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Engineering Professional Development for the Elementary Educator: A Review of the Literature

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Abstract

While standards and policies have been developed to increase elementary students' engagement with engineering, a lack of engineering-focused teacher preparation coursework and professional development (PD) has left the majority of K-5 teachers unprepared to integrate engineering into their current classroom practices. The purpose of this literature review was to explore the ways in which researchers have conceptualized, developed, and implemented engineering-focused PD for elementary educators. Findings suggest most PD sessions aimed to develop teachers understanding of and self-efficacy toward implementing engineering/STEM integration (n=15), the engineering design process (n=13), and engineering content knowledge (n=13). A balance of quantitative, qualitative, and mixed methods studies were employed to assess the success of each PD program which ranged in length from 6 hours-152 hours. Based on the findings from this literature review, the design, implementation, and evaluation of future development should address two gaps: (1) the needs of teachers who have experience with engineering education and (2) the lack of critical frameworks.

Aim

The purpose of this literature review is to explore the available research on engineering-focused teacher preparation and PD for elementary educators. More specifically, this literature review seeks to understand the focus and structure of existing PD programs, the theoretical and conceptual frameworks used to guide the development of each PD program, and to establish an understanding of the research methods and data collection tools employed to understand the impact of engineering-focused PD on elementary educators.

Problem

Until recently, there has been no well-established tradition of engineering in the K-12 classroom, however, the formation and adoption of the *Next Generation Science Standards* (*NGSS*) or similar frameworks by 44 states across the country (US), as well as the establishment of the *Framework for K-12 Science Education* (NRC, 2012), has brought engineering-focused practices, disciplinary core ideas, and crosscutting concepts towards the forefront of STEM instruction. Educational researchers have found that the integration of engineering into K-12 spaces can improve students' academic performance in math (Cunningham & Lachapelle, 2007; Diaz & King, 2007; Fortus et al., 2004) and science (Cunningham et al., 2020). Additionally, engineering education has the potential to engage students in 21st century skills (Meyer & Tauer, 2015), enhance students' understanding of what engineers do (Thompson & Lyons, 2008), and increase the number of students who would consider pursuing careers in engineering (Chan et al., 2019).

The problem with integrating engineering into the K-12 classroom then, lies not in the pedagogy itself, but in the preparation of the teacher, as most remain unprepared to engage students in engineering content and practices (Katehi et al., 2009). The majority of teacher preparation programs in the United States require minimal science, mathematics, and technology methods courses for pre-service teachers at the elementary level and historically, engineering has not been addressed at all. Additionally, opportunities for engineering-focused PD for in-service teachers are limited. Banilower et al. (2018) found that the majority of elementary teachers (63%) received less than 6 hours of science PD within a three-year span. The lack of attention to engineering in teacher preparation programs and PD programs is troubling, considering the vast majority of elementary teachers lack even a general understanding of what engineers do (Cunningham et al., 2006) and how engineers use mathematics and science (Hammack et al., 2020), therefore leaving teachers with little to no preparation for effectively engaging elementary students in engineering concepts and practices (Lachapelle & Cunningham, 2014; Katehi et al., 2009, National Commission on Mathematics and Science Teaching for the 21st Century, 2000).

To remediate this problem, some schools, universities, and organizations have developed and implemented engineering-focused PD in the hopes of increasing teachers' engineering content knowledge and self-efficacy, while simultaneously improving their pedagogical practices. The purpose of this literature review is to examine the ways in which educational researchers have developed, implemented, and examined the impact of engineering focused PD for elementary educators thus far.

Methodology

A three-phase process was employed to review the relevant literature on engineering-focused PD for elementary educators. Phase 1 included a search of the database, ERIC. Database scanning produced 193 peer-reviewed articles based on the main search terms of *engineering, PD, and elementary*. The database search indicated that a large portion of relevant articles were published in *School Science and Mathematics, Journal of Science Teacher Education*, and *Journal of Pre-College Engineering Education Research*. Phase 2 began with an initial screening of all 193 articles, which involved reading the title and abstract of each article. Application of the exclusion criteria eliminated studies that did not specifically focus on engineering (i.e. PD programs that addressed integrated STEM in general) and studies that did not include elementary educators, thus reducing the number of studies for further analysis to 40. To conduct Phase 3, a spreadsheet was created in Google Sheets to organize key pieces of information from each article such as the design of the study, delivery of the PD, and key findings. As each of the 40 articles were read, notes were added to the Google Sheet, which allowed for the analysis and synthesis of the articles over time. Additionally, the Google Sheet allowed for the comparison of frameworks, approaches, and findings across the articles.

Research Findings

The purpose of this literature review was to examine the ways in which educational researchers have developed, implemented, and examined the impact of engineering focused PD for elementary educators. In terms of the methodology employed, there were 13 quantitative studies, 14 qualitative studies, and 13 mixed methods studies. The most commonly used data collection tools included surveys and questionnaires, knowledge tests, interviews and focus groups, observations, and artifacts such as lesson plans. Less frequently used data collection methods included photos and photo-journals, the Draw-an-Engineer Test, reflective diaries, and research memos/field notes. Regarding theoretical and conceptual frameworks, Bandura’s self-efficacy theory (n=10), engineering integration or STEM Integration (n=5), the nature of engineering (n=3) and engineering design (n=2) were utilized most often. It should be noted, however, that nearly a third of all studies (n=13) failed to explicitly articulate the theoretical or conceptual framework utilized.

The focus and structure of each engineering PD varied. Educational researchers tended to address a specific grade, grade range, or elementary teachers as a whole. Other researchers developed more broad scoping PD programs in which multiple levels were included (i.e. elementary, middle school, and high school teachers). The length of the PD sessions varied widely, with some PD sessions lasting just one day (6 hours), while others were 4 weeks (152 hours) in length. The focus of the PD sessions was often on engineering/STEM integration (n=15), the engineering design process (n=13), and engineering content knowledge (n=13). Additional foci included curriculum development (n=5), the use of specific curriculum such as Engineering is Elementary (n=5) and engineering practices (n=4). During the PD sessions themselves, researchers engaged teachers in engineering design challenges, lesson planning, lectures and dialogue, dramatic inquiry, modeling and observing, tool development, and discussions with engineers as guest speakers.

Limitations

While this was an extensive review of the literature, it was by no means exhaustive. The cross referencing of other databases such as ProQuest and Google Scholar, as well as the consideration of studies cited in each journal article would further contribute to my overall understanding of engineering-focused PD for elementary educators. Additional search terms such as *teacher education, teacher preparation, elementary teacher education, teacher PD* should also be utilized in the future to ensure all applicable studies are retrieved for analysis.

Research Implications

The findings from this literature review call for the design, implementation, and assessment of engineering-focused PD for elementary educators in two specific areas. First, the majority of the engineering PD sessions evaluated were geared towards teachers who had little to no engineering experience. Given that the NGSS were written and adopted by states nearly a decade ago, it may be necessary to start gearing some engineering PD sessions towards enhancing the existing pedagogical practices of elementary teachers, specifically identifying and addressing any observable or perceived areas of need. Second, the PD evaluated in this literature review often lacked an explicit theoretical or conceptual framework to serve as the foundation of the study. Furthermore, none of the PD programs approached engineering instruction through a critical lens. Due to the increasingly diverse population of US schools and the overall goal of increasing the number of female and minority students pursuing STEM careers, it is imperative that teachers understand how to utilize students' personal identities as the premise of their STEM instruction. For that reason, future PD should employ theories and frameworks such as feminist theory, sociotransformative constructivism, or culturally relevant pedagogy as the foundation of their program development.

Conclusion

This literature review was conducted to better understand the present state of engineering-focused PD for elementary educators by elucidating current trends and patterns in this line of inquiry and identifying active gaps. Two gaps identified in this literature review included the lack of engineering PD geared toward teachers who have already integrated engineering into their elementary classrooms and the absence of engineering-focused PD that utilized critical theories, pedagogies, and frameworks as the foundation of their program development. This literature review can offer a conceptual basis for the development and implementation of future engineering-focused PD opportunities for elementary educators.

References

Banilower, E.R., Smith, P.S., Malzahn, K.A., Plumley, P.L., Gordon, E.M. & Hayes, M.L. (2018). *Report of the 2018 NSSME*. Horizon Research, Inc.

Chan, C. K. Y., Yeung, N. C. J., Kutnick, P., & Chan, R. Y. Y. (2019). Students' perceptions of engineers: Dimensionality and influences on career aspiration in engineering. *International Journal of Technology and Design Education*, *29*(3), 421-439. https://doi.org/10.1007/s10798-018-09492-3

Cunningham, C., Lachapelle, C., & Lindgren-Streicher, A. (2006). Elementary teachers' understandings of engineering and technology. American Society for Engineering Education-ASEE. https://peer.asee.org/200

Cunningham, C., & Lachapelle, C. (2007). Engineering is elementary: Children's changing understandings of engineering and science. American Society for Engineering Education-ASEE. https://peer.asee.org/1470

Cunningham, C.M., Lachapelle, C.P., Brennan, R.T., Kelly, G.J., Tunis, C.S.A., & Gentry, C.A. (2020). The impact of engineering curriculum design principles on elementary students' engineering and science learning. *Journal of Research in Science Teaching, 57*, 423–453. https://doi.org/10.1002/tea.21601

Diaz, D., & King, P. (2007). Adapting a post-secondary STEM instructional model to K-5 mathematics instruction. American Society for Engineering Education-ASEE. https://peer.asee.org/3054

Fortus, D., Dershimer, R.C., Krajcik, J., Marx, R.W., Mamlok-Naaman, R. (2004). Design-based science and student learning. *Journal of Research in Science Teaching, 41*(10),1081–1110. https://doi.org/10.1002/tea.20040

Hammack, R., Utley, J., & Ivey, T. (2020). Elementary teachers' mental images of engineers at work. *Journal of Pre-College Engineering Education Research, 10*(2). https://doi.org/10.7771/2157-9288.1255

Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K-12 education: Understanding the status and improving the prospectus*. National Academies Press.

Lachapelle, C.P. & Cunningham, C.M. (2014). Engineering in elementary schools. In Purzer, S., Strobel, J., & Cardella, M.E. (Eds.) Engineering in pre-college settings: Synthesizing research, policy, and practices (p. 61-88).

Meyer, N & Taure, T. (2015, April 24). *Engineering challenges promote 21st-century skills and engage youth*. Education Week. https://www.edweek.org/teaching-learning/opinion-engineering-challenges-promote-21st-century-skills-and-engage-youth/2015/04

National Commission on Mathematics and Science Teaching for the 21st Century. (2000). Before it's too late: A report to the nation. https://files.eric.ed.gov/fulltext/ED441705.pdfNGSS

National Research Council (NRC). (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. The National Academies Press.

Thompson, S., & Lyons, J. (2008). Engineers in the classroom: Their influence on African-American students' perceptions of engineering. *School Science and Mathematics*, *108*(5), 197-211. https://doi.org/10.1111/j.1949-8594.2008.tb17828.x

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