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Special Issue
Current Trends in K-12 Engineering Education

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Many K-12 educators approach STEM disciplines as if each one (Science, Technology, Engineering, and Mathematics) exist in isolation from each other integrate the content and skills of the disciplines that can engage students on many levels. STEM education is meant to be an interdisciplinary area of study that integrates the four disciplines rather than achieving skills and knowledge independently in each subject area. This paper examines the several attempts to define STEM and discusses the basics and issues related to the implementation of STEM programs and how engineering is a suitable vehicle for development and implementation of STEM programs, whether the focus of the course is science, technology, engineering, or mathematics. The value of the Next Generation Science Standards in this endeavor will be detailed. In addition, the paper will examine the relevance of STEM Career Technical Education (CTE) programs.

Keywords: STEM implementation; interdisciplinary approach; Next Generation Science Standards; curricula integration; K-12 education

The introduction of engineering in K-12 education in the United States offers new potential and challenges for schools interested in teaching engineering in the elementary grades. This study examines how a teacher frames engineering practices for her students through the teaching of an *Engineering is Elementary* (EiE) instructional unit. Discourse analysis of conduct was undertaken based on a set of classroom videos and artifacts. The method entails detailed analysis of the talk and actions of classroom members. Codes were developed to characterize the work on framing and engaging in engineering practices. Drawing from the materials provided in the curriculum, the teacher in this classroom used a set of discourse moves (e.g., posing questions, revoicing student responses, giving directions) to frame aerospace engineering as a field that is dedicated to principled uses of data to support design. This was accomplished by modeling ways of collecting data, controlling variables, and treating anomalies. Classroom activities in support of data use included analysis of science concepts and engineering designs, sharing within and across groups for collective decision making, and comparing data to draw inferences for engineering redesign. The teacher in this study was able to provide learning opportunities in this fourth-grade classroom by developing common foci around science concepts and engineering processes, holding students accountable to common standards of quality in engineering work, and encouraging students to develop agency as engineers.

Keywords: elementary; engineering; epistemic practices; discourse

The integration of science and engineering practices in K-12 science education is currently an area of growing national interest in the United States, as evidenced in the recently published document titled *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. However, to date, little is known about the extent to which these practices are covered in the widely used K-12 engineering programs. As a response to the dearth of research in this area, this study investigated the nature and extent to which science and engineering practices are covered in the widely used K-12 engineering programs in the United States. Nine programs that are widely used in the United States were analyzed via document content analysis method using the K-12 science education framework. The results revealed important findings showing the similarities and disparities in the coverage of science and engineering practices in the analyzed programs, grade levels, and in different science discipline units. This study is significant because an understanding of the current status of science and engineering practices coverage would be helpful to educators and curriculum designers as they strive to further the development of integrated science and engineering curricula, as well as shaping the scope and sequence of engineering design thinking learning activities in the K-12 science curriculum.

Keywords: engineering practices; science practices; K-12 engineering education; K-12 science curriculum

The Next Generation Science Standards now integrate science and engineering through their Core Ideas and Practices dimensions. Portions of the engineering design process included in these standards emphasize: (1) defining problems through identifying criteria and constraints, (2) developing solutions to those problems, and (3) optimizing those solutions to best fit the criteria and constraints. The Science Learning Integrating Design, Engineering, and Robotics (SLIDER) project, funded through the NSF DRK-12 program for five years, set out to investigate this integration through the use of robotics and design to develop conceptual understanding among 8th grade physical science students. Through three years of curriculum development and iteration, the SLIDER curriculum faced several challenges in making this integrated approach both effective and practical in a diverse array of

schools. This paper presents that story and makes suggestions critical to others designing for the NGSS and developing theory around integrated STEM learning.

Keywords: science education; engineering education; design; integrated STEM; curriculum development; Next Generation Science Standards

The social changes that have taken place in recent decades have determined the evolution of the educational system. Society nowadays demands new learning methods, focused on an appropriate selection and processing of information instead of memorization. The rise of the Information Technologies has led to different "Emergent Pedagogies". One of them is Informal Learning, which proposes shifting the generation and acquisition of knowledge from the individual to the collective plane.

The present research expects to raise K-12 students' interest in engineering by adopting some methods that are typical of informal learning in the field of formal learning. The objective is to stimulate the group learning processes for the generation of collective knowledge through multidisciplinary team interaction and dialogue. For this purpose, a group of 25 K-12 students organized in subgroups carried out a co-creative project. This project consists in the development of a sculptural assembly made of glazed ceramics over a steel structure, which will be installed in the educational centre. A concurrent project methodology was used to create the sculptural assembly. Here, each student must perform different tasks related to design engineering. An educational model based on Blended Learning was used, which proposes the combination of in-person sessions with virtual work by means of social networks as a group communication medium. Thus, each creative team member contributed with their own Personal Learning Environment in order to enrich the group learning process and provide it with their own personal singularities, thereby turning it into a Personal Learning Network.

The experience allowed K-12 students to discover the working process typical of design engineering through a recreational methodology based on Informal Learning. The students were able to make up for their shortcomings in terms of technical and creative skill, while becoming aware of their chances within the field of engineering. The project has been shown to be an incentive for K-12 students regarding their interest in starting engineering studies once they finish their K-12 stage.

Keywords: informal learning; K-12; engineering project; collaborative design; b-learning; PLE; social networking

This article reports on fourth-grade students' approaches to solving an introductory engineering design-based problem, namely, *Tumbling Towers*, which was implemented at the beginning of a three-year, longitudinal study. Set within a civil engineering context, the problem required student groups to design and then build the tallest tower within given constraints. The stability of their towers was tested by removing one pylon at a time, with the goal being to determine the minimum number needed for the tower to remain stable. Students completed a second design iteration in an effort to maximise the number of pylons that could be removed while still maintaining stability. A framework comprising five sets of engineering design processes was developed as a theoretical base and facilitated data analyses. Findings illustrate how fourth-grade students, for whom such problems were new, engaged in design processes in an iterative manner and applied mathematics and science content knowledge in doing so. Four levels of design were identified in the students' design sketches with the highest level being the most frequent in both initial designs and redesigns, with some decline in the latter. Students' application of content knowledge included an awareness of stability and load distribution, together with spatial reasoning involving pylon positioning, removal, and repositioning. Other findings include ways in which group negotiations and students' addition of meaningful contexts assisted in the designing and redesigning phases, and how students spontaneously used gestures to convey their design and construction ideas.

Keywords: design processes; engineering education; engineering-based problem solving; elementary/primary school

The InVenture Challenge seeks to bring design, engineering, invention, and entrepreneurship to K-12 education by providing a framework, curriculum, and competition that can be used by teachers in different disciplines with support from Georgia Institute of Technology faculty and staff. Modeled after Georgia Tech's InVenture Prize, a 'Shark-Tank' style competition for Georgia Tech undergraduates that is televised throughout Georgia, the InVenture Challenge attempts to deliver the same authentic experience to younger participants by providing resources and mentoring to K-12 teachers to implement engineering, design, and entrepreneurship lessons. In this paper, we present the motivation for the InVenture Challenge, lesson plans, resources, teacher survey feedback, and teacher focus group themes from the third year of implementation. The teacher survey data is related to perceptions of the program, self-efficacy for teaching engineering and entrepreneurship, observed student outcomes, challenges experienced during implementation, and recommendations for implementation within different schools and classroom settings. In general, teachers perceive the InVenture Challenge as an engaging way to introduce students to engineering and find value in the connection to the Georgia Tech community.

Keywords: invention; engineering; entrepreneurship; design; K-12; informal learning

This paper describes the design of WISEngineering, a computer-based engineering design environment focused on helping learners in formal and informal settings engage in informed engineering design activities. This paper compares and contrasts results of implementing WISEngineering projects in both formal and informal learning settings. In particular, this paper reports on insights gleaned from implementing WISEngineering middle school science and math classrooms as well as in after-school settings with Boys and Girls Clubs. We discuss design principles guiding the development of WISEngineering for school settings and how these principles were adapted and refined for youth and facilitators in informal learning contexts. We provide implications for the design of technology-enhanced engineering learning environments across school and out-of-school time settings.

Keywords: computer-based learning environments; K-12; formal and informal learning

This study explored the effect of Google SketchUp on students' learning achievements in spatial visualization. A quasi-experimental with pre-test and post-test design was used to conduct the research. Eighty-four fifth graders from a public elementary school in Taiwan voluntarily participated in the study. Students from different classes were divided into three instructional modules: Google SketchUp (with full features), Google SketchUp (with limited features), and traditional instruction (hand-held objects). Students in each of the three experimental groups were instructed to manipulate various 3D objects that were created by a class teacher. A criterion test was developed to measure students' understanding about basic concepts of spatial visualization. The educational experiment was completed within three weeks. The results showed that Google SketchUp (with full features) was an effective learning tool to support students in developing spatial visualization skills ($F = 8.20$, $p < 0.01$).

Keywords: spatial visualization; Google SketchUp; open source software; K-12 engineering education

Nations throughout the world have recognized the importance of having a Science, Technology, Engineering, and Mathematics (STEM) competent workforce in today's highly competitive and technical economy. As such, the past fifteen years have seen a sharp rise in introducing pre-college (P-12) students to engineering and engaging them in learning engineering principles. Policy decisions to include engineering in national curriculum and standards have not been informed by as rich a body of research as subjects such as mathematics and science; however, research on P-12 engineering education is on the rise. This paper presents a systematic review of the engineering education research in P-12 published in journals from 2000–2015. A systematic review follows a set of replicable, detailed procedures that describe how the articles were selected, reviewed, and analysed. The results of this review included 218 peer-reviewed journal articles. The paper details the kinds of research and research questions these papers focused on, and synthesizes and discusses findings of across different topics, and proposes research topics ripe for further work.

Keywords: systematic review; pre-college; literature synthesis

Research shows that interest is often reported as a primary reason for career choice selection among majority students but not necessarily for underrepresented students. At the same time, research focused on rural Appalachian youth in Virginia and Tennessee (students underrepresented in higher education broadly and specifically within engineering) has shown interest as preferentially important in engineering fields though not in other fields. To better understand how interest in engineering is sparked and sustained among Appalachian students, we used a qualitative multi-case study approach to first compare interest in engineering and healthcare fields among high school students and then to compare high school and college student interest in engineering careers. For high school students, our findings reveal interest sparks in engineering were more likely to be associated with organized experiences, while health care interests were primarily associated with personal experiences. We also found an association between engineering interests and a preference for math and science classes, but the same association did not exist for interests in health care fields, despite the potentially equivalent math/science intensity of these career fields. With regard to interest development phases among high school students, individual rather than situational interests tend to be associated with intention toward engineering majors, whereas the opposite was true for healthcare fields. For college engineering students, we identified a greater balance between individual and situational interest than in the high school sample of students interested in an engineering career. College students were also more likely than high school students to indicate a personal experience as sparking his or her interest in engineering than an organized activity. Finally, though we compared two case sites in rural Appalachia, our findings revealed commonality in interest levels and sparks across sites. In combination, these findings have implications for designing interventions intended to spark interests in engineering such that the interests can also be sustained.

Keywords: interest; Appalachia; career choice

This study investigated elementary school students' conceptions of engineers by conducting the Chinese-version of the Draw-an-Engineer Test (CDET) in classrooms. A mixed methods research methodology was adopted for achieving the research objective. In the quantitative part of this study, a content analysis method was used for analyzing students' drawing contents; in the qualitative part, a phenomenology approach was employed for collecting interview data. A total of 750 Taiwanese students voluntarily participated in the study. Quantitative findings showed the presence of gender stereotypes of engineers, specific types of engineers, and major conceptions of engineers in the drawings. Qualitative findings indicated that family members and mass media strongly influenced students' conceptions. Overall, most findings were supported by previous research results. However, the information on the proportion of stereotypes, types, and conceptions of engineers was unique to the current study.

Keywords: K-12 engineering education; conceptions of engineer; engineering epistemology

Sustainability is an innovative topic within the field of engineering and is becoming a fundamental component of the engineering curriculum in the twenty-first century. As global challenges arise, the development of sustainable design techniques is timely as engineers aim to address issues such as population growth and climate change. This research evaluates secondary school students based on their understanding of sustainability concepts with a focus on education level, gender, and ethnicity. Over three years, a pre- and post-assessment is provided to high school students who attend a summer engineering camp and participate in a ninety-minute lesson on sustainable engineering. The assessment results (based on 334 students) are compared over the three years to identify trends in demographics, pre-existing knowledge, post-module knowledge, as well as interest in sustainability and engineering. Demographic comparisons are explored using statistical analyses. Education level was found to be significant in terms of knowledge of sustainability topics and sophomores indicated a higher level of interest in sustainable engineering in comparison to all demographic groups. Three major recommendations are identified: (1) integrate sustainability education earlier on in the secondary school curriculum and continue integration of material throughout their junior and senior years, (2) focus on enhancing sustainability education for minority groups (such as camps, workshops, science fairs, outreach programs, etc.), and (3) continue to emphasize women in engineering disciplines and encourage all student groups to pursue engineering through exposure to sustainability topics.

Keywords: sustainability; engineering recruitment; high school; assessment