Introduction to engineering: a constructivist-based approach to encourage engagement and promote accessibility

Lisa B. Bosman†, Kelli L. Chelberg‡ & Stephanie A. Fernhaber*

Purdue University, West Lafayette, Indiana, United States of America†
College of Menominee Nation, Keshena, Wisconsin, United States of America‡
Butler University, Indianapolis, Indiana, United States of America*

ABSTRACT: In an attempt to overcome the many barriers faced by engineering students, and specifically underrepresented students including women and minorities, a constructivist-based approach to an Introduction to Engineering course was developed and deployed at a Bachelor degree minority-serving institution in the Midwest region of the United States of America. This course provides an environment, which allows students to gain knowledge about the varying engineering disciplines and improve their written and oral communication skills, while at the same time being both engaged and enlightened in the process, and building excitement throughout the course. Students were asked to construct their own learning and knowledge through the creation of a fictional book series that introduced young readers to the engineering fields. While it is true that book creation in an engineering course may seem unconventional to many, this course produced students with both sound communication skills and a fundamental understanding of engineering that has laid the foundation for their academic careers.

Keywords: Minority, writing, cultural awareness, underrepresented, interdisciplinary, humanities, arts

INTRODUCTION

According to the National Science Board's Science and Engineering Indicators 2016, women earned approximately 29.7% of all Bachelor degrees in engineering in 2012 awarded from many countries throughout the world [1]. In the United States, these numbers are even lower, whereas women earned a dismal 19.2% of engineering Bachelor degrees and minority students comprise a mere 16.5% [2].

Research suggests there are a number of barriers preventing recruitment, retention, persistence and completion in engineering [3]. Student identity and beliefs have a more significant impact on predicting student choice to enrol in an educational engineering programme than student performance and competence level [4]. Furthermore, an engineering identity is highly correlated with engineering retention and persistence [5]. Unfortunately, the *chilly climate* often associated with engineering can lead to feelings of self-doubt, isolation and questions of student belonging [6], which is reported more often by women and minorities. This lack of connection to the engineering discipline often leads to enrolment avoidance, transfer into non-engineering programmes or drop-outs prior to completing the degree.

Another major challenge has been identified as inadequate access to career counselling and, thus, lack of awareness related to potential academic or career pathways in engineering [7]. This knowledge gap is of particular importance to minority students who are frequently first-generation college students, resulting in a limited ability for parents to offer guidance and career advising.

In addition, lack of curriculum reforms and limited change in teaching pedagogies are rampant in engineering [8]. Instead of applying evidence-based teaching methods, which tend to be inclusive of all learners, such as experiential learning [9], instructors tend to teach the way they were taught commonly through the use of lecture. Lastly, a large barrier to success in engineering is the insufficient ability for code-switching. Code-switching refers to one's ability to communicate with people of all audiences, in both professional terms and popular terms [10]. These *soft skills* are of particular importance to engineers, who are often required to translate complex engineering concepts and terms into information that can be consumed by multiple audiences.

In order to overcome the barriers commonly faced by engineering students, and especially by underrepresented students including women and minorities, a constructivist-based lens was applied to an Introduction to Engineering course.

Constructivist teaching is based on the belief that learning occurs as learners are actively involved in a process of meaning and knowledge construction as opposed to passively receiving information [11-13]. Beyond the common goal of using a constructivist approach to introduce the students to the varying facets of what it means to be an engineer, this course sought to 1) provide students the opportunity to connect what they do in engineering and identify what they are learning to real-world situations; 2) provide students with information about career and academic pathways and opportunities; and 3) increase student skills related to communicating to a variety of audiences (e.g. code-switching). The course was developed and deployed at a Bachelor degree minority-serving institution in the Midwest region of the United States of America.

PART 1 - INTRODUCTION TO ENGINEERING COURSE

The 16-week Introduction to Engineering course is broken out into two parts. The first eight weeks provides the foundation for students to understand a variety of engineering disciplines and the potential career and academic pathways associated with each discipline. Following the constructivist teaching approach, students are actively involved in the learning process, which focuses on three main pedagogical styles: 1) problem-based learning activities; 2) on-line discussions; and 3) research and presentation. A sample curriculum for each of these pedagogical styles is provided below.

Each week, students work in teams to complete a problem-based learning activity. Each activity provides an experiential learning opportunity highlighting a different engineering application. For example, one of the problem-based learning activities is focused on better understanding civil engineering, where students work in teams to complete the Marshmallow Challenge [14].

Students also participate in an on-line discussion forum. The on-line discussion requires students to provide an initial post and respond to at least one peer post, offering an opportunity to learn with their peers and practice their communication skills. On-line discussions offer students the necessary amount of time required to submit a thought provoking response, allow students to take into consideration non-curricular resources and current news media to provide justification for responses, and afford students an opportunity to gain insight and learn from their peers [15]. Sample on-line discussion prompts are provided here:

- Civil engineers design, build, supervise, operate and maintain construction projects and systems in the public and private sector, including roads, buildings, airports, tunnels, dams, bridges, and systems for water supply and sewage treatment; the median annual wage for civil engineers was $US83,540 in 2016 [16]. Search the Internet to find a commercially available civil engineering focused design you think is especially innovative. Explain the product and why you think it is innovative. Select a peer's post. Compare and contrast your own post to a peer's post.
- Mechanical engineering is one of the broadest engineering disciplines. Mechanical engineers design, develop, build, and test mechanical and thermal sensors and devices, including tools, engines and machines; the median annual wage for mechanical engineers was $US84,190 in 2016 [16]. Search the Internet to find a successful mechanical engineer. Provide a brief background on the person and explain why you think this person is especially successful. Select a peer's post. Compare and contrast your own post to a peer's post.
- Computer hardware engineers research, design, develop, and test computer systems and components, such as processors, circuit boards, memory devices, networks and routers; the median annual wage for computer hardware engineers was $US115,080 in 2016 [16]. Search the Internet to find an ideal job posting for a computer engineering position. Briefly, explain the job requirements and provide a background on the company. State why you think this would be an ideal job and place to work. Select a peer's post. Compare and contrast your own post to a peer's post.
- Unfortunately, engineers have not done a good job in getting the word out about what they really do (perhaps, because they are too busy doing it!). As a result, a lot of misconceptions exist about what engineering is and what engineers do, with people believing engineers to be anything from locomotive train operators to mechanics/ technicians, to construction supervisors, to NASA personnel, to generic *computer people*. State how you would explain the role of engineers to an adult and to a child. Select a peer's post. Assume you are that unknowing adult or child. What types of follow-up questions would you ask to learn more about engineering?

Around mid-semester, at the end of the first section, student teams provide presentations based on research within topic areas exploring a variety of engineering disciplines. Students can choose which discipline to explore; however, each engineering discipline can only be used once. Teams are required to research and report on the following:

- Career opportunities in the engineering disciplines;
- Famous underrepresented heroes in the engineering disciplines;
- Research and design innovations in the engineering disciplines;
- Software and technology application(s) used in the engineering disciplines;
- Education requirements in the engineering disciplines.

These presentations offer student-driven and researched learning opportunities into the many different engineering disciplines, and also prepare for the next part of the semester long class.

PART 2 - INTRODUCTION TO ENGINEERING COURSE

The second eight weeks of the semester is where students work in teams to complete a book development process culminating in an engineering-focused culturally-cognisant children's book. Such an approach has been argued to not only increase writing and communication skills, but also offers a way to engage students and develop a deeper sense of connectivity or purpose in what they are doing [17].

Within the class, the book writing process involves a multi-disciplinary three-faculty instructional team representing engineering, the humanities and teacher education. The engineering faculty assists in validating content knowledge, the humanities faculty assists in facilitating the storytelling process, and the teacher education faculty advises the students on using age-appropriate language.

This process starts with student teams completing an initial book outline. An example is provided in Table 1. The students spend the remainder of the course filling in and writing the story. Each week, the instructional team provides feedback. At the end of the course, students submit text and proposed pictures for a 22-page children's book.

Table 1: Example children's book outline.

Component	Description
Engineering field	Civil engineering
Young engineer's name	Wendy Wolf
Cultural component	Wendy Wolf is a child born with a disability and needs to act as a warrior to overcome the conflict.
Conflict situation	A windstorm comes into the scene and blows down the hunting stand down. However, hunting season is soon to begin, so the hunting stand needs to be rebuilt as soon as possible.
Complications	Wendy Wolf tries to rebuild the hunting stand on her own, but cannot seem to get it right.
Elder/mentor who helps	Wendy Wolf's aunt comes to visit just before hunting season. She happens to be a practicing civil engineer and offers up her expertise.
Engineering skillset needed to succeed	The key engineering skillset required is the concept of counter weight and weight distribution (e.g. beam loads in technical speak).
Climatic complication	Wendy Wolf's parents come home and are excited to see the amount of self-motivation, work and effort put towards building the new stand.
Resolution	Dad (the hunting guide) inspects the new stand and is impressed by the design structure.
Denouement	Wendy Wolf and her dad go hunting. The hunting stand works well (no creaking or cracking). Wendy Wolf shoots a deer.
Opening	Tonight was the night. All week long the weatherman warned Wendy Wolf and her mother of a nasty storm that was going to start around midnight. Wendy went to bed somehow less worried than her mother who constantly reminded her to run to the basement if and when she told her to do so. Wendy slept soundly through the night, only to wake up the next day with a yard full of twigs and branches from nearby trees. The first thing he thought of was the deer stand. Wendy's mother asked if he heard the storm last night. *Oh no!* said Little Wolf, the *tree stand*. Little Wolf loves hunting with her dad and they live on a huge land lot with trees and creeks. One night a very bad wind storm knocked over some trees. Wendy was worried that the tree stand was damaged because of the strong winds.
Exposition	Hunting season was Wendy's favourite time of the year. She got to spend the most time with her father and enjoyed being outdoors. After sleeping soundly through a nasty windstorm, Wendy went to check on the deer cam and the deer stand. She was horrified when she got close enough to see that the deer stand had been blown over. *NOOO!* cried Wendy. Hunting season was only two weeks away and she knew her father would be disappointed that the stand had been destroyed. Wendy wanted to make things right before her father came home from a business trip for opening weekend. She shot her first deer from that stand last year and was sad to see it laying scattered across the forest floor in pieces. Wendy's family believes that most foods should come from nature. Wendy was given the responsibility to make sure the hunting area is cleaned. Her dad is out of town for work. Wendy wants to impress his dad with the new tree stand that she built without harming the trees with nails.

STUDENT ENGAGEMENT BEYOND THE CLASSROOM

Once the course is complete, the instructional team offers students the opportunity to take their work further and complete the following: 1) provide illustrations; 2) format the books for publishing; and 3) participate in book readings.

The high level of voluntary student involvement outside of class indicates elevated student engagement, and an increased sense of pride, identity and connection to engineering. Figure 1 offers a sample of student-drawn illustrations for the Civil Engineering - Wendy Wolf children's book referenced above.

Figure 1: Sample student-drawn illustrations.

The books were formatted using CreateSpace [18], which provides free tools to self-publish and market the children's books for free through Amazon.com. CreateSpace is easy to use, provides many options, allows students to create book covers using the book cover template software, assigns an ISBN, and automatically publishes the finished book to Amazon.com for purchase by millions of people throughout the world. See Figure 2 for an example book cover used for the Civil Engineering - Wendy Wolf children's book reference above. Once the children's books were completed and published, students polished their speaking skills by participating in book readings in schools and coffee shops throughout the local community. Additionally, the books were incorporated into after school programmes at a local YMCA After School Programme [19]. See Figure 3 for a picture from one of the readings.

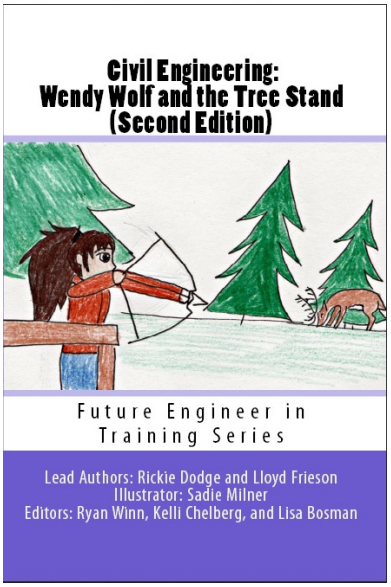

Figure 2: Example book cover for Civil Engineering - Wendy Wolf.

Figure 3: Book reading at a local coffee shop.

SUMMARY AND CONCLUSIONS

This Introduction to Engineering course was launched to test the hypothesis that the secret to engineering student recruitment and retention, especially for women and minorities, exists in providing students an opportunity to connect engineering to real-world situations, helping students develop knowledge about career and academic pathways and opportunities through constructivist teaching, and assisting students with communicating to a variety of audiences.

Like most incoming freshmen, the students at this institution typically arrive on campus with both limited knowledge about the varying engineering disciplines and evident deficiencies in their written and oral communication skills. This course provides an environment, which allows students growth in these areas, while at the same time being both engaged and enlightened in the process, and building excitement throughout the course. Students were asked to construct their own learning and knowledge through the creation of a fictional book series that introduced young readers to the engineering fields. This unique approach produced students with both sound communication skills and a fundamental understanding of engineering that has laid the foundation for their academic careers.

Many academic institutions experience interdisciplinary barriers caused by the preverbal educational silos. However, involvement of administration and the willingness of faculty allowed for an instructional team including faculty within engineering, education and the humanities. From start to finish, students became fluent in both the engineering fields they chose and the process required to write and format the books. The books have been collectively called the *Future Engineers in Training Series* [20], and after sending a few donation requests to a few high profile local organisations, funding was received that provided printed copies to the local schools and libraries that serve as educational partners. For more information on the series and process see the College of Menominee Nation site [21].

While this approach of asking students to write and communicate concepts to children may be unconventional, it is hardly the first attempt to recognise its potential for assessing students' mastery of a concept. A quote attributed to Albert Einstein states that …*If you can't explain it to a six year old, you don't understand it yourself.* Anecdotal evidences suggest that the book series caused our engineering students to not only understand the multiple disciplines in their field, but also build justified confidence in their communication skills. Yet beyond those admirable accomplishments, pride is taken in the fact that the students' intellectual investment in their first project kept them engaged long after their initial semester ended.

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BIOGRAPHIES

Lisa B. Bosman is in the Purdue Polytechnic Institute at Purdue University. She received her MS in industrial engineering from Clemson University in Clemson, South Carolina, USA, and her PhD in industrial engineering from the University of Wisconsin-Milwaukee in Milwaukee, Wisconsin, USA. Her research interests include solar energy performance modelling, STEM education and the entrepreneurial mind-set. She has particular research interests in engineering education.

Kelli L. Chelberg is in the Teacher Education Department at the College of Menominee Nation. She received her MS in education from Southern Illinois University in Edwardsville, Illinois, USA, and is currently pursuing her EdD in educational leadership from Edgewood College in Madison, Wisconsin, USA. Her research interests include STEM student retention, persistence and success, as well as STEM education, specifically in relation to under-represented and minority populations.

Stephanie A. Fernhaber is an Associate Professor of Entrepreneurship within the Lacy School of Business at Butler University in Indianapolis, IN, USA. In addition to teaching, Stephanie conducts research in the areas of international entrepreneurship, networks and new venture strategy. Stephanie received her PhD in entrepreneurship from Indiana University in 2006.