From Silos to Systems: The Evolution of \University's\ College of Engineering PreCollege Outreach

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Laura returned to academia after over 25 years of working in locations across the country and raising a family. She held engineering and manufacturing leadership roles with a variety of private and public companies, including President/Owner of a developing children's discovery museum, which brought outreach programs to underserved populations.

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From Silos to Systems: The Evolution of The University of Tennessee Tickle College of Engineering PreCollege Outreach (Work-in-Progress)

Introduction

For many years, K-12 engineering educational outreach in the University of Tennessee's Tickle College of Engineering existed in silos: departments and organizations operated independently of each other, overlapping only when additional support was needed for the execution of large-scale outreach events. Collaboration never occurred at the planning stage, meaning that faculty, staff, and students interested in outreach had to navigate roadblocks to engage in meaningful outreach with K-12 populations. A change of leadership and operating philosophy in 2019 brought about a reorganization of priorities and allowed the authors of this paper the ability to create a new vision of outreach for the College of Engineering.

In this paper, we will elaborate on how we moved from our silos to a purposeful system of outreach that has allowed us to expand our outreach into student ambassadors, service learning coursework, freely available pre-college lessons, and other resources. In this, we are hoping to serve as a model for collaborative outreach work across a College of Engineering. We will present a theoretical framework of systems-thinking, describe the prior state of engineering outreach in our College, outline how our shared vision for community engineering outreach developed, recount how our team formed, and outline several successful outcomes from our efforts using this innovative approach

First, we want to define outreach as we see it. We believe that outreach is a form of experiential learning for both the K-12 students and the college students involved in the process. As we engage in outreach, we try to connect the dots between what a K-12 student might be interested in and the potential future possibilities that pursuing a degree and career in engineering might afford them. We are not there to convince students they must become engineers but rather to expose students who may only have a stereotypical view of engineering, or may not know any engineers, to engineering as a career path. Many students may think that engineers are relatable to them in their current lives, which we know is not the case. Because of this, we integrate undergraduate students into our outreach activities at all times and in all cases, because we believe they serve as models of possibility to K-12 students.

Systems Thinking in Outreach

Any group or work pattern of interacting human and machine activities, directed by information, which operate to achieve a common specific purpose or objective is a system [1]. Most aspects of modern life function as part of a system, with parts operating together to achieve a shared goal. Although a system can be as diverse as patient care in a hospital or manufacturing processes which produce almost every item we touch each day, every system is made up of similar basic components. All systems consist of individual elements contributing to the output of the system, and their shared paths or interconnectedness.

The educational system in the US has these parts:

- Preschool and kindergarten,
- Elementary schools – grades 1-6,
- Middle schools – grades 7-8,
- High schools – grades 9-12, and
- Higher education, including 2-year community colleges, and 4-year colleges and universities.

We call this list of parts a "system" because the parts interact with each other to achieve overall goals, such as an educated population. The parts may interact through cause and effect or through the exchange of information or material. We can think of the input and output of the overall system, and we can also think about the input and output of each part; for example, some of the students who graduate from middle school (an output) go on to high school (an input). We can also think of the parts as being processes in the educational system. [2]

System success is influenced by the relationships between the parts and with outside elements, so in order to positively impact the outcome of the system, we must examine how all parts work together to balance efforts and form synergies, where the sum of the parts working together is greater than the sum of each contributing separately. A systems viewpoint can be utilized broadly across many industries and applications to improve efficiencies and success of a group.

However, successful organizations must operate with a systems-view in order to achieve synergies of their shared efforts. Peter Senge states learning organizations can achieve success by building knowledge in personal mastery, mental models, shared vision, and team learning [3]. Education and educational outreach are no exception. Utilizing a systems-view allows a standardization of activities and can eliminate wasted time and effort spent "reinventing the wheel" for every activity [4].

Organizations have utilized systems-thinking to successfully operate and improve activities, building synergies and creating innovative techniques to achieve greater goals. This applies to educational systems and community outreach. The difference between business and outreach models is how goals are defined and how relationships between the elements of the systems work together to reach common goals. We have leveraged this concept to optimize the impact of our outreach activities by collaborating across the system and state, and immediately saw greater engagement and improved outcomes. Through utilizing an intentionally open and dynamic systems-view, we achieved a synergy not possible through our individual contributions.

Siloed

Engineering educational outreach to K-12 community populations is an integral part of building a successful pipeline of future engineers and academic leaders. In a 2009 report from the National Academy of Engineering (NAE) and the National Research Council (NRC), *Engineering in K-12 Education*, a number of convincing arguments are made for engineering as "a catalyst for a more interconnected and effective K-12 STEM education system" [5]. And in

the spirit of true reform, the NAE recognizes that this outcome "will require significant rethinking of what STEM education can and should be" [6].

For many years, outreach within Tickle College of Engineering was siloed within departments, centers, or other units - a decision that made collaboration possible, but not probable. Outreach was seen as the individual responsibility of whoever initiated the activity (personal mastery): for example, STEM nights at local elementary schools were run completely by one group, afterschool programming might be another, and a third might be only doing classroom visits. The programs were very popular, however, there were difficulties with scalability and sustainability. Individual units lacked the collective resources or infrastructure to manage all the STEM nights at local schools, or the afterschool programs. This meant that only a few schools were being served by Tickle College of Engineering instead of many.

This did not fulfill our land grant mission, so in 2019 a change of leadership meant that we were able to restructure our operations and create a new way of approaching not only outreach, but student services in our college. Our Student Success Advisory board created several new groups to tackle college-wide student success through a shared vision. One of these was the Outreach Subcommittee, which brought together faculty and staff from across Tickle College of Engineering interested in outreach, several of which were coordinating pre-college outreach for their respective units. At the same time, opportunities in the forms of collaborative internal grants with cross-functional teams set the groundwork to build a system of campus and community partners for engineering and STEM outreach (team learning). The creation of the subcommittee and opportunity to receive financial support gave the subcommittee an opportunity to restructure outreach within the Tickle College of Engineering to be more sustainable and scalable.

As this was initiated, we leveraged systems thinking for our outreach activities, by collaborating across the system and state, and immediately saw greater involvement from our college students, increased engagement with K-12 populations and improved outcomes (e.g. new school partnerships, new grant funding, new variety of events).

One way that we leveraged our new system was to structure our outreach subcommittee as a one-stop for outreach requests: requests sent to one member were forwarded to everyone, so that events could be shared between departments and units (mental models). Additionally, the existence of the subcommittee gave a point-of-contact for referrals from college faculty and staff.

Once we began to streamline and work together, we were able to leverage existing opportunities and build our programs. One way we did this was by working with our local school district to provide more opportunities for teachers.

Examples of Purposeful Systems

By using common processes to optimize our outreach efforts, Tickle College of Engineering has been able to build synergies across the college by combining the efforts of several groups that had previously operated independently. Student outreach ambassadors, student organization members, students enrolled in a service learning course, faculty, staff, and other volunteers now

work together to ensure that resources are used effectively and efficiently, and that efforts are not being duplicated.

Since 2019, the new outreach system has allowed Tickle College of Engineering to substantially increase engagement with K-12 teachers and students, as well as other local groups such as Girl Scouts, STEM Scouts, and 4H. For example, before this new system was instituted, engineering students enrolled in EF 327, a service learning course focused on engineering education in K-12, partnered with a local elementary school to run a weekly after-school engineering club. This was a successful collaboration, but it was very limited because it only involved students at a single school, and students in the course developed their own activities with little input from other campus groups that were also doing outreach at other schools. Now, the after-school engineering club operates as a collaboration between students in this class, volunteers from the Society of Women Engineers, and engineering ambassadors from the Tickle College of Engineering. Activities for the after-school club are still developed by engineering students, but now, activities developed by other groups throughout the college are also frequently utilized.

Simultaneously, engineering outreach activities developed by students in the class are now able to be used in other ways as well. For example, many activities developed by students in EF 327 have been used at STEM nights, summer camps, and in subscription boxes that were sent to middle school teachers and 4-H groups. Furthermore, students in EF 327 now have the opportunity to participate in a variety of other outreach events as well, which was not possible before a systems approach to outreach was adopted. Additional examples of current outreach efforts in Tickle College of Engineering are described in the table below.

Table 1. Outreach table

Outreach Event	Campus Facilitators	Description
STEM Nights	Outreach Subcommittee, Engineering Ambassadors, additional faculty and staff, Service learning class	STEM nights are hosted for elementary schools featuring a variety of hands-on STEM activities geared towards younger learners.
Elementary age Mentoring	Departmental faculty and ambassadors	Several departments provide weekly one on one mentoring to local schools - one elementary school and one high school
Afterschool programs	Student Organizations, Service learning class	Student organizations visit a local elementary school and do activities with kids one day per week
STEM in a Box	Outreach subcommittee, Service learning class, additional faculty and staff	STEM boxes are provided both to K-12 students in the summer and K-12 teachers/4-H agents during the school year. They feature activities created by our students.
Teacher Professional Development	Outreach subcommittee, department faculty	Conduct teacher interactive training sessions with faculty, staff, and students to build relationships and skillsets

A critical decision we made was to leverage the resources of our university to scale our programs, starting by partnering with 4-H youth development. As a land-grant institution, we have the opportunity to collaborate with 4-H agents throughout our state's counties. We established a relationship with 4-H youth development, specifically curriculum developers and STEM specialists, to start sharing existing lesson plans and resources with their agents and clubs. For example, we became very involved with an energy-based summer program that had been running for over twenty-five years, even to the point of traveling the state during 2021 to take the summer program to different counties. We also started working with 4-H to write grants, and were awarded a grant from the Office of Naval Research for workforce development that expands existing outreach programs to Western TN.

This grant is one of several grants, both internal and external, that we received after we started to work synergistically. During the height of COVID, we wrote and received internal grants and seed funding to start several STEM in a box projects that allowed our outreach to expand across the state. The first boxes we produced, during the summer of 2021, were for students in grades K-12. These boxes were part of an asynchronous summer program where participating students could follow along with videos made by our students and posted to a website. This also included an option for high school students to learn about robotics or energy through an online Google sites course, partially funded by an Engineering Research Center at our university. The second box was built starting Fall 2021 and was targeted towards teachers and 4-H agents in rural counties. That box also shared STEM lessons with them, as well as supplies.

Another internal grant built on a collaboration with our local school system career and technical education leaders. They were seeking support to review an expensive library of educational resources before purchasing. They had questions on the usability and validity of the system, as well as its efficacy to prepare their students for college and career pathways. After working with these educators, the opportunity came to submit an internal grant application for a system-wide team to identify and build professional development courses for secondary school STEM educators. We received the grant, and when the challenge of virtual communication and learning forced a change of our plans, we pivoted to quickly develop and deliver the sessions and build a robust repository of support resources for educators across the state. This team began with college faculty and local, technical education administrators and teachers. It grew to include faculty and staff across our university system and secondary educational partners across the state. Utilizing the strengths and inputs of all of the participants allowed us to achieve synergy and realize greater outcomes, and influence future growth in our college and outreach efforts.

In addition to internal grants, we have also received external funding from organizations such as the National Science Foundation (NSF) to support outreach efforts by the Tickle College of Engineering. In 2021, a member of the outreach committee received an NSF grant to partner with faculty in teacher education to teach the service learning course described previously in tandem with a course for pre-service STEM teachers. This partnership has allowed the outreach committee to work synergistically with other campus departments and organizations and to further expand our outreach work in the local community.

Although many beneficial changes have already been made to expand and streamline the outreach efforts of the Tickle College of Engineering, this project is a work in progress, and there

are always further improvements that can be made. Currently, we are working on developing a searchable database where K-12 teachers, university students and faculty, and other community partners can locate engineering activities and projects to use in both formal and informal education. We also plan to include a mechanism for users to submit activities that will then be reviewed by experts using a standardized rubric before being added to the database. We have created and tested a pilot version of the review process and are currently working on developing the database.

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