Status of Elementary Teacher Development: Preparing Elementary Teachers to Deliver Technology and Engineering Experiences

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Abstract

For over a century, teacher preparation programs (TPPs) have experienced peaks and valleys in preparing preservice teachers to deliver technology and engineering (TE) experiences in elementary classrooms. Calls to integrate engineering concepts into elementary education (Katehi, Pearson, & Feder, 2009; Kimmel, Carpinelli, Curr-Alexander, & Rockland, 2006)—especially as it relates to the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013) and science, technology, engineering and mathematics (STEM) education—compels TE teacher educators to evaluate their curricular programs relative to elementary education. To assist teacher educators in this self-assessment, the Teacher Preparation Committee of the Council on Technology and Engineering Teacher Education undertook a mixed methods study, the purpose of which was to identify and characterize the models of teacher preparation programs that prepared preservice elementary teachers to deliver TE experiences in elementary classrooms.

Keywords: Elementary teacher education, Technology education, STEM

Review of Literature

During the evolution from manual arts into industrial arts (IA) in the initial decades of the 1900s, teacher educators encouraged elementary teachers to integrate constructive and investigative activities and content about how people transform materials to solve life's problems into general elementary education. In particular, Bonser and Mossman (1923) emphasized the *health*, *economic*, *aesthetic*, *social*, and *recreational* outcomes of IA (p. 7) as they related to becoming "efficient in the selection, care, and use of the products of industry, and . . . [becoming] intelligent and humane in the regulation and control of industrial production" (p. 6). Furthermore, they noted the efficiency and integrative power of IA to enhance the school curriculum as a method of teaching. Other manual training educators, however, advanced elementary industrial education from a more practical perspective, emphasizing instruction in tool use and handcrafts for students who were unlikely to attend school beyond the eighth grade (Foster, 1999).

By midcentury, elementary school industrial arts (ESIA) was evident within university curricula. Loats' (1950) survey suggested that 44 of 90 IA teacher training institutions in the United States offered a total of 91 IA courses for the preparation of elementary teachers with 10 of these institutions offering five courses each (pp. 144–145). Knowledge of "materials of industry," "finishing materials," and "general tools of industry" were the most frequently cited competencies stressed in these courses (p. 157). For example, the State University Teachers College in Oswego, New York, offered two programs to study ESIA (Kroh, 1957); one offered general elementary majors the opportunity to take a minor sequence in IA, and the other enabled IA majors to take a minor sequence in ESIA.

A decade later, Bruce's (1964) survey of industrial education departments indicated that 94 of 165 responding departments offered at least one IA course for elementary teacher education with a total of 143 separate courses identified (p. 41). All respondents indicated that constructional activities were valued within these courses with 83% of respondents emphasizing "their use in integrating other areas of study in the elementary curriculum" (pp. 81-82). In 1971, Ingram and Pace (1974) conducted a similar survey of IA teacher education departments with 80 of 103 respondents indicating that they offer coursework in ESIA through 125 separate courses. Required ESIA coursework was minimal among elementary majors (18.7% required), special education majors (12.5%), and IA majors (13.7%; p. 204).

During this same time frame, several textbooks and professional initiatives were evident. Scobey's (1968) textbook offered "a theoretical and pedagogical basis for the study of technology in the elementary school" (p. v), background information about industry, and classroom activities. The American Council for Elementary School Industrial Arts (ACESIA) was established in an attempt "to define, stimulate, and strive for the ideal form of industrial arts education in the elementary school" (Stunard, 1971, p. ii), and the *23rd Yearbook of the American Council on Industrial Arts Teacher Education* was dedicated to describing "a revival of [ESIA] theory building and program research and development" (Ray, 1974, p. 5).

During the 1980s and 1990s, many embraced technological literacy as a critical educational mission. The National Aeronautics and Space Administration (NASA) funded the Mission 21 project at Virginia Tech that demonstrated a framework to implement the study of technology in the elementary curriculum by developing and testing resource guides designed around problem-solving themes and design challenges requiring the integration of science, social studies, and math (Brusic, Dunlap, Dugger, & LaPorte, 1988). Within the profession, the *46th Yearbook of the Council on Technology Teacher Education* (Kirkwood & Foster, 1997) was dedicated to elementary school technology education (ESTE). In 1998, the Children's Council of the International Technology Education Association was formed "to build a collaborative network of educators dedicated to the advancement of technological literacy at the elementary level" (2017, para. 2). Yet in the face of enthusiasm for ESTE, technology TPPs at both the elementary and secondary levels experienced "a precipitous decline [in student enrollment] from the 1970 levels" (Volk, 1997, p. 66) with an estimate of only five IA or TE TPPs in the United States identifying ESTE courses (Dennis, 1994; as cited in Kieft, 1997).

The *Standards for Technological Literacy* (STL), originally published in 2000 by the International Technology Education Association, offered guidance to teacher educators and elementary teachers by identifying critical content for K–2, 3–5, and 6–8 grade bands, requiring that students "develop an understanding of the relationships among technologies and the connections between technology and other fields of study" (Standard 3), "the attributes of design" (Standard 8), and " engineering design" (Standard 9), and "develop the abilities to apply the design process" (Standard 11; 2007, p. 210). During this same time period, political leaders argued that improving STEM education is a necessary precondition to preserving the nation's pipeline of scientists and engineers as well as its' capacity for innovation and global economic competitiveness (e.g., *Engineering in K–12 Education*, 2009). The emphasis upon STEM education created opportunities for engineering to enter students' K–12 experiences (Pearson, 2014). Several professional development and curriculum development projects emerged to enhance in-service elementary teachers' STEM understanding and skills. From Hofstra University, the Integrating Mathematics, Science, and Technology in the Elementary Schools project prepared three-person leadership teams that, in turn, conducted workshops with over 1,200 elementary school teachers in New York (Burghardt & Hacker, 2002). The Children Designing & Engineering project at The College of New Jersey resulted in the development and evaluation of thematic instructional units that integrated science, technology, and mathematics standards (Hutchison, 2002). But perhaps, the Engineering is Elementary (EiE) curriculum, initiated by the Boston Museum of Science in 2003, has been the most extensively adopted curriculum with over 50,000 in-service teachers reporting that they used one or more of the 20 engineering units (Lachapelle & Cunningham, 2014).

The possibility of developing national K–12 engineering standards was explored, eventually dismissed, and replaced by a recommendation to identify core engineering concepts and skills across age bands (National Academy of Engineering, Committee on Standards for K–12 Engineering Education, 2010). Proponents of engineering education pushed for greater integration of engineering into the K–12 core curriculum (Miaoulis, 2014). Over time, engineering appeared within state curricular standards (e.g., Massachusetts Department of Elementary and Secondary Education, 2016), program evaluations (e.g., Public Schools of North Carolina, 2012), and a few elementary TPPs. For example, The College of New Jersey, which also prepared secondary TE teachers, initiated a K–5 Math/Science/Technology program in 1998 that continues today as Integrative-STEM with a specialization in TE (O'Brien, Karsnitz, Van Der Sandt, Bottomley, & Parry, 2014). In addition, elementary STEM programs associated with engineering institutions provided preservice TPPs. Hofstra University (2016), for example, offered a 36-hour "co-major" consisting mostly of science, math, and engineering courses, including courses like Designing the Human-Made World and Technology and Society, and "two STEM designated integrative courses that students will take at the end of the program" (para. 1).

More recently, the NGSS (NGSS Lead States, 2013) explicitly elevated "engineering design to the same level as scientific inquiry when teaching science disciplines at all levels" (p. 103) and strengthened existing linkages to the STL including crosscutting concepts of interdependence and influence of TE on society and environment (ETS2.A and ETS2.B; see National Research Council, 2012). Although elementary TPPs have traditionally been interdisciplinary, the focus for K–4 has been primarily upon teaching reading and writing with strong connections to social studies. The NGSS presents new engineering content and pedagogy and, thus, a need to update preservice teacher curriculum as it relates to TE content and pedagogies. A window of opportunity is open to the TE teacher preparation community to help prepare preservice elementary teachers to deliver engineering experiences. To inform this continuous improvement of TE TPPs, the current study attempts to identify and characterize TPPs that prepare elementary teachers to deliver TE experiences in elementary classrooms.

Methodology

A mixed methods approach using direct email, a questionnaire, document review, and telephone interviews were employed for data gathering. The researchers developed a questionnaire to solicit information about the nature of TE curricular offerings for preservice elementary teachers. The questionnaire included 19 items, such as type of program, standards, licensure, credentials, and clinical experiences. The final question asked respondents to provide contact information for another person or institution in their state or region that may offer TE opportunities for elementary preservice teachers.

The 53th edition of the *Technology & Engineering Teacher Education Directory* (Rogers, 2014) established the initial target population (n = 45). In October 2015, an email invitation was extended to the contact person of each institution asking them to complete the questionnaire, and a second invitation was extended two weeks later; 31 TPPs responded. In the case of non-respondents, the undergraduate catalog or course bulletin was acquired through a web search, and the program and course descriptions offered by the TPPs were reviewed. In addition, telephone interviews (n = 15) or email correspondence were conducted to expand and validate the nature of the TPPs. In all, data were gathered from 44 institutions that prepared TE teachers in the United States.

Results

Of the 44 institutions, 14 (32%) indicated that they provided learning experiences for preservice elementary teachers that prepared them to deliver TE experiences within elementary classrooms (Figure 1A). A wide range of program titles was evident, such as Elementary Technology Literacy, Integrative STEM, Integrated Science, and Elementary Education. When asked to classify the teacher preparation program that implements the TE experiences for elementary teachers, respondents indicated STEM (n = 4), elementary and elementary science education (n = 4), technology education (n = 2), technology and engineering education (n = 2), career and technical education (n = 1), and industrial arts or technology (n = 1; see Figure 1B). The reported student enrollment in STEM programs (n = 4) averaged to 100 students, whereas enrollment in non-STEM courses or programs (n = 4) averaged to 16 students.

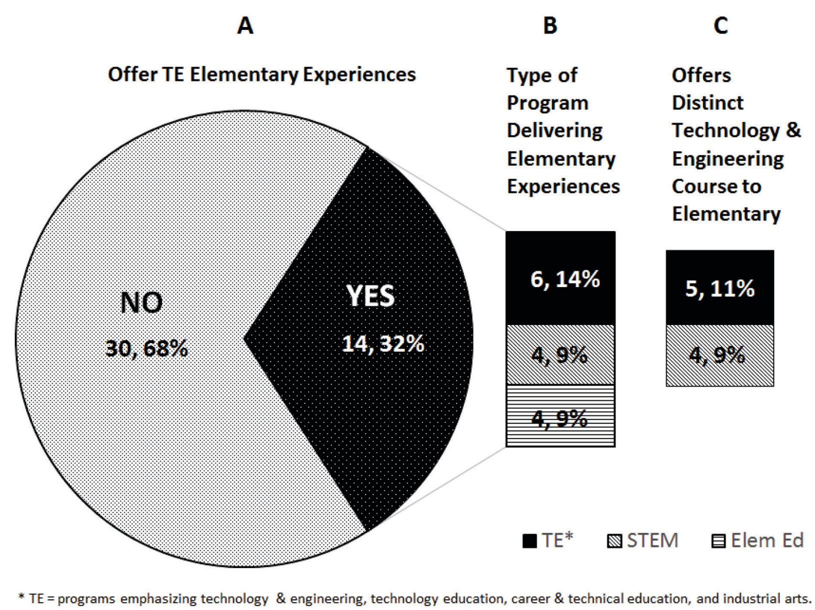

Figure 1. Responses from institutions offering technology and engineering (TE) teacher preparation programs regarding opportunities for elementary education students.

An analysis of program and course descriptions was conducted to identify courses that served elementary education students, explicitly addressed TE content, and referenced STEM goals or content. Direct contact with program affiliates confirmed these findings. The results indicated that nine of 14 programs offered distinct coursework examining TE concepts for elementary education students (Figure 1C). No program classified as elementary or elementary science education (n = 4) offered a TE-content-based course. One respondent explained that engineering design was employed as a pedagogical strategy through methods courses, especially a science methods course. It should be noted that in only eight of the nine programs were courses delivered by faculty members positioned within a TE teacher preparation program; one elementary STEM program was delivered by faculty members from engineering education. Furthermore, STEM goals and content appeared prominently in the program title, course titles, or description for six of the nine programs.

Respondents identified the content standards with which their curricular program aligned. The two most common standards were the NGSS and STL, each with eight programs. Seven programs were reportedly aligned with the Common Core State Standards (CCSS), and three programs responded “other.”

Respondents were also asked to indicate how extensively specific standards from the STL and NGSS were emphasized in their program using a 5-point scale ranging from *never emphasized* to *extensive emphasis*. Relative to the STL, the average response from nine participants indicated *strong-to-extensive emphasis* (=> 4.0) on Apply the Design Process, Attributes of Design, and Engineering Design. *Moderate-to-strong emphasis* (3.6 to 3.9) was found for Characteristics and Scope of Technology, Core Concepts of Technology, Relationships Among Technologies and Other Fields of Study, and Effects of Technology on the Environment. Overall the *lowest emphasis* occurred for the standards in the Designed World, such as medical, agriculture, and construction technologies. Six participants responded to the engineering principles and practices of the NGSS indicating a *moderate-to-strong* response with the strongest emphasis on Identifying the Problem and Selecting a Solution.

Regarding clinical experience, respondents indicated the extent of clinical experiences dedicated to delivering TE content in elementary classrooms. A bimodal distribution was evident with highest frequencies occurring for *0 hours* (n = 4) and *11–20 hours* (n = 3; see Table 1). Those reporting *0 hours* were from programs offering only “courses” to elementary education students (n = 2) or those positioned within states providing K–12 TE certification (n = 2). Programs reporting the highest hourly requirements for clinical experiences were STEM-centric programs (n = 3) and elementary education (n = 1). Furthermore, respondents from two elementary education programs explained that students were required to plan and implement engineering experiences with elementary learners as part of their science pedagogy requirement.

Table 1
Summary of Clinical Experience Hours Delivering Technology and Engineering Content in Elementary Classrooms

Clinical experience	Count	%
0 hours	4	36
1–5 hours	1	9
6–10 hours	2	18
11–20 hours	3	27
More than 20 hours	1	9
Total	11	100

Additionally, participants were asked to identify the curriculum and instructional packages used to prepare elementary preservice teachers within their teacher preparation program. The choices included EiE, PLTW (Launch or Gateway), I^3 Project: Invention, Innovation, Inquiry, Designing Human Exploration, Lego WeDo Curriculum, Engineering by Design (EbD), and an open-ended response. Two institutions indicated that they use EiE, and one responded that they use EbD to prepare teachers. The other responses included content from Science Learning through Engineering Design (SLED), state-designed curriculum, self-developed curriculum, and Teach Engineering. One participant responded, "We expose the candidates to the national curriculum packages, but primarily prepare our candidates to develop their own curriculum."

Credentialing practices were also examined. Completion of elementary-focused curricular programs was typically noted within institutional transcripts; in one instance in which this was not the case, a certificate was issued by the program. Relative to teacher licensing practices, the Pennsylvania Department of Education (2014) and the North Dakota Education Standards and Practices Board (2011) offered STEM endorsements to existing elementary teaching licenses, but these endorsements were not required for certified elementary teachers to deliver TE experiences or content in their self-contained classrooms. Although three states issued overlapping grade-level certification for TE teachers (i.e., Grades 5–12 in Wisconsin and K–12 in New York and New Jersey), two TPPs did not offer a specific course customized for elementary education students.

Models of Teacher Preparation

This study resulted in the identification of six models of TE teacher preparation for preservice elementary teachers, including the specific course, concentration, certificate, minor, major, and the combined undergraduate and graduate program. The following provides a glimpse of those models of elementary teacher preparation.

Specific course. The most basic way of integrating TE content into elementary teacher preparation was the specific course model. Both the University of Georgia (UG) and California University of Pennsylvania (CAL U) offered courses customized for elementary education majors. Undergraduates from UG (2016a) could have selected the Creative Activities for Teachers course (ETES2320-2320L) to fulfill a requirement of the Major in Elementary Childhood Education. The course offered students an opportunity to engage in "demonstration and hands-on learning, including problem solving, designing, construction, and testing of prototypes, and activities that increase aesthetic, psychomotor, and cognitive development" (2016b, "Course Description," para. 1). CAL U's Elementary School Technology Education course enabled students to "explore and develop instructional methodologies and assess student learning while addressing grade-level content standards for the study of technology in grades K-5" (2016, "TED 352," para. 1).

As part of their BS in Technology Education degree program that prepares teachers for 7–12 certification, CAL U (2016) also offered a required course entitled Teaching Technology in the Elementary School that focused on "teaching/learning activities that integrate concepts related to mathematics, science, communication and social science with technology" at the elementary level ("TED451," para. 1).

Concentration. A concentration—a coordinated set of courses with a common thread—was a model found among elementary education programs. For example, Ball State University (2015) required that all elementary education majors select a concentration of study consisting of 12 credit hours. As one among 13 options, the Technology concentration required students to take one TE course—Technology and Society—and two educational technology courses—Curricular Integration of Technology and Technology Policy and Ethics. Additionally, students could have taken the Capstone in Technology for the Elementary Grades course to fulfill the concentration requirements; this course provided hands-on laboratory experiences with technological systems, processes, and products (p. 111).

Certificate. Another model of teacher preparation was the certificate program, a coordinated set of courses that, when completed, resulted in a state-level credential. Unique among teacher education programs, Valley City State University (VCSU; 2014) offered several 100% online programs for undergraduates, graduates, and practicing teachers to enhance their understanding and pedagogical skills for delivering TE experiences to elementary learners. Majors in both elementary and secondary education at VCSU could have opted for a STEM Education Certificate of Completion consisting of 12 credits. Four of the required courses in the elementary certificate program were also required courses in the BS in Technology Education degree. Specifically, six credits were dedicated to the study of TE within courses called Invention and Innovation and Design/Technology/ Engineering for Elementary. In addition, a math course focused “on hands-on transdisciplinary investigations integrated with project-based engineering design activities” was required (p. 163). The state of North Dakota offered a license endorsement to students who completed the STEM Certificate if the student completed an approved field experience of 20 hours that included the implementation of TE experiences with elementary learners (Peder Gjovik, personal communication, December 10, 2015).

Minor. Two examples of minor programs were identified in the study. Millersville University (2016) offered a minor in Integrative STEM Education Methods for students majoring in early childhood education or special education. The minor was offered through the Department of Applied Engineering, Safety, and Technology and consisted of 18 credit hours. The required courses for the minor included Introduction to Early Childhood Education, Introduction to Integrative STEM Pedagogy, Product Design, Children’s Engineering, Integrative Learning using Experiential Strategies, and Integrative STEM Education Practicum.

Additionally, Pittsburg State University (2013) offered a minor in Technological Literacy for preservice elementary teachers. The minor consisted of 20 credit hours with three educational technology courses and three technology education courses that illustrated the “practical use and implementation of computer skills, design and problem solving skills and teaming concepts into real world practices and experiences” (para. 1). The course sequence included STEM Experiences for Elementary Education, Technology for the Classroom, Overview of Technology and Engineering in STEM Education, Instructional Technology for Educators, and Integrated Technology for Educators. Additionally, students were required to complete a special topics course in both educational technology and technology education.

Bachelor’s degree. One bachelor’s degree program was identified in the study. The College of New Jersey (2016a, 2016b) had engineering-related experiences for elementary and secondary teacher education candidates in several areas. They offered a Bachelor of Science (BS) in Technology/Pre-Engineering Education in secondary K–12 technology and engineering education (2016b) and a BS in Integrative-STEM Education (2016a) in elementary K–6 STEM education. In the Integrative-STEM Education program, elementary teacher education candidates could choose from one of five tracks including: Deaf and Hard of Hearing, Early Childhood Education, Elementary

Education, Special Education, and Urban Education. All five of these sequences provided engineering-related course work.

Specific to this study, we investigated the BS in Integrative-STEM Education and the Elementary Education major. This program led to elementary education certification in the state of New Jersey. Courses required for this major included: Calculus, Creative Design, Multimedia Design, Structures and Mechanics, and Integrated M/S/T for the Child/Adolescent Learner. Inside this program, teacher education candidates could focus on elementary or early-childhood teaching, K–8 mathematics, or K–8 science.

Combined undergraduate and master's certificate program. A combined bachelor's and master's program at the University of Arkansas (UA) was the final model identified during the study. UA offered a graduate certificate program with a concentration in STEM Education for their Master of Arts (MAT) in Childhood Education (elementary) program in the Department of Curriculum and Instruction. This program was developed to meet the demand for highly qualified teachers with both knowledge of STEM disciplines and expertise with integrating STEM into the elementary classroom. The program consisted of five courses (University of Arkansas, 2016). Typically, two courses were offered at the undergraduate level, and three were completed during the MAT program. The first course, Introduction to STEM Education, was a required course for all preservice elementary teachers and students in the technology education program. Additionally, students completing the certificate program were required to take Creativity and Innovation, Problem-Based Mathematics, Problem-Based Science, and Curriculum Design Concepts for Teachers. After completing the program, students were issued a graduate certificate. However, students could have completed the five courses at the undergraduate level with a departmental certificate of completion.

Other teacher preparation programs. Future elementary teachers may have encountered TE content and pedagogy as part of their science or educational technology courses or as part of their field experience. For example, the Elementary Education Integrated Science Major program at Northern Michigan University actively promoted students' understanding and application of the NGSS, including those concepts and practices identified as "engineering, technology, and applications of science" (NGSS Lead States, 2013), through professional methods courses (12 hours) that included engineering design as a pedagogy and educational technology courses (6 hours) that incorporated relevant digital learning tools (e.g., Lego robotics; Joseph Lubig, personal communication, January 22, 2016). In addition, the program engaged students in 12 hours of progressive field experiences related to planning and delivering TE experiences, much of which occurred through the services of a regional science and mathematics center (e.g., hosting the Michigan Science Olympiad).

Discussion and Conclusions

This descriptive study was an attempt to identify and characterize the models of teacher education programs that prepare preservice elementary teachers to deliver technology and engineering experiences within elementary classrooms. The population of the study was limited to U.S. educational institutions known to prepare technology and engineering teachers; thus, these results do not apply to institutions that prepare only elementary or secondary teachers in science. Caution should be taken when interpreting these results as overlapping teaching licensure (e.g., Grades 5–12 and K–12 certification in Wisconsin and New York, respectively), ambiguous nomenclature (e.g., endorsement and certificate), contradictory sources of information, and dynamic transitions within institutions may have confounded results.

The results of this study suggest that nine programs in the United States provide courses or curricular programs customized for elementary education majors that enable them to develop content knowledge in technology and engineering. Compared to Litowitz's (2014) analysis of undergraduate curriculum identifying three ESTE courses in the United States, the current findings indicate a slight increase with nine programs providing TE coursework to elementary education students. Given that six of these nine programs have explicit STEM components and two states offer STEM teaching credentials, the slight increase in elementary offerings might be a result of contemporary pressures that all teachers and teacher education programs should become more integrative in their curriculum and instructional practices. The significantly larger enrollment reported by programs classified as STEM programs as compared to TE programs provides further evidence that STEM programs are addressing some of the challenges to STEM integration discussed by Honey, Pearson, and Schweingruber (2014), e.g., enhancing teachers' STEM content knowledge and expertise in teaching integrated STEM.

Six structural models were evident among teacher preparation programs delivering TE content to elementary education students: specific course, concentration, certificate, minor, bachelor's degree, and combined undergraduate and master's certificate program. With the exception of the specific course and concentration models, the models requiring 12 or more credit hours were predominantly STEM-centric; program and course descriptions addressed specific TE content as well as integrative STEM pedagogy. In addition, most of these STEM-centric programs required significant clinical experiences in which students implemented TE experiences with elementary learners.

To further characterize these curriculum models, content standards were considered. There was equally reported alignment with the STL and NGSS content standards with slightly fewer programs aligning to the CCSS. In contrast to the emphasis on the Designed World standards of the STL (ITEEA, 2010) among secondary TE education programs (Litowitz, 2014), the results of this study showed an extensive emphasis on the design standards from the STL. Furthermore, most elementary and elementary science education programs represented in this study reported using engineering design as a unifying pedagogical approach to further connect STEM areas through design-based instruction.

Recommendations

As pressure mounts to integrate TE content into elementary science or through elementary STEM programs, TE teacher educators have a brief window of opportunity to evaluate their elementary curricular offerings and then collaborate with faculty members in elementary education, science education, or engineering education to revise or develop courses and programs that build elementary education students' TE content knowledge and pedagogical expertise.

Several questions for guiding the evaluation of existing programs may be inferred from the successful programs identified in this study. To what extent does the program:

- Include coursework explicitly customized for elementary education students?
- Familiarize students with elementary curriculum and instructional packages that address TE learning goals?
- Include STEM-centric courses that enable students to build both discipline-specific content knowledge and integrative teaching expertise, such as an integrative methods course?
- Require students to align their own curriculum and instructional plans to both STL and NGSS standards?
- Require significant clinical TE experiences with elementary-aged students?
- Celebrate the completion of elementary-level TE or STEM programs by issuing certificates or designations on transcripts? (This credential may be presented to prospective employers as teachers seek future employment in schools with a STEM focus.)

After program evaluation, faculty members should consider revision or creation of a new curricular offering for elementary education students by collaborating with fellow education faculty members in elementary, science, engineering, or mathematics. When initiating contact, TE faculty members should be well prepared to communicate research evidence that an integrative approach to STEM education at the elementary level (Becker & Park, 2011) and design-based learning as an instructional approach (Wells, 2016) has been shown to positively impact student achievement. Furthermore, faculty members should extoll the unique expertise and resources that they can bring to the collaboration, such as expertise in ill-formed problem-based and project-based instruction and hands-on skills and resources that enable execution of engineering and design activities (e.g., planning, graphic representations, modeling, and prototype development).

Researchers should systematically examine the extent to which curriculum models for elementary teacher education, instructional approaches, curriculum resources, and clinical experiences contribute to the formation of appropriate content knowledge, self-efficacy, and integrative STEM teaching expertise, as suggested by Honey, Pearson, and Schweingruber (2014).

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