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Teaching the Engineering Design Process to High School Students by Implementing a Non-Traditional Engineering Capstone Course

Joseph Woodard
Utah State University

TEACHING THE ENGINEERING DESIGN PROCESS TO HIGH SCHOOL STUDENTS BY IMPLEMENTING A NON-TRADITIONAL ENGINEERING CAPSTONE COURSE

by

Joseph S. Woodard

A plan B project submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Technology and Engineering Education

Approved:

Edward M. Reeve, Ph.D. Major Professor	Andrew Deceuster, Ph.D. Committee Member
Trevor Robinson, Ph.D. Committee Member	Gary A. Stewardson, Ph.D. Committee Member

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ABSTRACT

Teaching the Engineering Design Process to High School Students by

Implementing a Non-Traditional Engineering Capstone Course

by

Joseph S. Woodard, Master of Science

Utah State University, 2020

Major Professor: Dr. Edward M. Reeve, Ph.D.
Department: Technology and Engineering Education

This plan B project is to showcase the implementation of an engineering design capstone course at a remote, rural public high school, in a non-traditional (after-school) format with a small group of students. The project documents successful strategies along with challenges that were learned from such an implementation of this course. Three high school students were supported in learning to solve an extended design challenge, in this case creating an augmented reality (AR) sandbox. The project shows how a capstone course can be utilized in teaching students to solve complex, ill-structured problems.

In this project, a manuscript was prepared for publication (e.g., in the *Technology and Engineering Teacher*). The article from the teacher's perspective provides an overview of how Utah's high school "Engineering Capstone" course was developed and delivered in a non-traditional (afterschool) setting. The article details lessons learned by the teacher as students completed an engineering design challenge that required them to develop, build, and present a prototype of an augmented reality sandbox.

(35 pages)

ACKNOWLEDGMENTS

Appreciation is first due to my family who were at my side as I continued my education in pursuit of a master's degree. This includes my sweet wife who supported and encouraged me, and our young boys for their patience. I also thank Edward Reeve for his help from start to finish. He was pivotal in helping me make the project a reality and especially in preparing the written materials for this plan B project. It was to his credit that I chose to pursue any post-graduate coursework in the first place. He has also been a consistent support as I have tried to see it all to completion. I appreciate specifically Andrew Deceuster, Trevor Robinson, and Gary Stewardson for their guidance as members of my committee, Eric Packenham for his role on an earlier committee, and other instructors and mentors too numerous to list here that have pointed me in the right direction throughout my education.

Credit is also due to the three high school students who have been involved with me in this project along with their parents and other teachers and mentors. Students like these allow for an excellent high school engineering capstone experience. Together the students and I are very grateful for the support of a special projects grant from the Career and Technical Education office at the Utah State Board of Education that allowed the project to proceed. Also, I express appreciation to numerous other educators and fellow employees of the Uintah School District who played a role in making the project happen, particularly my CTE directors and secretary. And I thankfully acknowledge those in the local area from industry who were involved and supported the project.

Joseph S. Woodard

CONTENTS

CHAPTER I

INTRODUCTION

The activity proposed in this plan B project was to prepare a manuscript (see Appendix A) on the experience of mentoring three high school students who designed and prototyped an augmented reality sandbox as a senior design project. The purpose of this publication is to share with other technology and engineering educators the lessons learned as the teacher implemented Utah's high school engineering capstone course in an afterschool setting. The capstone course allows students to apply the engineering design process in a real-world challenge. The article discussed the learning outcomes associated with the project that included the following:

- defining an engineering design problem.
- managing a long-term project and functioning as a team.
- researching, designing, and meeting with stakeholders.
- producing a prototype within time, budget, and material limitations.
- presenting a prototype in a community setting.

These learning outcomes relate to those listed by the Utah State Board of Education (2018a) for the high school engineering capstone course in technology and engineering education. This one-credit course requires students to work in teams to solve an engineering design problem and present their solution.

Three high school seniors enrolled in the engineering capstone course and it was delivered as an after-school elective offering (non-traditional). These students selected an engineering design challenge and managed it through the various steps of completion

under my mentorship. As the prototype was completed, students made a formal presentation that was judged by industry partners. As other high school students became aware of the project, it increased schoolwide awareness of all engineering course offerings in the program, including the capstone extended design experience.

Needs Statement

A successful student design capstone project is important for technology and engineering students to learn how to apply larger problem-solving practices. Managing and running a quality capstone experience is a complex and unique challenge for teachers. A need existed to develop and deliver an afterschool engineering capstone course and document the lessons learned in the implementation of this course.

Purpose of the Project

The purpose of this project was to implement a high school engineering capstone course and document successful strategies along with challenges to assist other teachers in delivering a similar type of course. The final outcome for the project was a manuscript for publication that would serve as the primary means to inform teachers on best practices and possible barriers in delivering an extended capstone design course.

CHAPTER II

REVIEW OF LITERATURE

When beginning to plan and implement a high school engineering capstone course, there are three questions that needed to be considered. (1) What is the place of an engineering capstone course in the high school curriculum? (2) What are the concepts or content to be delivered in this course? and (3) What methods are to be used in teaching and assessing student learning? The following review addresses those questions.

(1) What is the place of an engineering capstone course in the high school curriculum? Engineering capstone fits in the broad area of Technology and Engineering as a Career and Technical Education (CTE) course. Importantly, the Utah State Board of Education (USBE) (2020) calls for the engineering capstone course in the state's high school engineering pathway beginning in 2020-2021 (p. 23). According to the USBE career pathways website (2020), career pathways show students "a direct connection between doing well in high school and being able to transition smoothly to postsecondary opportunities or getting a good job when they graduate." The new engineering pathway gives students several "explorer" and "concentrator" course options to choose from. But for the final, "completer" step, students have only two choices: either earn credit from a suitable CTE internship or take the Engineering Capstone. The latter course is the focus of this project. Thus, for high school engineering students, completing the engineering capstone course is considered a similarly favorable sendoff to having done an internship.

(2) What are the concepts or content to be delivered in this course? The Utah State Board of Education (2018a) has established strands and standards for this course

(see Appendix B). Students are expected to experience the engineering design process in-depth. This means having students solve an extended design challenge, a complex ill-structured problem that takes more than a few weeks to complete. The engineering capstone course standards ask that "as members of an engineering team, students apply science, technology, and mathematical concepts and skills to solve engineering design problems or to significantly innovate existing products" (p. 1). The accompanying state assessment of this course is not a written exam, but instead calls for a final presentation to be given by the students. Instead of the teacher giving a score, three mentors were to be involved throughout the design project, and those individuals evaluated the project using a "capstone project rubric" (see Appendix C) associated with the course (Utah Board of Education, Technology and Engineering Education, 2018b).

(3) What methods are to be used in teaching and assessing student learning? Teaching methods for the capstone course are not stipulated by USBE. However, many examples of teaching the design process have been shared by teachers. TeachEngineering (n.d.) is a collaborative project of several reputable colleges and universities for teaching engineering in grades K-12. Among this curriculum offered is a unit co-authored by Carlson, Cooper, and Zarske (2008). Their curricular unit, "Creative Engineering Design" including lessons for each of the design steps, and for the design process in general, was reviewed. An article by Baker and Reeve (2019) reporting on a design project that was longer-term with community involvement was also reviewed.

CHAPTER III

METHODOLOGY

The project was to create a manuscript centered around the needs of practicing technology and engineering teachers who might consider implementing a non-traditional engineering capstone course. The manuscript focuses on information helpful to teachers. This means it takes a "how-to" tone, showcases what was done, and includes important details, e.g., costs and time commitment.

The methodology used by the instructor of the engineering capstone course differed throughout various phases of the project. First, the instructor needed to help the students form teams and together define their problem. Guiding students in these early stages is critical. Second, the instructor supported teams in researching and developing solutions and connecting with industry partners or other mentors. Closely monitoring and pacing students through these middle stages was necessary for success. Third, the instructor facilitated the creation of working prototypes. This meant managing a diverse set of materials, processes, sets of expertise, and safety concerns. Fourth, the instructor needed to help student teams reach a satisfactory state of completion, arrange formal presentations, and manage a unique type of evaluation.

Timeline

In developing this course, the following timeline was used. Before beginning the course, the teacher spoke with other teachers about the potential project, and with the school's administration for their approval and possible funding.

- January: The teacher assembled a group of interested students and developed a work schedule
- February: The students clearly defined the problem and investigated various resources available.
- March: The students reviewed additional research and began the design and experimentation to build the prototype.
- April: The students constructed and tested the prototype.
- May: Students made minor modifications and improvements to the prototype. Students showcased and made presentations of the prototype.

CHAPTER IV

CONCLUSION

The purpose of this project was to implement a high school engineering capstone course and document successful strategies along with challenges to assist other teachers in delivering a similar type of course. The final outcome for the project was a manuscript for publication that would serve as the primary means to inform teachers on best practices and possible barriers in delivering an extended capstone design course. The publication focused on for this project was the Technology and Engineering Teacher.

The manuscript developed for this project (see Appendix A) is written from the teacher's perspective and provides an overview of how Utah's high school "Engineering Capstone" course was developed and delivered in a non-traditional (afterschool) setting. The article details lessons learned by the teacher as students completed an engineering design challenge that required them to develop, build, and present a solution to an extended design challenge, in this case a working prototype of an augmented reality sandbox.

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APPENDICES

Appendix A

Manuscript Developed in Plan B Project

DEVELOPING AND TEACHING A NON-TRADITIONAL HIGH-SCHOOL ENGINEERING DESIGN-BASED CAPSTONE COURSE.

Introduction

Technology and engineering programs across the country are attempting and struggling to implement a capstone course that focuses on students solving an engineering design problem that will consist of multiple ill-structured problems, many of which are not identifiable from the outset. In the State of Utah, the Utah Board of Education and its career and technical area known as technology and engineering education have developed a one-credit course entitled "Engineering Capstone" (Utah Board of Education, Technology and Engineering Education, 2018a). The purpose of this course and its description is stated below.

> As members of an engineering team, students apply science, technology, and mathematical concepts and skills to solve engineering design problems or to significantly innovate existing products. Students research, develop, test, and analyze designs using criteria such as cost, effectiveness, safety, human factors, and ethics. Long term project development by student teams and regular interaction with and presentations to members of industry are essential components to the success of this course (p. 1).

Such courses are typically offered during the school day at an assigned time and often a large group of students will sign-up and take the class. However, in this article, this was not the case.

The technology and engineering teacher showcased in this article teaches in a small rural school. The school does list Utah's engineering capstone course, but it has proven difficult to fill as a regular class. With only one technology and engineering teacher in the school, greater emphasis has been placed instead on exploratory high school engineering coursework. However, three senior students approached the teacher and wanted to take the engineering capstone course to increase their knowledge and skills in engineering and technology education.

The technology and engineering teacher approached the principal about the student's request, and the principal agreed to offer the capstone course in an after school (non-traditional) setting. The teacher agreed to teach the course that would focus on an engineering design challenge. Since the school is run on trimesters, the course was to be offered over two-thirds of the school year, or 120 days, as with other one-credit courses. This article details how the teacher successfully developed and delivered this non-traditional engineering design course.

After offering the course was approved and scheduled, the teacher reviewed Utah's Engineering Capstone Course to make sure that the strands and standards identified in the course would be covered (Utah Board of Education, Technology and Engineering Education, 2018a). In addition, the teacher reviewed the "capstone project rubric" associated with the course (Utah Board of Education, Technology and Engineering Education, 2018b). The rubric was used as intended by industry mentors to evaluate the students' final project.

In this course, the major strands listed required students to apply the engineering design process and to develop a solution to an engineering design problem. The teacher reviewed many models of the engineering design process and noted that they were similar in their ideas. The teacher chose the engineering design model to use in the capstone as the one developed and highlighted at TeachEngineering (n.d.) and modified it for the engineering capstone course. In the capstone course, students would be required to apply this engineering design process that would require them to:

(1) Identify the problem, including its needs, constraints, and stakeholders,

(2) Research the challenge, including identifying possible solutions,

(3) Build a prototype,

(4) Test and evaluate the prototype, and

(5) Communicate the results and improve as needed.

Identify the Problem

One of the major challenges associated with this course was to identify the engineering problem that the students would address. In this course, identifying the engineering design problem was driven by the students who identified a need for the school district to have an augmented reality (AR) sandbox.

At this stage of the course, the teacher was focused on supporting students in choosing a design problem, which meant staying very involved without attempting to steer the decision. For broad ideas, the teacher-directed them to the National Academies' list of "Grand Challenges for Engineering" (NAE, 2008). From there, students narrowed it down to a few areas of interest, and then eventually to a specific project. Within the

grand challenge of improving education in science and discovery, they settled on the idea of making an augmented reality sandbox.

An augmented reality sandbox is just one idea; other types of projects can be selected of course. Baker and Reeve (2019) reported on a community-involved project, for example, with students designing and creating signage for a local business. The implementation being reported in this article centers around students creating a mobile augmented reality sandbox. It is an overview of implementing an extended design challenge under the direction of the teacher with students working on it in an afterschool setting. The article discusses strategies the teacher found successful to implement the course and discusses possible barriers that need to be understood.

In planning to apply the engineering design process in solving a real-world problem, it is important that all stakeholders involved with the project be consulted. Both the students and the teacher were involved in making most of the initial contacts with the stakeholder. In this project, the stakeholders included:

- The technology and engineering teacher who would supervise the students.
- The school's geography teacher who would help in developing the learning outcomes associated with the project and use the AR sandbox.
- The school administration who would approve the non-traditional course.
- Teachers at other schools who would use the AR sandbox in their classrooms.
- The students involved in the project who were enrolled in the engineering capstone course.

- The school’s educational technology specialist.
- The school’s information technology (IT) technician.
- A small business owner and community leader.

Making initial contact with each of these people was important as it helped inform how the design problem was defined. It also established a support network that would be needed throughout the project. These individuals, once informed of the project, were also able to help with ongoing follow-up on the progress of the project.

Having students define their “own problem” from a world of possibilities and help make the stakeholder contacts was important. At the beginning of the course, the students took approximately three weeks to research and identity the problem. Having them identify the problem helped them to assume ownership in the project and motivated them throughout the project.

Research and Identify Possible Solutions

Outside of an engineering capstone, the research phase is an aspect of the design process that the teacher has found to be often rushed or even overlooked. This supports the work of Mentzer, et al. (2015). In a study of time usage by high school students in a design process, they report that “High school students’ lack of information gathering reduces their ability to engage in authentic engineering design experiences” (p. 428).

The teacher has observed that information gathering in a design process is a phase that takes place using some combination of computerized research, notetaking, and seeking information from other people. In the AR sandbox project, the rural high school students did use computerized research, notetaking, and made initial contacts with supportive stakeholders early in the project. Early contact with the supportive

stakeholders was very beneficial to the students as contact with these individuals helped to keep students motivated and they provided students with very helpful advice in the designing and building of a mock-up for the project.

Since the course was introduced in the middle of the school year, it did not begin with funding in place for supplies. However, a non-functioning mock-up was still sitting around from an attempt made previously by a few students in an introductory technology and engineering course. Essentially this was sand in a crate on an old A/V cart, with a projector haphazardly mounted atop an 8-foot board on the side. This mock-up was made available for the students in the capstone course to scrutinize and disassemble. The existence of a mock-up with obvious shortcomings combined with time spent waiting on unknown funding proved advantageous. The mock-up represented the attempt of others on a very limited budget to make something workable, which was exactly what the current engineering capstone course students knew they would face themselves. Materials could have been secured faster with other funding, but the teacher saw the advantage of not doing so. Students were being forced to plan and strategize, which is exactly what was needed during the second month of the project. The lack of a defined budget kept the students' research open to include everything from the lowest-cost to the highest-cost possibility. Even when a grant was secured, the exact amount available to utilize on the project was open for ongoing negotiation. In this way, the teacher facilitated the broadest and longest-lasting research effort he has ever seen with high school students as they worked to develop a defensible plan and budget for the AR sandbox project.

Build a Prototype

By the time funding was made available for prototyping, the students had asked enough questions in the research phase to more clearly define the problem. The teacher encouraged them to create a list of specific criteria and constraints. The list they developed noted:

- The size of the box should maximize the number of students who could gather around it and should be made using locally available materials
- The height should be able to provide students in approximately grades 4-10 a good viewing experience.
- The stand for the box must be able to hold the weight associated with the project.
- The depth inside the box should allow for maximum topology variations.
- The whole prototype should remain easily portable and fit through the school doorways
- The shape of the sand area should be correctly proportioned for the aspect ratio of the projector that was used to "augment" reality with the topographical overlay.

This list was one clear outcome of the students' previous several weeks of brainstorming. The teacher made sure students were talking to stakeholders and others. It was in those discussions that students were able to define the criteria and constraints related to the project. The teacher simply made sure this process was happening. Importantly, this list had not defined the problem from the outset, nor had it constrained the breadth of student's research or the process of ideation.

Even before the list of criteria and constraints was agreed upon, the students drew up several ideas and mentoring partners provided input to some of these early ideas. As the time for prototyping came, the teacher took care of the budgeting details. He also

made sure the students laid out a plan of work to account for how their time would be spent. Students had many details that could each potentially balloon into a larger project. There were structural concerns of containing so much heavy sand and concerns about how to make the project portable.

In the project, a computer and audio/visual (A/V) projector would be needed. A computer was needed and adapting an available computer was its own IT design problem. Finding out how different A/V projector specifications affected their possible placements in the design was another complex question that students had to address.

The teacher's role in all this was not to manage the project, but to keep students from getting "tunnel vision." Each checkpoint and daily interaction with the teacher were important so that students were able to continue to move along with the project. Otherwise, the teacher found the students tended to become too focused on just one aspect of the project and would not make progress. The teacher knew that constant refocusing was needed and he was able to facilitate this by asking the student team broad questions related to the project on a regular basis. This relationship kept the teacher involved and informed, but it kept the students as the leaders and main participants in the construction of the prototype.

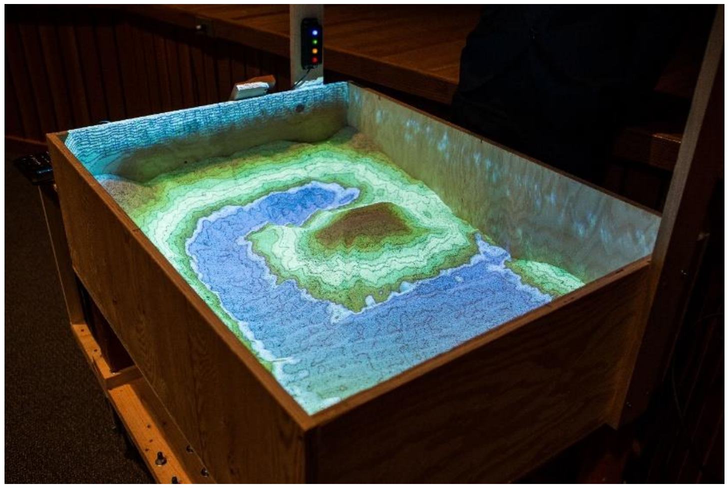

Figure 1. AR Sandbox Prototype. Photo and permission to use courtesy of Geoff Liesik.

Building the prototype (see Figure 1) required students to be detailed oriented as they had to firmly adhere to the criteria and constraints of the project. For example, the box width was driven by doorways, its length by a 4:3 projector aspect ratio, and the height of the sides by sand's angle of repose. Wheels were dictated by the stability, strength, and smoothness required. A framework was designed based on the height of the intended children users and the physical constraints on the rest of the project. Each of these portions of the prototype found the teacher supporting students in different ways (e.g., providing them with the next wave of materials, providing them with new a new workspace or tools, or by ensuring that they interact with other stakeholders and mentors).

Implementing the prototype also meant setting up the computer components, getting the software properly configured, calibrating and testing the unit, and routing the various cables and cords. All these considerations had to be accounted for in some form early on, but none were completely spelled out until that portion of the prototype was made. Drawings and CAD models were made along the way for each aspect of the

project. This allowed the project to be less overwhelming to students on a day-to-day basis. Throughout the prototyping phase, the teacher routinely was asking broad questions of the team and this formative evaluation pushed students to think creatively.

Test and Evaluate the Prototype

Building the prototype required students to continually test their ideas from the start to the end of the project. The teacher's task was to encourage frequent testing of the prototype. For example, the students built a sandbox on wheels to test to see if its height made it viewable to all students. In this design challenge, it was found that industry mentors and others gave feedback more readily on the evolving physical prototype than on the plans students would draw. Sometimes the team would face a setback as one design idea ran into conflict with plans for another aspect of the design. The teacher's role in this phase was to be supportive through setbacks and encourage students to continue testing until an ideal situation could be achieved.

During the design of this project, students' early testing found that the computer would need a larger graphics card, which meant the PC would need a larger power supply, which needed special cable connections to fit an older computer. Another challenge that arose with testing was students needed to find appropriate aspect and throw ratios for the projector. Testing with two different borrowed projectors, neither one a good fit, was also a learning experience. In each of these unforeseen steps, the teacher would consider and approve changes and contact, or have the students contact, stakeholders knowledgeable in that area.

In solving these problems, the students learned the importance of knowing how systems interact with one another and the need for communication and interdisciplinary

cooperation. As the apparent needs and budget evolved, the students also gained experience with purchasing procedures and helped request funding. All of this helped the AR sandbox be a capstone project in which students were experiencing authentic project-based learning. The teacher's critical role here was to help students experience testing embedded in the design process. Specifically, the technology and engineering teacher saw to it that testing occurred early and often. Throughout the project, especially in building the prototype, the teacher helped students overcome setbacks by providing them with continual support and guidance as they solved the various real-world problems they encountered.

Communicate the Results

The final phase of the project was the most rewarding for the students. The opportunity for recognition was a meaningful and important part of the capstone course experience. The casual involvement of others to test it at various stages helped boost motivation throughout the project. Toward the end of the project, the teacher and students had the opportunity to showcase the AR sandbox at two local events in the community. The local teachers' association was having a meeting and invited the students to showcase their work. Arranging this allowed the teacher to have other adults provide feedback to the students as they readied to make more formal presentations.

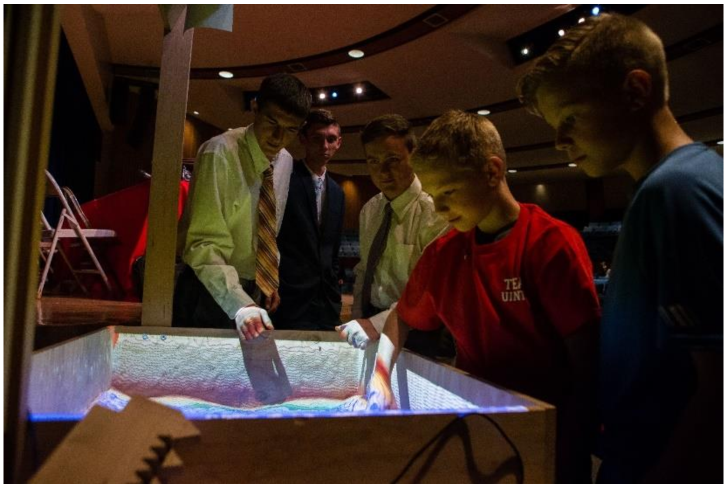

Figure 2. Students showing their AR prototype Sandbox to children at a school board meeting. Photo and permission to use courtesy of Geoff Liesik.

For their final assessment, students were required to formally present their design process and prototype to those mentors whom they had consulted during the project. These mentors included individuals from industry and with technical expertise from education. In preparing the students for the formal presentation, the teacher coached the students on how to develop and give a formal presentation. At first, the students seemed “nervous” in preparing for the formal presentation, but the teacher coached them to relax and this was achieved through students practicing an “elevator pitch” to several other people and by reviewing the Utah capstone project rubric criteria (Utah Board of Education, Technology and Engineering Education, 2018b) that would be used to evaluate them. The rubric form would be given to the mentors during the student’s formal presentation and evaluated them in areas related to their introduction, presentation, conclusion, and presentation mechanics. Before the student presentation, the teacher made sure that invitations were made to stakeholders, school personnel, as well as the industry evaluators, students’ families, and friends.

The teacher also arranged for students to present their capstone project to the public at a school board meeting (see Figures 2 and 3). The response was overwhelmingly positive among educators and families who were there with children of all ages receiving other recognition. The local media took an interest in the students' work, and a local photographer (i.e., Geoff Liesik) provided permission to use the photos shown in Figures 1, 2, and 3. Although the local paper did not print an article on the student's project, the school and district enthusiastically shared the outcome of the project through its own social media channels.

Figure 3. Students presenting their AR Sandbox Prototype to the local school board. Photo and permission to use courtesy of Geoff Liesik.

Conclusion

This article details the offering of an engineering design capstone course in an after-school setting (non-traditional) and shows what the teacher did to make sure students were successful in completing their engineering design challenge. Compared to most technology and engineering courses offered at the school, the engineering capstone design was different as it was driven by the students and the primary role of the teacher

was to act as a mentor help them to solve problems and succeed. Many lessons were learned in offering this course. Other teachers considering offering such a course should consider the best practices used in this course, as well as the potential barriers (see Figure 4).

Best Practices Used	Potential Barriers
• Having a student team identify their own engineering design project – increased student motivation. • Having students do multiple iterations of the design and prototypes. • Having students do in-depth research on their proposed project. • Identifying all project stakeholders and getting them involved early in the project – having students contact stakeholders. • Having the teacher continually using formative assessment (e.g., checkpoints at various stages during the project). • Having students do multiple formal presentations on their prototype.	• An unusual schedule (e.g., after school) could affect student motivation. • Complex budget. It needed to be developed by the students and many factors had to be considered. • The course was not structured as a typical course, and students often needed to be reminded of their roles and responsibilities. • Making sure students regularly contacted stakeholders. • Identifying and arranging appropriate community presentations.

Figure 4. Best practices and potential barriers associated with offering a non-traditional engineering design capstone course.

The process of selecting this augmented reality sandbox project and seeing it through was a great experience for the engineering and technology students taking the capstone course. For the teacher, it was a very new experience in an active support role rather than traditional teaching. Many other and younger students saw the project in process and were inspired to want a capstone engineering experience in the next year or two. This project made a lasting impact by creating a tool for learning in a variety of classes that can be used for years to come. As a teacher, this project increased my confidence in problem-based learning. I look forward enthusiastically to future cohorts of engineering capstone students, and the new in-depth projects which they will surely undertake.

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Appendix B

Utah's Engineering Capstone Course

STRANDS AND STANDARDS
ENGINEERING CAPSTONE

Course Description

As members of an engineering team, students apply science, technology, and mathematical concepts and skills to solve engineering design problems or to significantly innovate existing products. Students research, develop, test, and analyze designs using criteria such as cost, effectiveness, safety, human factors, and ethics. Long term project development by student teams and regular interaction with and presentations to members of industry are essential components to the success of this course.

Core Code	38.01.00.00.990
Concurrent Enrollment Core Code	None
Units of Credit	1.0
Intended Grade Level	12
Prerequisite	CAD Mechanical Design 2, and Engineering Principles 2
Skill Certification Test Number	USBE Project Rubric
Test Weight	1.0
License Type	Secondary Education 6-12
Required Endorsement(s)	Technology & Engineering, or
	Engineering

CTE Learning that works for Utah

STRAND 1

Students will follow safety practices.

Standard 1

Identify potential safety hazards and follow general laboratory safety practices.

- Assess workplace conditions regarding safety and health.
- Identify potential safety issues and align with relevant safety standards to ensure a safe workplace/jobsite.
- Locate and understand the use of shop safety equipment.
- Select appropriate personal protective equipment.

Standard 2

Use safe work practices.

- Use personal protective equipment according to manufacturer rules and regulations.
- Follow correct procedures when using any hand or power tools.
- Ref: https://schools.utah.gov/cte/tech/publicationsresources under the Safety Program and Management tab.

Standard 3

Complete a basic safety test without errors (100%) before using any tools or shop equipment.

STRAND 2

Students will describe a formal engineering design process to address a specific design problem.

Standard 1

Develop a clear, complete, and concise problem statement.

- Identify & define the design problem.
- List requirements.
- Identify constraints.
- Conduct research to identify similar efforts and become an expert on the topic.

Standard 2

Write a clear, complete, and concise design specification.

- Brainstorm solutions.
- Develop a decision matrix to compare and rank potential solutions.
- Synthesize the results and select the best solution.
- Sketch and annotate ideas and details while designing a prototype.

Standard 3

Create models & build a prototype.

- Mathematical models
- 3D solid models
- Scale models

Standard 4

Test the prototype.

- Record test results data.
- Evaluate the test results against the requirements.
- Identify weaknesses.

Standard 5

Redesign and optimize.

- Record findings.
- Improve on the initial design.
- Consider discarded ideas.

STRAND 3

Functioning as part of a team, students will design a solution to an engineering problem.

Standard 1

Employ a formal engineering design process to create a solution to an existing problem.

- Identify specific principles of design used in engineering and use them appropriately and effectively.
- Demonstrate creativity, resourcefulness, and the ability to think abstractly while applying a formal design process in the solution of an authentic engineering problem.
- Employ fundamental design principles within the context of a sequential and iterative design process while identifying, locating, and using mathematical, scientific, and technology-based resources to solve an engineering problem.
- Effectively apply a "systems thinking" approach in the solution of a specific and authentic engineering design challenge reflective of current industry practices.
- Create a Project Proposal document and/or presentation that justifies moving forward with a chosen problem.
- Perform a peer design review to evaluate the design in an effort to identify and correct potential mistakes and design flaws.
- Collaborate with and seek input from industry experts and mentors throughout the design process.

Standard 2

Develop and test a prototype.

- Design and implement a prototype testing procedure and data collection plan.
- Create a set of working drawings to document their proposed product design.
- Determine and document resource needs, including a bill of materials, tools, equipment, and knowledge required to build a prototype.
- Perform a cost estimate to build a prototype of the proposed product.

- Communicate professionally with experts and mentors to obtain feedback on the technical feasibility of the design, document the interactions, and implement recommended changes.

STRAND 4

Students will develop a marketing plan.

Standard 1

Evaluate the market to determine whether solving the problem is compelling to other entities.

Standard 2

Identify the target market for a potential solution to an identified problem. If so, create, execute, and evaluate a market research plan to gather data related to an identified problem.

Standard 3

Define, explain, and demonstrate an understanding of common vocabulary words used in association with product cost analysis.

Standard 4

Formulate a product cost analysis for a given product.

Standard 5

Demonstrate an understanding of packaging design requirements and will design a package for the product.

Standard 6

Document and summarize a patent search; disclose and appraise all current and past solution attempts available as commercial products or patents.

STRAND 5

Students will develop a production plan.

Standard 1

Identify, describe, and use research-based contemporary management processes in the design and development of specific engineering problems.

Standard 2

Design and implement a current industry standard system for quality control as part of an engineering design enterprise.

STRAND 6

Students will evaluate and reflect on their design process and will report on each step of their design process.

Standard 1
Utilize an engineering notebook per established conventions throughout the entire project.

Standard 2
Contact stakeholders and experts directly related to this project and problem and share the results of the testing results and effectiveness of the design solution.

Standard 3
Complete a comprehensive, multimedia presentation and portfolio that provides an overview of each step of the design experience using a variety of media.

Standard 4
Present a comprehensive report of the design to a panel of industry experts for their evaluation by the approved rubric.
https://schools.utah.gov/cte/tech/courses

Skill Certificate Test Points by Strand
Project rubric.

Performance Skills

1. Create and utilize an engineering notebook per established conventions.
   https://schools.utah.gov/cte/tech/publicationsresources
2. Demonstrate practice of the *Technology & Engineering Professional Workplace Skills*.
   https://schools.utah.gov/cte/tech/publicationsresources
3. Participate in a significant activity that provides each student with an opportunity to render service to others, employ leadership skills, or demonstrate skills they have learned through this course, preferably through participation in a Career & Technical Student Organization (CTSO) such as the Technology Student Association (TSA).

Appendix C

Utah's Capstone Course Evaluation Rubric

Technology & Engineering Education

Capstone Project Rubric

Industry Evaluator #1: ______________________________

Industry Evaluator #2: ______________________________

Student Name: ______________________________ Industry Evaluator #3: ______________________________

SCORING CRITERIA

0-4	5-7	8-10
MARGINAL	**ADEQUATE**	**COMPLETE**
Limited thought process, ample room for improvement	Gaps in thought process, room for improvement	Well thought out, limited room for improvement

1 - INTRODUCTION	
Welcome	
Outline of presentation objectives	
2 - PRESENTATION	
Idea Generation	
Problem statement - clear, concise, & focused on a single problem	
New and/or unique terms & vocabulary	
Why was this topic chosen?	
Relevant history of topic	
Research & Justification	
Professional & academic literature citations (no magazines, newspapers, or internet media)	
Compare & contrast specific, documented approaches to solving the problem	
Scientific laws, engneeering principles, & conventions that are demonstrated in the solution	
Explanation of why is this solution superior to existing solutions	
Planning, Construction, & Testing	
Project plan & budget	
Technical drawings	
Construction details & methods	
Display & operation of prototype	
Test plan & procedures	
Design iteration & modification cycles	
Analysis & Conclusion	
Data collected	
Information presentation & analysis	
Final result of data analysis	
3 - CONCLUSION	
Summary of project results	
Acknowledgement of support	
Questions & objections	
Closing Statement	
4 - PRESENTATION MECHANICS	
Time management (2-5 minute introduction, 15-20 minute body, 2-5 minute conclusion)	
Confident, polished, professional presentation	
Easy to read/view slides that are free of distracting transitions	
Main idea on slides, presenter elaborates rather than simply reads	
Correct spelling & grammar with relevant graphics	
Handling of questions & objections	
Appropriate attire	
TOTAL	0

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