Hammack aims to advance understanding of how to enhance STEM education in rural schools and communities, providing opportunities to meet the unique needs of rural students.

Julie Robinson, University of North Dakota

Dr. Julie Robinson is an Assistant Professor at the University of North Dakota and the Director of UND's Center for Engineering Education Research. Her research explores strategies for broadening access and participation in STEM, focusing on culturally relevant pedagogy in science and engineering. She also investigates strategies for increasing representation in STEM through teacher professional learning opportunities and by exploring the impact of group gender composition on girls' motivation and engagement. Dr. Robinson is a PI and Co-PI on several NSF sponsored grant projects which focus on teacher professional learning and self-efficacy with implementing culturally relevant engineering education, connecting to place and community, and centering culture and Indigeneity within STEM education. Dr. Robinson has over twenty years of K – 12 teaching experience, including seven years as a teacher leader of professional development in the Next Generation Science Standards, the Common Core State Standards in Mathematics, and in elementary science and engineering pedagogy.

Min Jung Lee, University of North Dakota
Dr. Tugba Boz, Indiana-Purdue University

Dr. Tugba Boz works as a postdoctoral scholar at PURDUE UNIVERSITY.

Martha Inouye, University of Wyoming
Meghan Macias
Ashley Iveland

DRK-12 Examining Changes in Elementary Teachers' Engineering Self-Efficacy Across a Year-Long Professional Learning Program

Introduction

Engineering education prepares students to think critically, make decisions, and pursue STEM careers and educational trajectories. The three-dimensional approach to STEM instruction and the integration of engineering within *A Framework for K-12 Science Education* represents a paradigm shift embodied by the Next Generation Science Standards (NGSS) (National Research Council, 2012; NGSS Lead States, 2013). One of the hurdles to achieving this ambitious vision is the preparation of teachers (Banilower et al., 2019). Many teachers, particularly in elementary grades, lack the self-efficacy needed to incorporate engineering in their lessons (Hammack & Ivey, 2017; Cadero-Smith, 2020). Self-efficacy to teach engineering is an individually held belief that is associated with classroom behaviors and learning outcomes (Yoon et al., 2014).

Conceptual Framework

Teacher self-efficacy in any content area is a strong predictor of both student motivation and learning outcomes; this is particularly notable in STEM domains. Teachers' perceptions of their own STEM knowledge are shown to directly affect the effectiveness of their instruction (Hammack & Ivey, 2017; Zee & Koomen, 2016). Therefore, understanding the components and conditions of professional development that will have the greatest impact on teachers' engineering education self-efficacy, particularly across various subgroups, is essential for providing more meaningful teacher training to impact practice.

Self-efficacy is a person's conviction they can successfully produce desired outcomes, Bandura (1977; 1982) delineated the following dimensions: efficacy expectation and outcome expectancy. Efficacy expectation is a person's belief that they can successfully perform the behavior required to achieve the desired outcome, while outcome expectancy is the belief that carrying out that behavior will result in the expected outcome. Self-efficacy arises from four sources: mastery experiences (e.g., experiencing success), vicarious experiences (e.g., observing a role model succeeding in a particular area), physical and emotional/affective states (e.g., positive emotions or physiological responses), and social or verbal persuasion (e.g., feedback given by role models). These sources of self-efficacy illuminate components of professional learning that have the potential to impact teachers' perceptions of their ability to deliver engineering instruction.

Research on engineering teaching self-efficacy has identified multiple domains (Yoon et al., 2014): engineering knowledge, and instructional, disciplinary, motivational and engagement self-efficacy, and outcome expectancy. Research exploring teachers' engineering self-efficacy indicates that each of these domains may be impacted differently through professional learning and intervention. Activities that involve explicit reflection and those that develop teachers' content and pedagogical mastery have been found to have the greatest impact on teachers' overall engineering self-efficacy (Yesilyurt et al., 2021).

Research Questions

RQ1) To what extent did the intensive PL experience improve teachers' self-efficacy and outcome expectations associated with NGSS-aligned engineering instruction?
RQ2) What changes, if any, were observed in teachers' engineering self-efficacy during the following academic year?

Project Description

Participants

Researchers located in each of the four states coordinated the recruitment of approximately 150 rural teachers in grades 3-5. This study had an analytic sample of 87 teachers who fully participated in PL and research activities between July 2023 and June 2024. Participants were nearly evenly distributed across CA, MT, ND, and WY (18-26 teachers per state). Teaching assignments during the study period spanned grades 3 (n=29; 33.3%), 4 (n=20; 23.0%), and 5 (n=10; 11.5%), plus some teaching multiple grades (n=28; 32.2%). Seventy-seven percent of participants taught in self-contained classrooms (all core academic subjects).

Professional Learning Intervention

During July-August 2023 a team of PL experts facilitated an intense, online five-day PL. The weeklong institute was co-designed and delivered by K-12 Alliance, who are adept in online PL with many years of experience helping educators make sense of the NGSS. Topics in the PL covered the shifts called for by NGSS, including 3-dimensional instruction and engineering design, along with the implications for instruction. Teachers completed synchronous and asynchronous activities each day, which were designed to allow for collaboration. Details about the PL intervention have been reported previously (Hammack et al., 2024).

Modest Supports Throughout School Year

Over the 2023-2024 academic year, we provided teachers with modest supports to promote enduring PL outcomes (Sandholtz et al., 2023). Seven 90-minute-long online professional learning community (PLC) sessions were offered during 2023-2024. Two 90-minute-long online PLC sessions were engineering-focused, which will be briefly summarized for the purposes of this paper (see Hammack et al., 2024). The first of these PLCs introduced participants to the Culturally Relevant Engineering Design (CRED) Framework (Bowman et al., 2024), they used this framework to design engineering lessons around extreme weather problems specific to their place. The second of these PLCs afforded participants time to work collaboratively in grade-level breakout rooms to finalize their CRED lesson plans. Participants were also given access to a variety of electronic supports via a Google Classroom and materials for teaching these lessons.

Measures

We administered the Teacher Efficacy and Attitudes toward STEM (T-STEM) Survey (Friday Institute for Educational Innovation, 2012) before and immediately following the summer PL institute. Participating teachers completed the Engineering Teaching Efficacy and Beliefs (11 items) and the Engineering Teaching Outcome Expectancy (9 items) subscales of the T-STEM Survey via Qualtrics. A delayed post-PL survey was conducted near the end of the school year.

Data Analysis

Data were analyzed in R (Bryer & Speerschneider, 2016). Confirmatory factor analysis results approached satisfactory model fit across all time points. Comparative Fit Index ranged .829 to .925 (>.90; Byrne, 1994), which were acceptable, and Tucker Lewis Index ranged .786 to .942 with good fit (>.90; Bentler & Bonett, 1980). Each of the T-STEM subscales used displayed acceptable internal consistency and reliability for each time point (Taber, 2018); Cronbach's alpha self-efficacy (.74 to .86) and outcome expectancy (.89 to .91). Paired t-tests and repeated measures ANOVA were used to compare the mean responses collected using these subscales across multiple time points. Adjusted p-values were computed as needed to interrogate statistical significance of pairwise comparisons. Mauchly's test of sphericity was used to examine the variances of the differences between all combinations of related groups.

Results

Pre-PL to immediate post-PL (RQ1) results indicate a significant increase in participants' engineering self-efficacy, $t(86) = -11.14$, $p = <.001$. The observed change in outcome expectancy during the same period was also significant, $t(86) = -3.75$, $p = <.001$. Based on Cohen's d, the intervention had a moderate-large effect on participants' self-efficacy (.73) and a small (.18) effect on their outcome expectancy (Cohen, 1988).

Paired t-tests were used to investigate changes observed during the academic year (RQ2). Results indicate a significant increase in participants' engineering self-efficacy between the immediate post- and the delayed post-PL time points, $t(86) = -0.08$, $p = .932$. The change in outcome expectancy during the same period was not significant, $t(86) = 0.748$, $p = .456$. Investigating change across the three time points simultaneously, using repeated measures ANOVA, indicate significant changes in participants' efficacy beliefs. For Engineering Teaching Efficacy, the mean scores significantly increased from 2.99 (SD = .67) pre-PL to 3.72 (SD = .41) immediate post-PL, then held steady at 3.72 (SD = .45) delayed post-PL. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(df) = .87$, $p = .003$. Adjusted values were significant: Greenhouse-Geisser, $F(2, 153) = 108.66$, $p <.001$; Huynh-Feldt, $F(2, 156) = 106.62$, p <.001. Participants' engineering teaching outcome expectancy also increased significantly, $F(2, 172) = 6.69$, $p <.05$* $\eta g2= .02$. Mean scores increased from 3.49 (SD = .50) pre-PL to 3.67 (SD = .56) immediate post-PL, and stayed positive at 3.63 (SD = .55) delayed post-PL.

Self-efficacy and outcome expectancy data were further explored alongside individual and group level variables. No statistically significant differences were observed based on participants' teaching experience or the grade level(s) taught (grades 3, 4, 5, or multi-grade). Similarly, no significant differences were observed between groups based on rurality (state, locale).

Discussion

Participants showed growth in their engineering self-efficacy and outcome expectancy between pre- and immediate post-PL following intense, online PL. Teachers' self-efficacy and outcome expectancy was mostly maintained during the subsequent year. Findings are consistent with prior research that have leveraged similar interventions with elementary teachers (Sandholtz et al., 2023). The modest supports that were part of the long-term intervention in this study (e.g., engineering PLC sessions) appear to help sustain positive outcomes. Related research has found that structured collaboration can aid the development of teachers' instructional practice (Weddle, 2022). This research has direct implications for improved teacher PL design along with the prospect of impacting student learning through improved instruction.

Acknowledgment

Research presented is supported by the National Science Foundation (NSF) under DRK-12 Award #2201249. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.

References

A. Bandura, "Self-efficacy: Toward a unifying theory of behavioral change," *Psychological Review*, vol. 84, no. 2, pp. 191–215, 1977.

A. Bandura, "Self-efficacy mechanism in human agency," *American Psychologist*, vol. 37, no. 2, pp. 122–147, 1982.

E. R. Banilower, "Understanding the big picture for science teacher education: The 2018 NSSME+," *Journal of Science Teacher Education*, vol. 30, no. 3, pp. 201–208, 2019.

P. M. Bentler and D. G. Bonett, "Significance tests and goodness of fit in the analysis of covariance structures," *Psychological bulletin*, vol. 88, no. 3, p. 588, 1980.

F. Bowman, B. Klemetsrud, and J. Robinson, *Impact of professional development in culturally relevant engineering design for elementary and middle school teachers*, Proceedings of the American Society of Engineering Education Annual Conference, Portland, OR, USA, 2024.

J. Bryer and K. Speerschneider, "Likert: Analysis and Visualization Likert Items (1.3.5)," 2016. [Online]. Available: Computer software, https://bryer.org/project/likert/ [Accessed Jan. 14 2025].

B. M. Byrne, "Testing for multigroup invariance using AMOS graphics: A road less traveled," *Structural equation modeling*, vol. 11, no. 2, pp. 272-300, 2004.

L. A. Cadero-Smith, *Teacher professional development challenges faced by rural superintendents.* I. Sahin & P. Vu (Eds.). San Antonio, TX: ISTES Organization, 2020.

J. Cohen, *Statistical Power Analysis for the Behavioral Sciences*. Milton Park, UK: Routledge Academic, 1988.

Friday Institute for Educational Innovation, "Teacher efficacy and attitudes toward STEM survey," North Carolina State University, 2012. [Online]. Available: http://miso.ncsu.edu/articles/t-stemsurvey-2 [Accessed Jan. 14, 2025].

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.

R. Hammack, J. Robinson, T. Boz., M. J. Lee, R. Summers, A. Iveland, M. Inouye, M. Macias, M. Zaman, J. Galisky, N. Johansen, and C. Ringstaff, *Supporting Elementary Engineering Instruction in Rural Contexts Through Online Professional Learning and Modest Supports*, Proceedings of the American Society of Engineering Education Annual Conference, Portland, OR, USA, 2024.

National Research Council, *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press, 2012.

NGSS Lead States, *Next Generation Science Standards: for states, by states.* Washington, DC: The National Academies Press, 2013.

J. H. Sandholtz, C. Ringstaff, and J. Triant, "Professional development tune-up," *Phi Delta Kappan*, vol. 104, no. 8, pp. 31-35, 2023.

K. S. Taber, "The use of Cronbach's alpha when developing and reporting research instruments in science education," *Research in science education*, vol. 48, pp. 1273-1296, 2018.

H. Weddle, "Approaches to studying teacher collaboration for instructional improvement: A review of literature," *Educational Research Review*, vol. *35*, no. 100415, 2022.

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

S. Yoon, M. G. Evans, and J. Strobel, "Validation of the teaching engineering self-efficacy scale for K-12 teachers: A structural equation modeling approach," *Journal of Engineering Education*, vol. 103, no. 3, pp. 463–485, 2014.

M. Zee and H. M. Y. Koomen, "Teacher self-efficacy and its effects on classroom processes, student academic adjustment, and teacher well-being: A synthesis of 40 years of research," *Review of Educational Research*, vol. 86, no. 4, pp. 981–1015, 2016.