

How Does Service Learning Increase And Sustain Interest In Engineering Education For Underrepresented Pre-Engineering College Students?

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1. Introduction

The United States has established itself as a leader in the global economy. However, there is mounting concern that the STEM workforce is losing its capability to sustain and advance science and engineering research initiatives [1]. American dominance in Science, Technology, Engineering, and Mathematics (STEM) will not be achieved without intensive efforts and investment [2]. Continued economic growth requires individuals who bring knowledge, creativity, and diverse perspectives in order to sustain growth and retention through a diverse workforce [3]. Unfortunately, despite considerable efforts over the past years, a large gap in educational attainment, specifically at the bachelor's level, exists between whites and all underrepresented minority groups [1]. According to the most recent National Science Foundation Science and Engineering Indicators (2016), of those college graduates that have a degree in Science and Engineering. The demographic breakdown is as follows: White 76%, Asian 8.4%, Hispanic 7.7%, Black 7.2%, and American Indian or Alaska Natives 0.3%. Furthermore, the attainment of Bachelor's degrees in Science and Engineering awarded to American Indian or Alaska Native students has remained flat at less than 1% since 2000 [1]. Engaging this underrepresented group may hold the key to the United States continued economic prosperity.

Many barriers exist for American Indian students pursuing STEM degree programs. The open enrollment policy of many Minority Serving Institutions, and in particular Tribal Colleges and Universities (TCUs), was established with the intention to meet the needs of low-income, at-risk, first generation, and underrepresented students [4]. As a result, many TCUs have received a higher quantity of underprepared students. The latest report on TCU placement tests indicates that 62% of incoming first-time students were placed into remedial math, providing further evidence that STEM skills, in general, are lacking [5].

Federally recognized TCUs are uniquely suited to raise these percentages because of their shared mission to provide 21st Century educational opportunities for American Indian students [6]. In an attempt to highlight TCUs potential for recruitment and retention of American Indian students and add to the United States' STEM workforce,

this paper will address the following research question: **How does service learning increase and sustain interest in engineering education for underrepresented pre-engineering college students?**

2. Service Learning

Experiential learning is an educational pedagogy that accentuates learning through experience. It is based on the learner creating his/her own knowledge based on their experience. Kolb's Experiential Learning Theory defines successful experiential learning "as the process whereby knowledge is created through the transformation of experience"[7]. Knowledge results from the combination of grasping and transforming experience. Service learning is a type of experiential learning in which students apply their knowledge and skills to solve problems in the community, often working collaboratively with others as a team [8]. A student who participates in service learning experiences benefits by gaining hands-on experience through the application of critical thinking and problem-solving skills, relevant class content, and opportunities for communication, collaboration and leadership. Service learning compliments traditional classroom learning (lectures and textbook readings) by giving a student the opportunity to participate and apply knowledge and skills learned while having an impact on the lives of others.

In recent years there has been an increased interest in providing service learning opportunities in engineering programs by shifting from conventional engineering curriculum to one that includes training future engineers to become socially responsible citizens [9]. One reason may be that in addition to technical skills, the Accreditation Board for Engineering and Technology (ABET) requires engineering program graduates to have the ability to understand their professional and ethical responsibility, have the ability to function on multidisciplinary teams, and possess the ability to understand the impact of engineering solutions in a global, economic, environmental, and societal context [10]. These outcomes can be achieved through a service-learning design project that allows for engineering students to learn and practice design, interact with and serve others, and meet societal needs as a mission to their profession [11]. Some of the ben-

efits of service-learning includes increased recruitment and retention, boosting social awareness, increased appreciation of the profession of engineering, the teaching of engineering ethics, and involvement in an experience that accentuates both technical and non-technical skills [12]. Service-learning projects are an effective strategy in meeting the needs of current trends in undergraduate engineering students' education and meeting the needs of the 21st century.

3. Arcs Model Of Motivational Design

Motivating students with real and relevant instruction has been shown to increase their learning of theoretical concepts, and provides students with a positive outlook towards the learning process [13]. The ARCS Model of Motivational Design provides a framework to better understand the motivation process [14]. The acronym ARCS refers to the four key elements of motivation: "A", Attention; "R", Relevance; "C", Confidence; and "S", Satisfaction. This framework can be used to understand a student's motivation. Attention is a prerequisite for learning and arouses the students' curiosity. Relevance considers whether or not the material, content, or experience is relatable and meets the goals of the learner. Confidence provides both scaffolding for student success (builds self-efficacy) and offers learners the opportunity to acquire new skills under low-risk conditions [13]. Satisfaction builds students sense of achievement and provides intrinsic reward.

Many engineering educators are working on improving student motivation to learn through increasing student awareness of his/her roles as an engineer contributing to society [15]. One way of increasing student's awareness of their contributions is through the use of service learning in the college environment. "Service learning's motivational impact on such learning outcomes is especially noteworthy because service learning is one of the instructional strategies that has the potential to improve students' motivational attitudes on these ARCS factors" [15].

Questions that instructors should consider when designing a service learning experience are: (1) Attention:

Is this learning interesting to the student? (2) Relevance: What's in it for the student? Will working on this project benefit the student now or in the future? (3) Confidence: Is the student capable of successfully completing this learning task? (4) Satisfaction: Will the student feel good about this project and what he/she is learning? [15]. Using the ARCS model as a strategy for improving student motivation and student retention through the use of service learning has a measurable impact on the way students learn to become successful and contributing engineers.

4. Service Learning Program Design

The College of Menominee Nation's service learning program was designed for underrepresented pre-engineering college students based on the ARCS Model of Motivation Design [14]. The program was implemented in collaboration between the College of Menominee Nation (CMN), a federally recognized TCU, and the Greater Green Bay YMCA, both of which are located in northern Wisconsin. The Greater Green Bay YMCA currently serves five "at-risk elementary schools" within the Green Bay area. The schools are categorized as "at-risk" due to the large percentage of students facing high poverty and low math/reading scores. Each of the five school sites has an "after school program" running daily for about two to three hours after the traditional school day ends. Each site is equipped with a coordinator and volunteers to assist in supervising the children and providing meals. CMN developed the program, to allow its pre-engineering college students the opportunity to utilize the ARCS model to mentor at-risk children through the YMCAs pre-existing After School Program.

- **Attention** was encouraged by building a team comprised of a college student and one to three children. Together, the team participated in an experiential "hands-on" learning experience building STEM-based K'NEX kits. Each experience allowed for the college student to build rapport and engage with the children through constructing renewable themed structures and discussing the renewable energy it modeled. Prior research suggests experiential and hands-on learning is an effectively pedagogy for building interest and keeping student attention.
- **Relevance** was promoted through the use of culturally relevant topics, including renewable energy and fostering a sense of community. As a federally recognized Tribal College and University, the College of Menominee Nation has a large percentage of American Indian students. Due to the natural connection between American Indian peoples and nature, renewable energy and the environment is a natural and relevant context to increase interest and participation for American Indian college students. The STEM-based

K'NEX kits were centered on renewable energy technology including solar, wind, and hydro. Furthermore, in general, American Indian communities often work towards a greater cause to benefit the entire tribe. As a result, the program was designed to build relationships and a sense of community between the American Indian college students and the at-risk children, by utilizing the same group of teams throughout the program.

- **Confidence** was stimulated through the incorporation of the service learning methodology, which has many benefits including building social confidence. CMN offered the program free to the Greater Green Bay YMCA, in an effort to provide a mutually beneficial service learning opportunity for both the underrepresented college students and at-risk children.
- **Satisfaction** was fostered through students work with at-risk children, which aimed to naturally build intrinsic motivation. The use of daily reflections assisted the students in better realizing the impact, personal growth and development acquired by working with at-risk children.

5. Participants

The service learning program was conducted at all five Greater Green Bay YMCA afterschool sites over three semesters that included CMN's Spring 2015, Fall 2015, and Spring 2016. A total of 63 college student mentoring positions were filled. The students were predominantly American Indian, female, part-time, non-traditional, and were either enrolled or planning to enroll in the Pre-Engineering degree program.

6. Data Collection

Data was collected using both quantitative and qualitative methods. The CMN students completed a post-then-pre survey assessing the interest and self-efficacy related to renewable energy and STEM skills. Additionally, the college students developed a pre- and post-"Philosophy of Mentoring Statement". Finally, the college students submitted daily reflections responding to prompts focused on that day's interactions. The program had a 100% response rate.

The renewable energy and STEM skills survey assessing interest and self-efficacy included multiple choice and Likert scale items taken from the Energy Literacy Survey [16], which is used by various NSF-funded projects to gauge student attitudes toward renewable energy. The survey was administered through a retrospective post-then-pre survey at the end of the experience. Each student was first asked about his/her current perceptions and then asked to reflect back on their perceptions prior to beginning the project. For analysis, negatively worded items were reverse-coded. Next, paired sample t-tests were

conducted to examine the mean differences at the item level for each of the perceptions.

The Philosophy of Mentoring Statement consisted of five open-ended reflective prompts focused on student perceptions of mentorship goals, including but not limited to (1) What are your values, beliefs, and goals as a mentor? (2) Why is mentoring important to you and your community? (3) What does the ideal mentoring situation look like to you? (4) What skills/knowledge should learners obtain as the result of your mentoring? (5) How might you obtain new skills/knowledge to improve your mentoring?

Reflection prompts were administered on a weekly basis throughout the mentoring experiences. Each week students received an open-ended, reflective prompt focused on their perceptions of their general experiences and the impact of the mentoring program, including prompts such as: (1) Please describe your experiences and feelings during your first session. (2) Please describe what you have observed thus far in your children's behavior. What impact have your children had on you and what impact have you had on your children? (3) What are some of the pressing needs/issues currently facing the youth in your community? How does your work and the work of others at the YMCA address those needs? (4) Please describe what you and your child have learned during this experience. How can you apply what you have learned in the future?

7. Analysis And Results

STEM and Renewable Energy Interest Surveys

In general, the averages for the majority of items were higher on the post-survey when compared to the pre-survey. Significant differences ($p = 0.05$) emerged between the pre-survey and the post-survey for the following items: (1) Saving energy is important, (2) I don't need to worry about turning the lights or computers off in the classroom, because the school pays for the electricity, (3) More oil fields should be developed as they are discovered, even if they are located in areas protected by environmental laws, (4) We should make more of our electricity from renewable resources, (5) More wind farms should be built to generate electricity, even if the wind farms are located in scenic valleys, farmlands, and wildlife areas.

Philosophy of Mentoring Statement

The analysis focused on both students' growth in response to maturity and exploratory analysis of clustering for respondent themes. On average, students provided more detailed reflections following the mentoring experience. However, there was not a significant difference between the word count for pre-reflections ($M=136.21$, $SD=94.31$) and the word count for post-reflections ($M=166.14$, $SD=102.63$); $t(13)=-1.60$, $p=0.13$, $d=0.30$. Four major themes emerged from an exploratory

cluster analysis of the data. Themes included: (a) desire to serve children and community, (b) developing positive attitudes and skills, (c) preparing children to be respectful community members, and (d) impact of mentorship on children and students. These themes are described in greater detail below:

The first Philosophy of Mentoring theme was the desire to serve children and community. Philosophy of Mentoring Statements illustrated students' desire to "give back" to the community and support the youth. For example, when talking about the importance of mentoring, one student said, "Mentoring is important to me because I believe in giving back. As a child myself, I was able to participate in after school activities that ultimately helped me overcome any obstacles in life." This student was motivated to give back because he/she had such positive experiences in an after school program as a child. Another student seemed to suggest a responsibility to give back by saying, "I believe in giving back and I strongly believe in 'It takes a village to raise a child.'" Students were passionate about making a difference in the lives of the children.

The second Philosophy of Mentoring theme was developing positive attitudes and skills. Leadership, teamwork, communication, and problem solving skills were among the skills emphasized by students in their mentoring statements. These were identified as skills that were important to the students and in the community. Students also expressed a desire to help children gain positive attitudes about themselves and their community. This included helping children gain confidence, a sense of trust, and a willingness to ask for help. One student shared about their hopes for the children, "That they [can] do anything they put their minds to, can trust me and ask me for help, can problem solve, and communicate effectively and not be afraid to ask for help or offer help and assistance." Another student echoed this desire and discussed how the skills and attitudes that students gain will be used to improve the ability of the community to communicate and share ideas, "They should also learn how to be [a] critical thinker, to be creative, to work well with others and to be confident. After all, this is how they become active and positive members of their communities." Students identified learning goals for children in hopes of developing responsible children who would go on to improve the community and serve its members.

The third Philosophy of Mentoring theme was preparing children to be respectful community members. The Philosophy of Mentoring statements illustrated a desire among students to improve the community through mentorship. Specifically, students recognized the importance of children in the community and the need to help them socially mature into responsible and respectful adults. One student shared, "Mentoring is important because it shows children how to be respectful young adults, and encourages them to do great in life. It is important to our community because they are our future leaders and

to build them to be awesome people so that we can all have a good environment to live in." This student believes it is important to prepare children to become respectful in order to ensure the community is a positive environment. Other students also discussed the importance of respect and the need to recognize, encourage, and respect the children they mentor. One student shared, "I believe that showing [children] the appropriate amount of respect from a mentor to a child is expected. They are just little people. We may have to communicate with them a little different but they deserve to be praised, encouraged, and respected." Students recognized children are the future of the community and stressed the need to treat them well and model respectful behaviors.

The fourth Philosophy of Mentoring theme was the impact of mentorship on children and students. Students recognized the magnitude of mentorship on children. For example, one student shared when reflecting on the importance of mentoring, "It is important because the small time that I invest could be a life altering event for a child. I hope that there will be a snowball effect, and that the children I helped, can one day help somebody else." In addition, students discussed the impact mentorship had on them and what they learned from serving as mentors. One student stated, "Mentoring also gives me the opportunity to learn from the children [as] opposed to them only learning from me." Other students reflected on the impact that the mentoring experience had on their perceptions of their community and other communities. One student captured this, saying, "[Mentoring] has changed my perspective on my community by understanding that the need is there to have more mentoring programs on the reservations so kids can make healthier and better choices." Another student expanded their outlook through mentorship and gained a better understanding of other communities, stating, "I never paid much mind to any other community besides my own. . . Now this program has opened my eyes to all of the smart young minds in our public schools." The defining conclusion is that the mentoring experience broadened the perspectives of those students serving as mentors.

Weekly Reflections

Four major themes emerged from an analysis of the data. Themes included: (a) excitement for learning, (b) changes in behavior, (c) the importance of education, and (d) learning gains. Those themes are described in greater detail below:

The first reflection theme was excitement for learning. Some students discussed feeling nervous going into the first YMCA mentoring session and described the first experience as overwhelming or chaotic. The children were sometimes described as hyper or reserved. However, the majority of comments were very positive with students discussing how excited the children were and how engaged they were in the activities. One student shared, "I

really enjoyed the groups at [School A]. The students are very well behaved and well mannered. The group of girls I had were very excited to learn about the wind sail car and about meeting with me again next week. I had a great time talking with the students and overall [was] very happy with how the session turned out." Another student shared about feeling nervous at the beginning but having an enjoyable time interacting with the children and contributing to their learning, "My experience with the first session was pretty good. I went in very nervous but came out feeling great. I loved it. The kids I had were funny and very smart. They seemed to like the [K'Nex] and they really had their own ideas of what they wanted to build instead of what was in the book, so I tried to encourage them that engineering isn't what was just on the paper. It was fun and I enjoyed it. Student reflections suggested that children were excited to learn and that the students enjoyed observing and contributing to their learning. Students were excited to return and get to know the children better.

The second reflection theme was positive changes in behavior. Students described changes in the children's behavior when compared to the previous week. One student shared, "I worked with one of the same kids as I had two weeks ago. The first time we met she was very quiet and reserved. This week, she was talkative and laughed a lot. She came and sat by me during the story and enjoyed playing with [K'Nex]." Those students who previously described the children as "hyper" felt they were "well behaved" and those students who previously described the children as "reserved" felt the children were "speaking up more" and "gaining more confidence." Students hoped they were making an impact on the children by providing a safe environment and taking an interest in their lives. Case in point, a student shared, "One of the kids was wondering if I have ever been bullied. I said yes, a few times, and he said he used to but is now a cool kid. He thought it was cool we could relate and I felt good because I made him feel like he was not the only one." Students were making strong connections with the children by providing safe environments where the children felt comfortable opening up and then taking an interest by relating to the children when they did open up. Students were able to identify how the children were impacting them as well. Students were enjoying themselves and feeling like the children were impacting their outlook. One student shared, "The impact [the children] have made on me is nothing but positivity. They have restored my desire to continue to work with young children. It has reminded me that the future of our world still has hope. They have actually provided me with [my] happiest times in my recent days, which is a welcomed blessing." Students felt that the children were important to the future and deserving of and in need of mentoring and role models to unlock their full potential.

The third reflection theme was the importance of edu-

cation. Poverty, drug/alcohol abuse, troubled home lives, and lack of mentors/role models were all listed as issues children face. The major theme that emerged from these reflections was the importance of education and the need for the youth to be encouraged to pursue higher education. One student shared, "Issues facing the community [are the] youth not going on to college or dropping out of school. YMCA is addressing this by helping to show kids that learning is fun and [that] it's important to continue their education." This student, along with others, recognized that the YMCA program was addressing the needs of the youth by providing them with positive mentors and a fun learning environment that encourages them to pursue a higher education.

The fourth reflection theme was learning gains. Several students felt children acquired skills in problem solving, teamwork, and communication. Students also felt that children gained confidence and were opening up more. One student shared about their learning and the children's learning, "I have learned that there are so many things in the world that I have taken for granted". Talking and interacting with these children has given me the opportunity to view things from a different perspective. I think that my students learned that they hold the key to their own knowledge. They also were able to take knowledge and apply it as a skill. Lastly, this program allows children to speak freely. At such a young age it is easy to get overlooked. These children were able to have a voice, finally, which they rightly deserve." The student describes the children as being empowered and able to apply their knowledge as a result of the YMCA program. The student also describes how the children have expanded his/her perspective. Along with impacting students' general outlook, students described patience as a major takeaway from the YMCA program. One student shared, "I learned to take a deep breath, that some of the behavior cannot just be the child's fault but an example of their situation. The more you praise and show encouragement the more they respond, open up, and enjoy the time they are having. [I learned] to make sure I ask more questions, speak in a soft voice, and have an understanding that sometime kids home life isn't always rainbows and butterflies." This student has become more sensitive to the needs/issues facing the youth of the community and applied that to become a more patient mentor.

8. Discussion

The qualitative assessment findings suggest that college students have a desire to mentor children and serve the community by preparing children to become respectful community members and helping them develop valuable skills in problem solving, teamwork, and communication. The college students developed safe learning environments that allowed the children to gain confidence, open up, and develop meaningful relationships. Interacting

with the children furthered the intentionality, and the students exhibited an awareness of the issues facing children and the community in general. Students identified equitable access to education as a major issue and stressed the significance of counseling the at-risk children about the importance of education. The quantitative findings suggest that student attitudes toward renewable energy improved as evidenced by increased averages on items from the survey. Many barriers exist for American Indian students pursuing STEM degree programs. However, appropriately designed service learning experiences offer an effective approach to overcome these barriers in an effort to recruit and retain a diverse population into STEM fields [17].

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