Ficklin, K., Parker, M., & Shaw-Ferguson, T. (2020). Qualitative research on the influence of engineering professional development on teacher self-efficacy in a rural K-5 setting. *Contemporary Issues in Technology and Teacher Education, 20*(4), 687-703.

Qualitative Research on the Influence of Engineering Professional Development on Teacher Self-Efficacy in a Rural K-5 Setting

Kelly Ficklin
University of North Carolina Pembroke

Michele Parker & Tammy Shaw-Ferguson
University of North Carolina Wilmington

As part of an embedded mixed-method study, qualitative research was conducted to understand how Engineering Is Elementary (EiE) professional development influenced the self-efficacy of K-5 elementary teachers required to teach engineering in a rural school in Southeastern, North Carolina. In fall 2016, proportional stratified sampling was used to select 14 teachers by grade level and specialty area who participated in EiE training. Teachers were interviewed to obtain in-depth information about their perceived self-efficacy. The interviews were transcribed and analyzed for content by person, by interview questions, and across all interviews using narrative data analysis methods. The data showed three themes: (a) teachers feel preparation programs lack STEM training, (b) integrating engineering is achievable in the K-5 classroom, and (c) professional support is an issue in improving this engineering initiative. The results demonstrated how elementary educators' self-efficacy evolved while engaging in professional development to prepare to teach engineering. Implications for educational practice and research are provided.

In the United States, the demand for science, technology, engineering, and mathematics (STEM) education initiatives has increased. As such, STEM methods courses in teacher education programs and STEM professional development opportunities have increased. For instance, Webb and LoFaro (2020) created a STEM methods course for preservice elementary teachers. In comparison, Dr. Calvin Mackie developed STEM NOLA (2020) to expose, inspire, and engage teachers in underserved communities in STEM education. DiFrancesca et al. (2014) even described a STEM-focused elementary program.

Despite STEM education advances, engineering is often a neglected component. (DiFrancesca et al., 2014). Yet, integrating engineering in the curriculum maximizes student learning and achievement, increases understanding of engineering and STEM-related skills, and enhances and refines 21st-century skills (Cunningham et al., 2012; Dejarnette, 2012; Fortus et al., 2005; Kolodner et al., 2003). Even with positive outcomes, many teacher education programs do not adequately influence preservice elementary teachers' level of self-efficacy in the area of teaching engineering, although attention to the topic largely depends on the requirements of each school of education (Cone, 2009; Hechter, 2011; Joseph, 2010, Tschannen-Moran & Woolfolk-Hoy, 2001).

The purpose of this article is to report how Engineering Is Elementary (EiE) professional development influenced the self-efficacy of K-5 elementary teachers required to teach engineering in a rural school in southeastern North Carolina. This research was part of a more extensive study that used an embedded mixed-method research design combining survey and interview data to provide a comprehensive overview. In an earlier article, the survey data from the more substantial part of the study were reported (Parker et al., 2020).

Background Literature

Literature about Engineering Is Elementary (EiE) professional development and the self-efficacy of teachers can be organized into four main categories: (a) Self-efficacy in STEM and Engineering, (b) Professional Development in Teaching Engineering, (c) Engineering Is Elementary and (d) Educator Perceptions of STEM integration. In keeping with this understanding, the literature synthesis is outlined similarly.

Self-Efficacy in STEM and Engineering

Bandura (1977) identified four sources that impact self-efficacy: “mastery experiences, vicarious experiences, social persuasion, and physical and emotional states” (p. 193). Mastery experiences are those that are personal and practical to the learner. Observing the performance of another with like skills is considered a vicarious experience.

Social persuasion includes negative or positive feedback. Physical and emotional states are related to the individual's feelings or emotions at the time of the learning. Mastery experiences have the most significant impact on teachers and learners (Bandura, 1977, 1997; Bleicher, 2007; Cone, 2009; Tschannen-Moran & Woolfolk-Hoy, 2001).

Self-efficacy is linked to teacher motivation, teacher support for students, student motivation, student achievement, and attitudes of teachers and students related to the subject matter being taught (Brand & Wilkins, 2007; Cone, 2009; Joseph, 2010, Tschannen-Moran & Woolfolk-Hoy, 2001). According to Bandura (1997), "A teacher's sense of efficacy is likely to be especially influential on young children" (p. 242).

To investigate the effect of a STEM methods course, Webb and LoFaro (2020) collected self-efficacy survey and focus group data from 14 elementary preservice teachers. After the course, the preservice teachers' self-efficacy to teach engineering increased, and their emotional state was linked to positive self-efficacy changes. Similarly, Gunning and Mensah's (2011) results demonstrated that self-efficacy in STEM is influenced by preservice elementary teachers feeling inadequate in their abilities to teach science effectively.

Using various research methods, scholars revealed that K-5 teachers do not feel adequately prepared to teach engineering methods to their students (Frost et al., 2018; Hammack & Ivey, 2017; Webb & LoFaro, 2020; Yoon et al., 2014). According to data collected by Douglas et al. (2004),

> Over ninety percent of surveyed teachers agreed that they are better teachers when they understand more about engineering. Furthermore, 85% of them felt as though students were interested in learning more about engineering and how it relates to the real world. (p. 11)

Providing teachers with well-designed, engaging instruction increases the development of high self-efficacy toward understanding, teaching, and integrating engineering into the K-5 elementary curriculum. Teachers must be able to understand the relationships between their lives, real-world issues, and the engineering curriculum (Fredericks-Volkwein et al., 2004; National Research Council [NRC], 2015). Teachers need a clear understanding of the science of teaching and learning engineering and its impact on self-efficacy, strategies for integrating engineering, and benefits to the future needs of society (Darling-Hammond et al., 2020; Olson & Labov, 2012).

Professional Development in Teaching Engineering

Teachers can better understand engineering and how to integrate it with the required content through professional development. The most effective professional development opportunities for teachers in engineering include research-based, hands-on, inquiry-based strategies that incorporate collaboration between colleagues (Morrison, 2006; Sinclair et al., 2011; Wojnowski & Pea, 2014). For educators to benefit most from PD, researchers have shown that it should be a long-term process that recurs consistently (Darling-Hammond et al., 2017); Fullen, 2007; Guskey, 1994; Regional Educational Laboratory Southwest, 2007).

Engineering Is Elementary

EiE (2020) is a systematic, inquiry-based STEM curriculum designed to teach students the skills needed to think and reason as engineers. Each of the 22 hands-on units are built around a five-step engineering design process (EDP) cycle. The five steps within the EDP cycle include ask, imagine, plan, create, and improve (Video 1, Engineering is Elementary, 2016a).

Video 1 Engineering Is Elementary Overview (YouTube)
https://www.youtube.com/watch?v=WH90ough55c

EiE offers professional development opportunities for teachers designed to provide engaging, inquiry-based, collaboration experiences through real-world problem-solving. Each research-based engineering challenge is designed to enhance teachers' understanding of content and improves their self-efficacy toward teaching engineering (EiE, 2016b). To promote teaching engineering practices, DiFrancesca et al. (2014) discussed EiE incorporation in a STEM-focused elementary teacher preparation program and the impact of this inquiry-based STEM curriculum on program goals (EiE, 2020).

Educator Perceptions of STEM integration

To investigate educators' perceptions of STEM integration, a phenomenological study of 13 expert STEM practitioners was conducted (Sandall et al., 2018). The authors revealed that structural implementation phenomena and interpersonal implementation phenomena were critical components and implementation factors. The former includes subject integration, project-based learning, and professional development. Meanwhile, the latter involves leadership; collaboration; willingness; authentic, relevant, and meaningful experiences for participants; and outside support). Concomitantly, Sandall et al.'s implications for further research included exploring how professional development contributes to integrated STEM.

Methodology

This examination is part of a more extensive mixed-methods study, wherein the qualitative data was embedded within the quantitative methodology (as also described by Creswell & Plano Clark, 2018). The primary research question examined the influence of EiE professional development on teachers'(a) engineering teaching efficacy and beliefs, (b) engineering teaching outcome expectancy, and (c) engineering instruction.

While the more extensive study consisted of quantitative and qualitative data, this article pertains to the interview data relevant only to the expressed purpose and question expressed here. This paper aims to describe how EiE professional development influenced the self-efficacy of K-5 elementary teachers required to teach engineering in a rural school in southeastern North Carolina.

The secondary research question asked about teachers' perceptions, experiences, and self-efficacy toward integrating engineering in the K-5 classroom. Hence, the interviewed teachers provided in-depth information about their perceived self-efficacy after 1 day of EiE professional development (PD).

Participants

A total of 55 teachers received the PD, and 43 teachers consented to participate in a 6-month study of EiE PD training. Teachers were grouped by grade levels (1 – 5 and special education), and two participants from each group were randomly selected to participate in the qualitative interviews. Hence, a proportional stratified sampling method was used to identify interviewees (as recommended by Krathwohl, 1998). Ten (71.43%) of the participants were between 25 and 44 years old, and 9 (64.28%) of them had 0-10 years of teaching experience. See Table 1.

Table 1 Demographic Information of Interviewees

Categories	*n*	%
Race		
Native American	13	92.85
African American	1	7.15
Gender		
Male	1	7.15
Female	13	92.85
Teaching Experience (Years)		
0-5	3	21.42
6-10	6	42.86
11-15	5	35.72
Degree Earned		
Bachelor	8	57.14
Master	6	42.86

Interviews

The benefits of interviewing include collecting in-depth information from the participants and the flexibility to include probing questions to deeply understand the participant's experiences (Brinkmann & Kvale, 2014). The qualitative data were obtained via semistructured teacher interviews. The interview protocol was adapted from several North Carolina Department of Instruction documents that established STEM education goals, expectations, and rubric criteria for teachers (North Carolina Department of Public Instruction [NCDPI], 2014, 2017; NC STEM Center, 2020; Public Schools of North Carolina [PSNC], 2020).

The 11 interview questions addressed a range of topics, including experiences, educational background, content knowledge, preparedness, and self-efficacy. The questions prompted teachers to provide information about their perceptions, experiences, and self-efficacy toward integrating engineering in the K-5 classroom. Example of questions included the following:

- While completing your college education, how were you prepared to teach mathematics? Science? Engineering?

- What strategies do you use to integrate STEM into your classroom?
- After participating in the EiE professional development, what does engineering mean to you?
- How do you feel about your ability to teach engineering (self-efficacy)?

Procedures

The face-to-face interviews occurred during Week 16 of the study, 2 weeks before the final EiE PD session. Each interview was scheduled at the convenience of the participants and lasted between 30 minutes and 1 hour. The interviews took place in a quiet setting.

First author Kelly Ficklin, elementary education professor at The University of North Carolina at Pembroke, transcribed each of the 14 interviews verbatim into a Microsoft Word document. The interviews were analyzed using a thematic approach. The interviews were analyzed for content by participants, by interview questions, and across all interviews. During initial coding, Ficklin wrote descriptors, to summarize each response within the transcripts' margin. Based on a systematic analysis of similarities and differences across participants, relevant terms, phrases, or sections were reduced to codes.

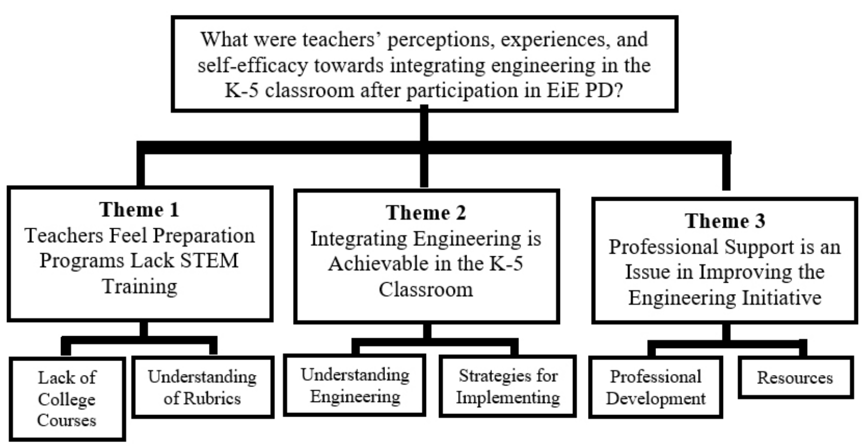
Examples of initial coding included Lack of resources, relativeness to curriculum, lack of financial resources, and scarcity of hands-on support and lesson plans (See Table 2). Next, Ficklin examined similarities and differences between codes to develop a reduced list of categories. Categories were established to make connections among the codes, as well as tested to develop the categories further (as recommended by Leech & Onwuegbuzie, 2008). Given the commonalities and hierarchy among categories, themes were identified, as illustrated in Figure 1.

To ensure rigor in the qualitative research (e.g., credibility and transferability), specific strategies were used. For instance, the same open-ended interview questions and setting were used with each participant. A full description of the innovation, context, participant characteristics, data collection, analysis, and results are provided (Corbin & Strauss, 2008; Creswell, 2013, 2014; Gibbs, 2007; Miles et al., 2014; Tufford & Newman, 2012).

Table 2 Qualitative Analysis of Interview Data and Resulting Themes

Initial Coding Framework	Themes
Lack of courses offered related to engineering. Lack of engaging activities. Lack of resources. Relativeness to curriculum.	Teacher preparation programs
Familiarity with hands-on approaches. Experiences with problem-solving and critical thinking questioning. Incorporating small groups. Incorporating Project-Based Learning (PBL) and experiments.	Integrating is achievable
Lack of financial resources to purchase necessary materials. No professional development prior to study. Scarcity of hands-on resources and lesson plans. Lack of administrative understanding of engineering standards.	Professional support

Figure 1 Visual Representation of Qualitative Research Coding and Themes from the Interviews



Results

Three themes organize the qualitative results: (s) teachers feel preparation programs lack STEM training, (b) integrating engineering is achievable in the K-5 classroom, and (c) professional support is an issue in improving the engineering initiative. Each theme is discussed in subsequent sections.

Theme 1: Teachers Feel Preparation Programs Lack STEM Training

The first theme that emerged from the interviews was that teachers feel preparation programs lack STEM training. The interviewed teachers felt unprepared to teach engineering. Teachers explained that coursework in STEM-related content courses did not prepare them to integrate each aspect of STEM effectively into the mandated curriculum from the State Department.

Each teacher reported completing college coursework related to mathematics and science content, but no specific courses designed to teach technology or engineering. When asked to describe their experiences in each mathematics course related to the implementation of math in the K-5 setting, eight of the 14 interviewees recalled "hands-on experiences using manipulatives." Two teachers reported developing math kits to be utilized when they began their teaching experiences.

When asked about the preparation for teaching science in the K-5 setting, 11 of the 14 teachers reported little or no science teaching exposure, despite their completion of required science-related courses in the general education curriculum. Only three of the 14 teachers recalled participating in science experiments, hands-on learning, and projects related to the implementation of science within the K-5 setting. All 14 teachers reported having no courses or experiences with the implementation of engineering content in the K-5 classroom or engineering-related courses while in college. One participant stated,

> I never even heard the word "engineering" while I was in college. Before this EiE professional development, I felt unprepared and anxious about implementing engineering in my third-grade classroom. I thought engineering related to building bridges and car engines. I thought you had to be very smart in math and science to be an engineer. Now I realize engineering happens in everyday life through problem-solving and collaborating with others.

Before participating in the EiE PD, all the teachers stated they had no prior knowledge of the accountability requirements for integrating engineering in the K-5 classroom. All participants were unaware that in 2012 North Carolina implemented two rubrics within the Standard Course of Study to hold K-5 teachers accountable for the integration of engineering within the state-mandated curriculum. In response to a question related to the integration of engineering, one participant stated,

> If you had not provided our school with engineering professional development, I would not have even understood that engineering was part of everything we do in the real world. I was shocked when I found out I am responsible for teaching my kindergartners these skills needed to be engineers and to help them understand the many different engineering opportunities available for them.

The NC STEM Attribute Implementation Rubric for Elementary School and Engineering Connections Aligned With STEM Attribute Principles for Elementary School are a result of this mandate (NCDPI, 2014; PSNC, 2020). However, none of the interviewees were aware of the document's existence and the responsibility they had in meeting these standards.

Theme 2: Integrating Engineering Is Achievable in the K-5 Classroom

A second theme that emerged from the interviews was that integrating engineering is achievable in the K-5 classroom. This theme focused on the perception K-5 teachers have regarding understanding the definition of engineering and its implementation in all subject areas in the K-5 curriculum.

After completing the first EiE PD intervention, teachers had an opportunity to share their renewed understanding of engineering. Most of the teachers interviewed agreed that engineering was problem-solving, collaboration, and experiencing real-world situations. Nine of the participants identified engineering in everyday practices. The teachers were surprised to realize engineering strategies were things they were already implementing in their classrooms. When asked what engineering meant, one teacher stated,

> I didn't realize I was already using engineering in my classroom until we completed the EiE training. Engineering is everyday questioning and thinking. It is communicating with others. It is talking and solving problems together. It is working in small groups and using hands-on strategies. Most importantly, it is learning how to make corrections in your thinking and own planning to improve your initial solution. I am excited about telling my students they are engineers!

When asked about implementation plans, 11 of the 14 teachers believed that participation in the EiE training provided strategies that could easily be implemented into the required, state-mandated curriculum. One teacher responded in the following manner:

> Before our workshop, engineering meant working on machines, technology, and building bridges. I never thought about implementing engineering in a classroom with young children. Now that we have had the training, engineering is problem-solving that moves into solutions through questions and errors. Students should have the opportunity to think outside the box and to research new solutions to old problems.

Theme 3: Professional Support Is an Issue in Improving Engineering Initiative

The third theme that emerged from the interviews was that professional support is an issue in improving the engineering initiative. This theme focused on the perception the K-5 teachers had regarding their lack of opportunity for PD and the resources needed to implement engineering effectively within all subject areas in the K-5 curriculum. When asked to describe what benefit the PD provided to integrate engineering, one teacher stated,

> Before the EiE training, we had no training or professional development related to engineering. I think that is the case because, technically, engineering is not tested on the EOG's [End of Grade Testing]. I now realize engineering is in everything we do, so it is tested. I am so grateful for the EiE professional development we have had. I hope this training leads to more support and opportunities.

Before completing the EiE PD, all interview participants stated that they had no professional support or prior experience integrating engineering in the K-5 classroom. Twelve of the 14 participants adamantly expressed greater interest in attending local conferences and PD to improve their understanding and ability to integrate engineering within the K-5 curriculum.

The teachers stated that administrators and district-level personnel needed to provide more significant support to improve confidence in their abilities to integrate engineering. The participants stressed the need for additional funding to provide opportunities to become comfortable with teaching and integrating engineering in the K-5 curriculum. Ways in which they expressed needed support included opportunities for more PD, resources, mentors, facilitators, and additional funding to improve their instruction quality.

Discussion

The qualitative findings from this study indicated that the EiE PD positively impacted the self-efficacy and attitudes of the K-5 teachers toward integrating the STEM initiative's engineering content area within the state-mandated curriculum. After teachers completed the first EiE training, their self-efficacy changed.

Based on Guskey (1994) and Tal et al.'s (2001) research, the findings from this study may not have permanently impacted the self-efficacy of K-5 teachers, because ongoing PD is needed for a lasting change to occur over time. K-5 teachers must believe in their ability to teach engineering before they can teach students. Improved self-efficacy happens with participation in PD designed to take place over several months, in which educators have several opportunities to receive feedback, implement strategies, collaborate with other educators, share experiences, and ask questions (Hammack & Ivey, 2019; Hunzicker, 2010; Yoon et al., 2013).

This study's results align with the results of Wenner (1995), who examined the relationship between teachers' preparation and their attitudes toward teaching. He found that teachers who had more experience, training, and college coursework felt more prepared and qualified to teach the required content. Conversely, teachers with little exposure and content-focused college courses felt less confident and unqualified to teach the content (Tschannen-Moran & Woolfolk-Hoy, 2001; Wenner, 1995).

Like the participants in Wenner's (1995) study, the participants in this study identified having no college courses or PD related to integrating engineering into the K-5 classroom before the study. Therefore, their beliefs and self-efficacy reflected what Wenner reported, and participants similarly lacked self-efficacy in their ability to teach engineering. After teachers completed the EiE training, their feelings toward their self-efficacy changed. Many of the teachers made comments similar to these teachers: "I am grateful for the EiE professional development," and "Before we had the EiE training, I did not understand that I could teach engineering in my language arts classroom. I am excited about integrating engineering to engage my students!"

Tate (2009) and Douglas et al. (2004) indicated that teachers felt more confident with integrating engineering into their curriculum after participating in PD, as did the participants in this study. The EiE PD positively impacted their self-efficacy and attitudes about engineering.

Although North Carolina has not adopted the *Next Generation Science Standards* (NGSS, 2013), many districts and teachers in the state are integrating the NGSS within the state standards (NRC, 2012). As identified through the NGSS, engaging in engineering design-based learning activities like EiE helps K-5 educators and researchers learn more about children's earliest identification with engineering.

American policymakers and educators focus on teaching STEM subjects and believe this content must be implemented beginning with the kindergarten curriculum to meet this need for the future of our nation (NRC, 2010). Early exposure to STEM initiatives and strategies positively impact K-5 students' perceptions and dispositions related to the workforce of the future (Bybee, 2011).

The limitations of this study are supported by the quantitative research reported previously (Parker et al., 2020). Further research related to K-5 teachers' self-efficacy for integrating engineering into the regular curriculum is needed. A study designed to compare participants' feelings about attending PD with colleagues differs from that of participating without colleagues. Comparing the two groups may provide insight as to the advantages and disadvantages of peer-only PD.

References

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191–215.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. W. H. Freeman and Company.

Bleicher, R. E. (2007). Nurturing confidence in preservice elementary science teachers. *Journal of Science Teacher Education, 18*(6), 841–860.

Brand, B., & Wilkins, J. (2007). Using self-efficacy as a construct for evaluating science and mathematics methods courses. *Journal of Science Teacher Education, 18*(2), 297–317. https://doi.org/10.1007/s10972-007-9038-7

Brinkmann, S., & Kvale, S. (2014). *InterViews: Learning the craft of qualitative research interviewing* (3rd ed.). Sage.

Bybee, R. W. (2011). Scientific and engineering practices in K-12 classrooms: Understanding a framework for K-12 science education. *The Science Teacher, 78*(9), 34–40.

Cone, N. (2009). Preservice elementary teachers' self-efficacy beliefs about equitable science teaching: Does service learning make a difference? *Journal of Elementary Science Education, 21*(2), 25–34.

Corbin, J. M., & Strauss, A. L. (2008). *Basics of qualitative research* (3rd ed.). Sage Publications.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Sage Publications.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.

Creswell, J. W., & Plano Clark, V. (2018). *Designing and conducting mixed methods research*. Sage Publications.

Cunningham, C. M., Lachapelle, C. P., & Hertel, J. (2012). *Research and evaluation results for the Engineering Is Elementary Project: An executive summary of the first eight years*. Museum of Science.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24*(2), 97-140.

Darling-Hammond, L., Hyler, M., Gardner, M., & Espinoza, D. (2017). *Effective teacher professional development*. Learning Policy Institute. https://learningpolicyinstitute.org/sites/default/files/product-files/Effective_Teacher_Professional_Development_REPORT.pdf

Dejarnette, N. K. (2012). America's children: Providing early exposure to STEM (science, technology, engineering, and math) initiatives. *Education, 133*(1), 77–84.

DiFrancesca, D., Lee, C., & McIntyre, E. (2014). Where is the "e" in STEM for young children? Engineering design education in an elementary teacher preparation program. *Issues in Teacher Education, 23*(1), 49–64.

Douglas, J., Iversen, E., & Kalyandurg, C. (2004). *Engineering in the K-12 classroom: An analysis of current practices and guidelines for the future*. https://www.asee.org/documents/conferences/k12/WorkshopDocuments/Engineering_in_the_K-12_Classroom.pdf

Engineering is Elementary. (2016a, November 7). Engineering is Elementary overview [Video]. Museum of Science. YouTube. https://www.youtube.com/watch?v=WH90ugh55c

Engineering Is Elementary. (2016b). *Research and evaluation for the Engineering is Elementary project 2004-2016: An executive summary. Museum of Science.* https://resources.finalsite.net/images/v1560878571/davisk12utus/drozcqiiis7y4l46rebw/eie-executive-summary.pdf

Engineering Is Elementary. (2020). [Brochure]. *Open young minds to the world of engineering*. Museum of Science. https://cdn2.hubspot.net/hubfs/436006/2018%20Marketing%20Email%20Graphics/Engineering%20is%20Elementary%20Brochure%202018.pdf

Fortus, D., Krajcik, J., Dershimer, R. C., Marx, R. W., & Mamlok-Naaman, R. (2005). Design based science and real-world problem-solving. *International Journal of Science Education*, 27(7), 855–879.

Fredericks-Volkwein, J., Lattuca, L., Terenzini, P., Strauss, L., & Sukhbaatar, J. (2004). Engineering change: A study of the impact of EC2000. *International Journal of Engaging Education, 20*(4), 318-328.

Frost, L., Greene, J., Huffman, T., Johnson, B., & Kunberger, T. (2018). SPARCT: A STEM professional academy to reinvigorate the culture of teaching. *Journal of STEM Education, 19*(1), 62–69.

Fullan, M. (2007). *The new meaning of educational change* (4th ed.). Teachers College, Columbia University.

Gibbs, G. R. (2007). Analyzing qualitative data. In U. Flick (Ed.), *The Sage qualitative research kit* (Vol 6; pp. 1-232). SAGE Publications.

Gunning, A. M., & Mensah, F. M. (2011). Preservice elementary teachers' development of self-efficacy and confidence to teach science: A case study. *Journal of Science Teacher Education*, *22*(2), 171–185.

Guskey, T. R. (1994, April). *Professional development in education: In search of the optimal mix*. [Conference session]. Annual meeting of the American Educational Research Association, New Orleans, LA. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.905.9336&rep=rep1&type=pdf

Hammack, R., & Ivey, T. (2019). Elementary teachers' perceptions of K-5 engineering education and perceived barriers to implementation. *Journal of Engineering Education*, *108*(4), 503–522.

Hechter, R. P. (2011). Changes in preservice elementary teachers' personal science teaching efficacy and science teaching outcome expectancies: The influence of context. *Journal of Science Teacher Education, 22*(2), 187–202.

Hunzicker, J. (2010). *Characteristics of effective professional development: A checklist*. http://files.eric.ed.gov/fulltext/ED510366.pdf

Joseph, J. (2010). Does intention matter? Assessing the science teaching efficacy beliefs of preservice teachers as compared to the general student population. *Electronic Journal of Science Education*. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.689.368&rep=rep1&type=pdf

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting Learning by Design into practice. *Journal of the Learning Sciences, 12*(4), 495–547.

Krathwohl, D. R. (1998). *Methods of educational and social science research: An integrated approach* (2nd ed.). Longman.

Leech, N. L. & Onwuegbuzie, A. J. (2008). Qualitative data analysis: A compendium of techniques and a framework for selection for school psychology research and beyond. *School Psychology Quarterly, 23*(4), 587–604.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). Sage.

Morrison, J. (2006). *TIES STEM education monograph series: Attributes of STEM education*. TiesTeach. http://www.wytheexcellence.org/media/STEM_Articles.pdf

National Research Council. (2010). *Standards for K-12 engineering education?* National Academy Press. https://doi.org/10.17226/12990

National Research Council. (2012). *A framework for K-12 science education: Practice, crosscutting concepts, and core ideas*. National Academy Press. https://doi.org/10.17226/13165

National Research Council. (2015). *Reaching students: What research says about effective instruction in undergraduate science and engineering*. The National Academies Press. https://doi.org/10.17226/18687

Next Generation Science Standards. (2013). *Next generation science standards: For states, by states, next generation science standards*. https://www.nextgenscience.org/

North Carolina Department of Public Instruction. (2014). *NC school report cards: Public Schools of Robeson County*. https://ncreportcards.ondemand.sas.com/src/district?district=780LEA&year=2014&lng=en

North Carolina Department of Public Instruction. (2017). *North Carolina Department of Public Instruction STEM education schools and programs: NC STEM attribute implementation rubric elementary school*. https://ncsmt.org/wp-content/uploads/2013/09/STEMAttributesRubric_Elementary_v4_Aug2013_v2a.pdf

NC STEM Center. (2020). *STEM in North Carolina: What is STEM?* https://www.ncstemcenter.org/learn/stem-in-north-carolina/

Olson, S., & Labov, J. B. (2012). *Community colleges in the evolving STEM education landscape: Summary of a summit*. The National Academies Press.

Parker, M., Ficklin, K., & Mishra, M. (2020). Teacher self-efficacy in a rural K-5 setting: Quantitative research on the influence of engineering professional development. *Contemporary Issues in Technology and Teacher Education Journal*, *20*(4).

Public Schools of North Carolina. (2020). *K-12 engineering connections aligned with the NC STEM rubric principles*. http://science.unctv.org/content/education/stem

Regional Educational Laboratory Southwest. (2007). *Reviewing the evidence on how teacher professional development affects student achievement*. http://ies.ed.gov/ncee/edlabs/regions/southwest/pdf/REL_2007033.pdf

Sandall, B. K., Sandall, D. L., & Walton, A, L. J. (2018). Educators' perceptions of integrated STEM: A phenomenological study. *Journal of STEM Teacher Education, 53*(1), 27–42.

Sinclair, B., Naizer, G., & Ledbetter, C. (2011). Observed implementation of a science professional development program for k-8 classrooms. *The Association for Science Teacher Education, 22*(7), 579–594.

STEM NOLA. (2020). *Growing the innovators, creators, and makers of the future*. https://www.stemnola.com

Tal, R. T., Dori, Y. J., & Keiny, S. (2001). Assessing conceptual change of teachers involved in STES education and curriculum development-The STEMS project approach. *International Journal of Science Education, 23*(3), 247–262.

Tate, M. L. (2009). Workshops: Extend learning beyond your presentation with these brain friendly strategies. *Journal of Staff Development, 30*(1), 44–46.

Tschannen-Moran, M., & Woolfolk-Hoy, A. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education, 17*(7), 783–805.

Tufford, L., & Newman, P. (2012). Bracketing in qualitative research. *Qualitative Social Work*, *11*(1), 80–96. https://doi.org/10.1177/1473325010368316

Webb, D. L., &, LoFaro, K. P. (2020). Sources of engineering teaching self-efficacy in a STEAM methods course for elementary preservice teachers. *School Science and Mathematics*, *120*(4), 209–219. https://doi.org/10.1111/ssm.12403

Wenner, G. (1995). Science knowledge and efficacy beliefs among preservice elementary teachers: A follow-up study. *Journal of Science Education and Technology, 4*(4), 307–315. https://doi.org/10.1007/BF02211262

Wojnowski, B., & Pea, C. H. (2014). *Models and approaches to STEM professional development*. National Science Teachers Association.

Yoon, S. Y., Diefes-Dux, H., & Strobel, J. (2013). First-year effects of an engineering professional development program for elementary teachers. *American Journal of Engineering Education, 4*(1), 67–84. https://doi.org/10.19030/ajee.v4i1.7859

Yoon, S. Y., Evans, M. G., & Strobel, J. (2014). Validation of the teaching engineering self-efficacy scale for K-12 teachers: A structural equation modeling approach. *Journal of Engineering Education, 103*(3),463–485. https:/doi.org/10.1002/jee.20049