Advancing High School STEM Education: Implications for Engineering Technology

Dr. Anne M Lucietto, Purdue Polytechnic Institute

Dr. Lucietto has focused her research in engineering technology education and the understanding of engineering technology students. She teaches in an active learning style which engages and develops practical skills in the students. Currently she is exploring the performance and attributes of engineering technology students and using that knowledge to engage them in their studies.

Dr. MESUT AKDERE, Purdue University

Mesut Akdere is an Associate Professor of Human Resource Development in the Department of Technology Leadership & Innovation at Purdue University, West Lafayette. Mesut Akdere received his Ph.D. from the University of Minnesota in Human Resource Development with a minor in Human Resources and Industrial Relations. Currently, he is serving as the Director of Purdue Polytechnic Leadership Academy helping STEM students develop their leadership competencies. He is also the inaugural faculty research fellow at the Center for Intercultural Learning, Mentorship, Assessment, and Research at Purdue University. Dr. Akdere's research focuses on workforce development in STEM fields, developing intercultural leadership competencies through immersive learning technologies including augmented reality and virtual reality, quality management, and performance improvement through training and organization development. He is currently serving as the Director of HRD Virtual Lab as well as HRD Analytics Lab in the Department of Technology Leadership & Innovation. Dr. Akdere published in business, management, technology, training, human resources, organization development, and education journals. He teaches courses in human resource development, leadership, training, organization development, cross-cultural management, and strategic planning. He is serving on the editorial boards of several international journals including Human Resource Development Quarterly and Total Quality Management & Business Excellence.

©American Society for Engineering Education, 2020

Advancing High School STEM Education: Implications for Engineering Technology

Abstract

A novel STEM education approach focused on competency-based education was implemented in a college preparatory high school. This high school is intended to provide students access to a nearby higher education institution, with the intent of aiding the students in obtaining STEM based education. This program prepares the students to move into the university environment by encouraging faculty collaboration with the high school, coursework promoting creativity and problem-solving skills, and the use of case studies in classroom instruction. These case studies are grounded in real-life scenarios students can expect to encounter in a professional setting. This study focuses on the implementation of the program through the first-year experiences of teachers and administrators through semi-structured interviews. The results presented highlight study findings and shed light on challenges in establishing a student-focused STEM learning environment while exploring new pedagogies, developing an innovative curriculum, and teaching.

Literature Review

While the high school being studied is intended to provide preparation for a STEM competency-based college experience, the authors focused on educators involved with engineering technology (ET), as it is an often-overlooked field of study. Often ET is either combined with engineering or ignored, with little literature available regarding its pedagogy and the skills needed to succeed in ET and other similar technology programs [1]. Further, faculty preparing curriculum and pedagogies for students considering these areas of study are challenged by their students' ability to perceive materials, differences in learning abilities, and differences resulting from background experiences [1].

When comparing the demographics of students in different areas of STEM, students who chose technology programs exhibit differences in culture and environmental exposure [2, 3] . This makes developing a school intended to teach and prepare students for the unique environment of a hands-on curriculum a challenge.

Faculty at the high school where this study took place find themselves in a unique working environment. The students in the high school, as opposed to traditional classroom techniques, typically thrive in hands-on and applied learning environments; with the expectation that the students are expected to pursue post-secondary careers [4, 5]. When considering the STEM fields and the level of hands-on involvement at the professional level, understanding the differences between the fields and the expectations during the post-secondary experience is

important to the creation of a successful, impactful curriculum and learning environment. Figure 1 shows the relationship of hands-on experiences both in the classroom and work environment of the STEM fields as compared to one another, an important consideration for those developing curriculum.

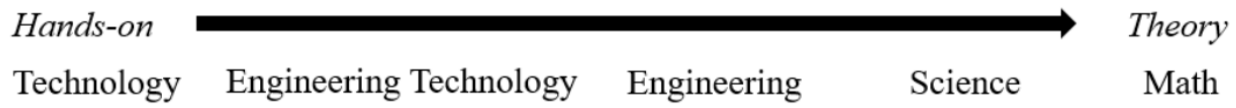

Figure 1. Hands on Continuum [6]

Preparing students for technology programs, such as engineering technology, is difficult because students in these areas are often overlooked. Little is known about ET students, what types of pedagogy is appropriate, or even the skills engineering technology students need to succeed in such programs [7]. To combat this, faculty in engineering technology frequently rely on what they already know, resulting in methods and curricula generally focused on their own experiences in engineering, or evidence derived from student populations in engineering. To provide further perspective of the portion of ET; if the number of graduates in engineering and engineering technology are combined, less than 2% of these graduates hold engineering technology degrees [8].

Engineering technology programs combine both theoretical and hands-on but have more of an emphasis on hands-on experiences rather than the traditional theoretical experiences found in engineering programs [7]. As such, students that enter college to pursue an engineering technology or similar technology major, are often unprepared for the rigorous and unfamiliar courses related to theoretical concepts that are part of the curriculum at this higher level of understanding. As a result, students that are not prepared for this situation often drop out shortly after entering college, a problem that the program being studied aims to alleviate [9].

Background

The high school under investigation for this research study is a STEM college preparatory school located in an urban environment. The school offers STEM-based education to students with the intent of aiding them in pursuing a post-secondary career in a STEM-based field. The high school works closely with nearby higher-education institutions for support in developing curriculum and in other collaborative ways. Students at this school come from a wide variety of backgrounds consistent with urban environments, including students who are challenged by their circumstances and background and other students with less challenging circumstances.

The coursework at this institution centers on pedagogies that introduce and require students to utilize creativity and problem-solving skills, with emphasis on hands-on learning and case studies. This relatively recent, competency-based program allows students to self-pace their learning which is focused on STEM. This however results in challenges for the administrators and teachers in developing curricula while also teaching around the self-paced, competency-based approach. The development of the program required the educators implement coursework emphasizing industry-driven approaches. The teachers interviewed for this study were those teaching a variety of coursework, with a varied level of experience. The teachers were challenged by the first year of the novel curriculum development while also teaching students from various backgrounds.

Research Questions

As part of a more extensive study, this paper is intended to focus on faculty and administration experience at this school during the first year. To focus the study, the following questions were developed:

- *What are the teacher and administrator first-year experiences with the implementation of a new STEM competency-based curricula?*
- *What challenges do teachers face when switching to a different style of learning based on competencies?*

Methodology

After developing questions to delve into a breadth of topics, faculty and administrators were interviewed individually and in a group setting. The intent of the questions and the ensuing discussion was to further understanding of the first-year experience at the high school. None of the educators or administrators surveyed had previously experienced this type of curriculum change before.

The interviews and group discussions were recorded and transcribed. The transcripts were examined by both reading through the transcripts and utilizing software to develop basic word clouds of frequently used words, to highlight the aggregate of the individual discussions as well as the group discussions. The analysis of the transcripts is intended to showcase what areas educators and administrators like and dislike about the implementation of this new way of teaching. The results of which will show what areas may be kept and which areas may need to be developed further.

Limitations

There are some limitations associated with the use of word clouds for this type of study. Word clouds can cause the data to lose context and neglects the importance of certain phrases since each word is treated separately[10]. However, since this is only an initial look at the results of this study, the researchers feel that word clouds are appropriate to gain an understanding of the general themes of the results.

Findings

Word clouds were generated using aggregated individual and group interviews. The word cloud resulting from the aggregated individual interviews is shown in Figure 2. The word cloud from the group interview is shown in Figure 3.

Figure 2. Aggregate Individual Discussion

Figure 3. Aggregate Group Discussions

The comparison of these word clouds provides a clear indication that those interviewed for this study are student-centered as both show the word “student” in a dominant manner. For the individual aggregate results, the words “change,” “content,” “creating,” and “communicating” dominate. These words suggest that the curriculum development was focused on content creation, but that communication played a significant role.

Comparing the word clouds, it can be shown that the words “change,” “content,” and “activities” dominate both individual and aggregate. All these words are indicative of a new methodology, based on activity and substance related to the high school and the mission of the school during its first year.

Further observations from the transcript indicate two major issues discussed by the participants; the first adjusting of the curriculum and the other realistic problem-solving.

> **Adjusting of Curriculum.** The faculty regularly discussed having to adjust and readjust the curriculum. This was done to assure that the content was beneficial to the students and remained as such. Faculty in the group interview had an in-depth discussion, and one statement stands out:
>
> "*Because it did not work the last time, so that is why we are trying something else.*"

These interview participants shared that it was healthier for students to grow in an environment where they see adults fail and continue by trying different things. They shared several situations that supported this concept. The interview participants called it the "*Step Up and Step Back Concept."* This then leads to the next issue in the discussion.

Realistic Problem Solving. Admitting failure and taking a step back provides a means to put students in situations that take them out of their comfort zone and encourage them to think deeper about the concepts and problems being discussed. One interview participant shared:

"*I think the thing that makes us different from a traditional school is the fact that our students not only receive the content, but they also have the hands-on aspect*," thus preparing them for an active learning environment in the university. This hands-on environment is different from traditional education, which places students out of their comfort zone and encourages growth.

Another issue discussed in this forum was the differences in life experiences among students and teachers. Students entering this school grew up in different parts of the urban community, resulting in varying life experiences. For example, some of these students may not have been on an airplane or traveled outside the state or have had other such encounters/experiences. This puts these students at a distinct disadvantage when compared to other students in the school and is a challenge that educators must address.

Conclusions/Future Work

Early examination of the data through word clouds and interview transcripts suggest that faculty and administration were supportive of the new pedagogy. While they believed it to be promising, they understood that there were challenges that came with the changes and new ways of teaching in a self-paced, competency learning environment.

The group discussion provided additional insight as the interview participants shared that the curriculum development moved quickly and the faculty did not have time to incorporate all the ideas they had into materials for the students. The participants shared that the constant creation and revision of the classes during the initial year of the school's existence was challenging and took away from other things they would have liked to do for the students. The participants noted that students exhibited resistance to the change from traditional teaching methods. The educators countered this issue by providing the students time to transition to the new method while teaching in a traditional formal classroom method. This too was very time consuming and subtracted from the educator's intent to prepare students for transition and the amount of materials they could present.

The interview participants also shared that some STEM concepts and demonstrations are best learned through traditional STEM education approaches, a possible disadvantage of the new curriculum. They provided examples, such as Conservation of Energy. They shared that it was difficult to showcase this concept in a workshop environment. To successfully teach this material, they had to use traditional teaching methods.

Finally, all the faculty and administration involved in the interviews stressed the importance of faculty involved in these processes having experience. They also shared that the constant change and multi-disciplined environment was challenging and that they relied on their personal experiences to get through everything they needed to teach in this new environment successfully.

Future work is intended to delve deeper into these results beyond word cloud study. Qualitive coding methods such as thematic coding will be used, in addition to word clouds, to further understand the dataset. Additional work will also be needed in order to understand the role of communication in this process, rather than just relying upon the use of word clouds and thematic coding. Word clouds and thematic coding are limited in certain aspects regarding providing an overview of what the educators and administrators may be conveying. Therefore, analysis of the communication is vital to understand the whole situation as it relates to the educators and administrators, but would be best analyzed when the educators and administrators have had more experience than just a year teaching this new form of pedagogy.

References

[1] A. M. Lucietto, J. D. Moss, and R. M. French, “Examining Engineering Technology Students: How they perceive and order their thoughts,” in ASEE Annual Conference, Columbus, OH, 2017.

[2] A. Lucietto, E. Dell, E. Cooney, L. Russell, and E. Schott, “Engineering Technology Undergraduate Students a Survey of Demographics and Mentoring,” in ASEE Annual Conference, Tampa, FL, 2019.

[3] A. M. Lucietto, “Identity of an Engineering Technology Graduate,,” in 123rd ASEE Annual Conference & Exposition, New Orleans, LA, 2016.

[4] C. A. Malgwi, M. A. Howe, and P. A. Burnaby, “Influences on students' choice of college major,” *Journal of Education for Business*, vol. 80, no. 5, pp. 275-282, 2005.

[5] J. S. Rolston, and E. Cox, "Engineering for the real world: Diversity, innovation and hands-on learning," *International perspectives on engineering education*, pp. 261-278: Springer, 2015.

[6] A. Lucietto, M. Taleyarkhan, and E. Schott, “Engineering Technology Students: Senioritis Female and Minority Students Perspective,” *Journal of Women and Minorities in Science and Engineering*, vol. 1, no. 1, 2019.

[7] A. M. Lucietto, and E. Efendy, "Systematic Review of Engineering Technology Education Literature."

[8] J. Roy. "Engineering by the Numbers," January 26, 2020; https://www.asee.org/documents/papers-and-publications/publications/college-profiles/Engineering-Technology-by-the-Numbers-2018.pdf.
[9] J. L. Glass, S. Sassler, Y. Levitte, and K. M. Michelmore, “What's so special about STEM? A comparison of women's retention in STEM and professional occupations,” *Social forces*, vol. 92, no. 2, pp. 723-756, 2013.
[10] C. McNaught, and P. Lam, “Using Wordle as a supplementary research tool,” *Qualitative Report*, vol. 15, no. 3, pp. 630-643, 2010.