Bringing Design and Construction into Elementary School Classrooms with Sandcastles

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Abstract

The design and construction professions face a continuing need to attract talented and trained individuals. A promising approach is to introduce these professions to students in elementary school classrooms. The Sandcastle Project is a collaborative effort that will bring students and faculty in the Cal Poly College of Architecture & Environmental Design (CAED) and the School of Education into local elementary school classrooms. The CAED includes departments in Architectural Engineering, Architecture, City & Regional Planning, Construction Management and Landscape Architecture and can provide students and faculty who are competent in all areas of building design and construction. Students in the School of Education are the optimal means of introducing technical concepts and practices for the present and future education of elementary school students.

The goals of the Sandcastle Project are to stimulate elementary school students' creativity and an interest in building design, engineering and construction and to use real world examples of math and science to reinforce standard curricula. Teacher candidates from the School of Education and students from CAED will join elementary school students initially in the classroom and later in an afterschool program. Exercises will give the elementary school students the experience of acting as the architect, engineer and contractor. The culmination of the project will be a sandcastle competition. Students will design and plan the construction of their sandcastles and will build them at a local beach on a Saturday morning. The paper will describe the goals of the Sandcastle Project, the method of its implementation, assessment methods and future steps.

Introduction

Studies by the National Academy of Engineering[1] and President's Council of Advisors on Science and Technology (PCAST)[2] among others have identified the need to enhance the pathways to careers in science, technology, engineering and math to attract an abundant, diverse and proficient workforce. This will involve both improving our educational content and conveying the importance, value and satisfaction that can be achieved in such careers. As the PCAST report emphasizes improving STEM education requires we "focus on preparation and inspiration." This is a task best accomplished collaboratively by educators, industry and government each bringing resources and skills to change the decline of interest and ability in students in science, technology, engineering and math.

As Ellis, Jackson and Wynn[3] have proposed introducing young students to engineers and connecting subject matter to relevant applications in engineering can support "imprinting" engineering as a career pathway. Increasing student understanding of engineering in relation to the world around them can minimize misperceptions, and highlight the many ways engineering

improves the quality of our lives. Engineering can motivate the need to master the principles and concepts presented in science and math and make them more accessible.

Background

The authors' outreach work has explored a number of different methods for informing and engaging K-12 students in engineering. These have included using story and hands-on experiments in elementary grades[4], as well as more formal lessons to high school students including computer simulations of structural behavior. This outreach program was stimulated by the ideal location and situation of California Polytechnic State University in the San Luis Obispo community and was modeled, in part, on a similar outreach program in the San Francisco Bay Area. Leap Arts in Education[5] sponsors an annual sandcastle contest which joins Bay Area art and design professionals with elementary school children in building sandcastles of the students' design. The beaches surrounding San Luis Obispo, multiple school districts with diverse populations, a polytechnic university well known for its architecture and engineering programs as well as its teacher credential program and strong links between the university and the local professional community provide the optimal foundation for developing a similar contest on the Central Coast.

The program is supported by a small university grant which encourages collaboration across colleges as well as among departments within colleges. We have chosen to work with faculty in the School of Education who are teaching and mentoring candidates in the teacher credential program. The Sandcastle Project is envisioned in four parts: engineering content enrichment for teacher candidates, classroom lesson for grades 4 through 6 to introduce the design process and the professions involved in accomplishing a construction project, an after-school program for interested 4^{th} – 6^{th} graders to undertake the sandcastle planning and design, and finally construction of the sandcastles at a local beach. The design of the program incorporates the six guidelines for improving K-12 engineering education and outreach presented by Douglas et al.[6] It employs hands-on learning, takes an interdisciplinary approach, addresses current math and science curriculum standards, engages teachers in the development of the lessons and enriches their understanding of content, provides mentors and role models who represent the diversity sought in the professions, and makes use of partnerships between multiple stakeholders.

Goals

The Sandcastle Project will introduce the design and construction professions (architects, engineers, contractors) into local elementary school classrooms with overall goals that are two-fold. One goal is to use the design and construction practices to provide elementary school teachers with real world examples of math and science to reinforce standard curricula. Examples include the calculation of slopes, areas and volumes, and applying scaling principles.

A second goal is to introduce the design and construction professions to elementary school students with the hope that this will ignite an interest in some of the students that may lead to rewarding careers. Beyond that it is hoped for all of the students an introduction to the design and construction professions will: 1) introduce them to the design process as a means of problem solving, 2) teach them to think about space and imagine how they can affect the built

environment in which they live and 3) reinforce the importance of teamwork and collaboration by describing how they are used in the building design and construction process.

The approach of the Sandcastle Project is to work jointly with teacher candidates and faculty from the School of Education and students and faculty from the CAED. This collaboration will employ the knowledge and expertise of both colleges. CAED faculty will use their knowledge of design and construction to educate the teacher candidates about these professions and to help develop content and lesson plans. The teacher candidates are already embedded in local elementary school classrooms and so are in an ideal position to lead the elementary school classroom instruction. They will be supported in the classrooms by the CAED students and observed by CAED and School of Education faculty. This approach appropriately employs the expertise of the students and faculty from both colleges. It also encourages the professional development of the students of both colleges. The School of Education's teacher candidates will be introduced to technical concepts and practices of the design and construction professions and also to real world examples of math and science they may use to reinforce standard curricula. CAED students will develop a fuller understanding about the place of these professions in the world.

Implementation Plan

The implementation of the Sandcastle Project will occur in four phases: teacher candidate training, classroom session, after-school program and the sandcastle competition.

Teacher Candidate Training. The teacher candidates now have little or no knowledge of the design and construction industry or professions. In a survey of 39.1% of teachers most teachers surveyed said that they and their students would benefit from increased engineering exposure in their classrooms. [6] CAED faculty will therefor provide them an introduction to that industry. The CAED will also prepare proposed learning outcomes, content and lesson plans for the teacher candidates to use in the next phases. The CAED students will join the teacher candidates in the training sessions. The training sessions will be a two-way process. Although the CAED faculty and students will describe the work of the building design and construction professionals, the teacher candidate students will share their knowledge of work in the classroom.

Classroom Session. The classroom session is envisioned to be a 50 minute long module that will: 1) introduce the elementary school students to the design and construction professions, 2) provide an activity in which the elementary school students can practice these roles and 3) encourage students to continue in the after-school program and sandcastle competition. The basis for the session is founded on work conducted by senior architectural engineering students at California Polytechnic State University to introduce elementary students to professions in design, engineering and construction of buildings.[7] The activity is to design and construct a bridge structure that meets a client's wants and needs. The elementary school students will be formed into teams of 3 or 4 students each and these teams will be formed into groups of three teams each. The three teams in each group will sequentially take on the roles of client, designer and contractor. The design of the activity follows the several of the guidelines for improving K-12 engineering education and outreach that are documented by Douglas et al[6]. The lesson

involves hands-on learning and takes an interdisciplinary approach by incorporating writing, drawing and construction and presents the perspectives of different disciplinary role players.

Each team will first play the role of the client. They will describe the goals of the bridge structure. How long must the bridge be? What appearance is desired? The teams will then pass on the descriptions of the client's requirements to another team.

The next role played by the teams will be that of the designer (engineer) that will translate the client's needs and wants into drawings from which the contractor will work. The drawings should be a translation of the client's words into a design. The drawings might include a plan of the structure and side views. The teams will then pass on the drawings to another team who will be the contractor.

In the role of the contractor the teams will determine the types and quantities of materials needed to build the bridge structure. This will be an exercise in planning and the use of math concepts such as area and volume. The teams will build models of the structures from a kit of parts, Figures 1 and 2.

Figure 1. Completed "suspension" bridge.

Figure 2. Loaded "beam" bridge.

The teams and groups will compare what they have accomplished. Did the designs reflect what the clients requested? Did the construction reflect the drawings? It is hoped that the elementary school students will be encouraged to enroll in the after-school program.

After-School Program. The after-school program is envisioned to be two 90 minute long two sessions that will lead to the sandcastle competition. The after-school sessions will have two components, additional lectures and activities that describe the design and construction professions and industry. This will be an opportunity to present simple engineering concepts and supplement their math and science curriculum. The sessions will focus on understanding steps in the design process, a key feature of Massachusetts Department of Education[8] engineering standards for grades 3-5.

The second component will be to prepare for the sandcastle competition. Using a theme presented to them, the elementary school students will prepare a design for their sandcastle.

They will have to consider what forms are feasible, the tools they will need, what they can build given the size of the team and the time allotted. This design and planning are of course reflections of activities undertaken in the profession.

Competition. The competition is envisioned to take place on a Saturday at a local beach attended by the student teams, parents, the candidate teachers and students and faculty from the School of Education and CAED. Judges from the colleges and local firms will assist with prizes and lunch for all. It should be a fun and memorable experience.

The implementation plan described above incorporates the goals of the project. It uses the design and construction practices to provide elementary school teachers with real world examples of math and science such as the calculation of slopes, scales, areas and volumes. It also introduces the elementary school students to the design and construction professions to elementary school students with the hope of interesting some of the students in those professions and also introduces them to the design process as a means of problem solving, teaches them to think how they can affect the built environment and reinforces the importance of teamwork and collaboration by.

Assessment

To evaluate the effectiveness of the program we will conduct both pre- and post- program surveys of teacher candidates and elementary students. The pre-program survey will investigate students' prior knowledge of the distinct work of the professions, their personal interest in pursuing careers in these professions and their perceptions of their math abilities. Teacher candidates will be surveyed to assess their familiarity with the professions, the application of science and math to the professions and their perceptions surrounding their students' abilities and interests. Additionally, we will work with teacher candidates to develop post activity assessment focused on evaluating math concepts that were employed in the Sandcastle Program with the goal of determining if providing a practical application for these concepts enhanced student learning.

Conclusions and Future Steps

This work in progress introduces elementary school students to the design and construction professions through a Sandcastle Project. Its goals are to stimulate creativity, an interest in building design, engineering and construction and to use real world examples of math and science to reinforce standard curricula. Cal Poly College of Architecture & Environmental Design (CAED) and the School of Education are collaborating to bring university student into local elementary school classrooms. Future work includes validation of the program, expanding to more classrooms and improving links with the local design and construction community.

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