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# Update on: Undergraduate Design & Innovation Curriculum to Reach New Audiences

SESSION VI: MVTTEC – Related Research

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## Introduction

At the 104th Mississippi Valley conference (2017), Strimel and Kelley shared the development of a Design and Innovation (D&I) minor at Purdue University. The D&I minor provided opportunity for the Engineering Technology Teacher Education (ETTE) faculty to reach new audiences and maintain strong enrollment in ETTE required courses. Since 2017, the D&I minor at Purdue continues to grow in enrollment across multiple majors and colleges. Additionally, Drs. Strimel and Kelley have partnered with Anthropology (Liberal Arts) and Business (School of Management) to develop transdisciplinary courses co-taught with cross-disciplinary faculty for the D&I minor. This approach created cross-collaborative and cross-cutting shared practices in innovation, human centered-design, and business development.

Recently, researchers at Purdue led by Dr. Strimel were awarded a National Science Foundation Improving Undergraduate STEM Education grant to study this collaborative initiative, through a program called Mission Meaning Making (M3). The M3 program is designed to synergize key strengths of three partnering academic units (Purdue University's Polytechnic Institute, College of Liberal Arts, and Krannert School of Management) to create a leading-edge undergraduate experience. The M3 overarching goal is to serve as a model to help universities to better prepare undergraduates for addressing complex, contemporary challenges in innovative, and transdisciplinary ways to best harness the nation's great scientific and technological potential.

This paper will provide details about theM3 educational model and the D&I minor as well as other key initiatives including: a) building a campus wide design and innovation learning community, b) developing a career pathway to college for underserved students, and c) M3s overall design-based research model. Preliminary program research results will also be included in the paper. The presentation focus will also provide a model for other ETTE programs to maintain enrollment and expand to new audiences.

## Engineering Technology Teacher Education and Undergraduate Learning

Creating new approaches to the way in which teacher education programs are positioned are seemingly more critical now than ever before. In general, there is an ongoing need to support the teacher workforce. In particular, as mentioned by Volk (2019) that the few remaining traditional ETTE programs that remain are in jeopardy as the future teaching workforce continues to decline and alternative pathways to teaching continue to grow. But, while Volk (2019) states that traditional ETTE programs are no longer relevant in the U.S. today, there can be an opportunity to leverage and make relevant ETTE content and practices beyond teacher education. Therefore, these new approaches are important to consider not only to just sustain the remaining programs but to also reach new audiences and bring diversity of experiences and backgrounds to the engineering technology content and practices. In addition, changing the way engineering technology teacher programs are positioned can help bring valuable learning experiences that many students no longer have access to in secondary schools to the broader campus community. These learning experiences can include content and practices related to designing, making, and innovating that are becoming more valuable across disciplines as well as pedagogical approaches that support integrated and/or transdisciplinary learning. With a variety of educational transformation initiatives happening at universities today, engineering technology programs seemingly have value in shaping the way that undergraduate learning occurs.

Although ETTE programs remain challenged across the country in terms of enrollment, the field has much to offer that is of value to undergraduate learning. First, how many times can one hear professors in engineering or engineering technology programs complain about students "not being able to practically accomplish tasks." How often do new makerspaces have limited participation beyond a select few students. How often do people still hear students saying they lack engaging learning experiences in their undergraduate programs. However, these questions were historically address through the pedagogical approaches and content/practices taught through technology teacher education programs. These approaches/content/practices seem well situated to support engaging and transdisciplinary learning that universities continue to struggle with today. So, the question is "how do engineering technology teacher education programs leverage their value related to transdisciplinary learning through design and innovation to reach new audiences while sustaining programs that develop teachers.

**Reaching New Audiences: A Transdisciplinary Design & Innovation Approach**

To create an innovation experience for the broader community of undergraduate students, universities need an educational model that helps them to evolve structurally at the largest level. Oftentimes, universities are structurally challenged to change which leaves even the strongest educational solutions siloed within individual departments and schools (Brix, 2019). Consequently, the Purdue ETTE program has begun to establish a model to guide the transformation of traditional undergraduate learning experiences to span across multiple disciplines, minimizing the silo effect of academic departments and individual courses. This model, referred to as the Mission Meaning Making (M3) project, has been designed to integrate the key strengths of three partnering academic units to provide a leading-edge undergraduate innovation experience (see Figure 1). These three units include the university's Polytechnic Institute (in which the ETTE program is housed), College of Liberal Arts, and School of Management. The M3 overarching goal is to leverage the content and practices of ETTE along with the human interface of liberal arts and the economic perspectives of business management to serve as a model to

*Figure 1. M3 Program Philosophy for the Teaching of Innovation.*

help universities to better prepare undergraduates for developing an innovative mindset to support resolving problems of today and tomorrow in novel and valuable ways. This approach is positioned to help universities harness the nation's great technological potential for social and economic impact. And, this is important as universities can provide the resources and network for students to truly practice innovation connected to their own passions while they have the freedom and flexibility to fail, iterate, learn, and make an impact on their lives, communities, and beyond. Through this model students can be better supported to move innovative designs and ideas outside the classroom walls to potentially make an impact on their own lives and others. Establishing an educational model such as this finds value for the content, practices, and pedagogical approaches of ETTE. In addition, operationalizing this model provides opportunity for ETTE faculty to reach new and more diverse audiences as well as maintain strong enrollment in ETTE required courses.

The M3 educational model has been developed to enable undergraduates to become emergent innovators (see Figure 2). This model consists of three different components. First, is a community with both people and resources that are committed to helping students achieve outcomes of innovation and learn the related practices through collaboration. The second component includes the college domains which allow for professors in different departments to share areas of interest and key issues for co-teaching innovation-focused courses. Lastly, the curriculum of the model emphasizes shared practices and discourse for innovation through co-learning experiences. The educational model creates a unique collaboration between the partnering colleges with the goal to blend expertise that includes functional performance of engineering/technology/design, human interface of liberal arts/social sciences, economic perspectives of business management, and global/cultural appreciation to foster students' innovation-capabilities for a diverse world. As a result, the educational experience is positioned to promote transdisciplinary learning and increase innovation experiences for the broader campus community.

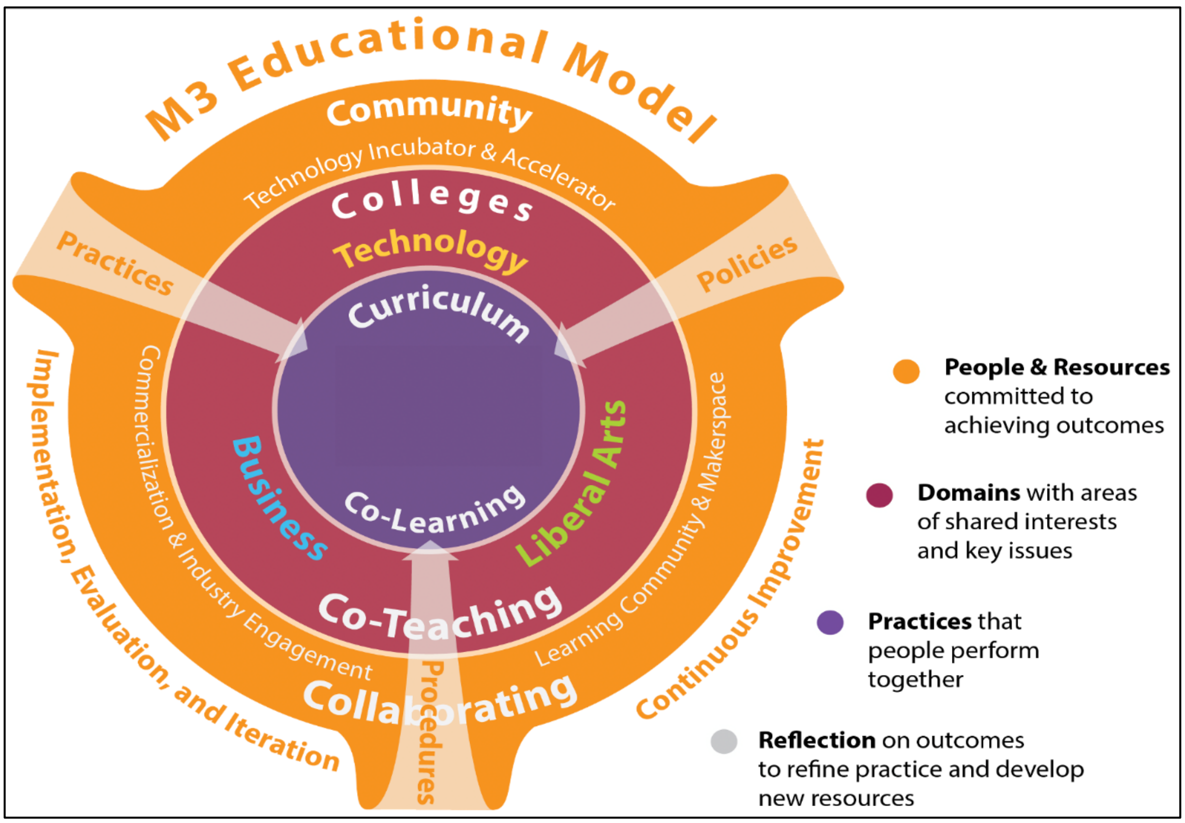


*Figure 2. M3 Educational Model Overview.*

At the center of the M3 model is the Design & Innovation (D&I) minor. The D&I minor was the starting point for piloting ideas for transforming undergraduate learning within a traditional academic structure as well as leveraging ETTE design coursework to reach new audiences.

This minor then provides a common thread of design and innovation throughout students' undergraduate programs with multiple "entry points" to innovation based on their majors. The coursework is synchronized with several plans of study and therefore, becomes a new situated learning experience that does not require multiple additional credits for participation. The two core course elements of the Design & Innovation Minor that is at the center of the M3 program, which are required ETTE courses, have evolved to a) be co-taught with faculty across colleges and b) provide the space for students across all degree programs to interact with each other and begin to learn shared practices authentic to innovation. The first core course, *Designing Technology for People: Anthropological Approaches*, is a required ETTE course that is co-taught with ETTE faculty and Anthropology faculty from the College of Liberal Arts. This course engages students in ethnographically studying human and technology interactions to support scoping problems and designing appropriate solutions for, and with, people. For ETTE students, this provides them with the experiences and instructional examples necessary to teach design skills and innovation practices as they become middle and high school teachers. The second core course, *Prototyping for People: Thinking Strategically & Making Decisions*, is a required ETTE course that is co-taught with ETTE faculty and business management/entrepreneurship faculty. This course engages students in iteratively prototyping design solutions for problems people face as well as prototyping potential business models related to these solutions. The students are led through the process of making strategic decisions related to their designs as they deepen their understanding of customer/user needs, market segments opportunities, costs of goods, competitor operations, and market strategies. This is an important approach to help students realize the viability of their design solutions to impact people. For ETTE students specifically, this provides them with the experiences and instructional examples necessary to teach practical prototyping capabilities and the realistic innovation practices of business development/entrepreneurial thinking when they enter middle and high school classrooms. For example, Strimel, Kim, and Bosman (2019) highlight how the process of design can be informed through the integration of entrepreneurial thinking in secondary engineering programs. In addition, these courses are based upon the *Design Thinking in Technology* course which is led by ETTE faculty, is required by ETTE students, and has become a required first-year design course for all Polytechnic majors. The M3 D&I learning sequence/plan of study can be found in Table 1.

Table 1. *M3 Design & Innovation Learning Sequence (15 Credits)*

<table>
<tr><th></th><th>Polytechnic Institute</th><th>College of Liberal Arts</th><th>School of Management</th><th>Community of Practice Resources</th></tr>
<tr><td rowspan="2">Intro Design & Innovation Experience</td><td>Design Thinking in Technology (Required ETTE Course)</td><td>Technology & Culture</td><td>Making the Business Case</td><td rowspan="3">Coursework embeds connections to Innovation & Technology Commercialization resources to build a community of practice for all participating students:<br>• Alumni Network</td></tr>
<tr><td colspan="3">Disciplinary-focused introductory innovation coursework leverages each college's expertise: builds the "on-ramp" to innovation.</td></tr>
<tr><td>Core Design & Innovation Experience I</td><td colspan="3">Designing Technology for People: Anthropological Approaches<br>(Required ETTE Course)</td></tr>
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| | | |
|---|---|---|
| | Co-Taught by Technology & Anthropology Faculty<br>• Engages students in ethnographically studying human and technology interactions.<br>• Helps students develop problem scoping skills in order to devise appropriate solutions for, and with, people.<br>• Supports students in realizing that innovation opportunities emerge through observing and talking with people about how they interact with the world. | • University Incubators & Accelerator<br>• Office of Technology Commercialization<br>• University Makerspaces<br>• Student Co-working Spaces & Learning Community<br>• Innovation Competitions<br>• Careers Centers and Internship Programs |
| **Core Design & Innovation Experience II** | Prototyping for People: Thinking Strategically & Making Decisions<br>(Required ETTE Course) | |
| | Co-Taught by Technology & Business Management/entrepreneurship Faculty<br>• Engages students in iteratively prototyping design solutions for problems people face and prototyping related business models.<br>• Helps students develop entrepreneurial thinking while continually engaging with people to refine solutions.<br>• Supports students in considering issues related to developing innovations that extend beyond technological feasibility to include customer desirability, social impacts, and business viability. | |
| **Global/Cultural Experience** | Provides students with opportunities to immerse themselves in different cultures to build more inclusive, diverse, and equitable perspectives critical for innovation successes that serve the whole of society. | |
| **Specialization** | Provides students with credit-bearing opportunities for expanding expertise related to their innovation areas through industry capstones, coursework, internships, or undergraduate research. | |

In addition to the D&I minor, the M3 program seeks to build a community to nourish the innovation spirit of undergraduate students. Accordingly, a Design and Innovation-focused learning community was approved and launched as part of the M3 model. This community has been designed to provide incoming undergraduate students with a campus network for both learning and technology commercialization. The learning community had a successful launch with 50 new students entering the design and innovation community as they began their college experience. The learning community is led by faculty across technology, liberal arts, and business management and directly connects students with ETTE laboratories/facilities and introductory ETTE coursework for prototyping skills. This learning community as well as the D&I minor also supports student innovation by providing a Design & Innovation Competition at the end of each semester which provides students an opportunity to win cash prizes to help fund their innovative ideas as well as scholarships to continue pursuing the D&I minor.

Lastly, the M3 model includes a pathway to innovation approach with a new structure to offering a dual credit coursework to urban schools. This new approach has been designed to enhance access to the minor/program starting in high school. The new dual-credit approach which is called the facilitator approach, allows high school (ETTE) teachers to be trained in facilitating the innovation-focus curriculum in their schools day-to-day but with the university faculty being the instructor of record to evaluate the student progress. This helps to navigate policies that inherently limit student access to early college learning while lowering the cost of tuition to only $25 per credit.

All of the elements discussed in this section combine to serve as the current iteration of the M3 educational model. This model can serve as a blueprint for bringing academic units together to rethink design and innovation-focused education at the undergrad level in order to move beyond the status quo and offer a cross-disciplinary approach to learning to the broader campus community. The M3 model can then help enhance the value of higher education for undergraduates as they can learn while bringing their own ideas to fruition as well as expand the impact of ETTE programs.

**Design Based Research Approach**

As part of the NSF grant, the M3 program is currently in the process of applying a design-based research (DBR) approach to refine the educational model which includes the D&I minor. This research approach focuses on examining the ways in which learning can be transformed to span across disciplines, following evidence-based teaching practices, to foster innovation-capabilities of diverse learners. This approach specifically leverages DBR methods to develop an educational model focused on democratizing the practice of innovation across the campus community while examining ways in which to work across college boundaries. A DBR approach was selected for this project as this methodology supports the blending of empirical educational research with theory-driven research to provide a deeper understanding of the phenomenon that is being studied (The Design-Based Research Collective, 2003; Gravemeijer & Cobb, 2006). As such, this method is providing the M3 researchers a framework for iteratively testing and refining the educational model to address the identified institutional barriers and achieve close alignment to the anticipated student learning outcomes (i.e. integrative learning abilities, intercultural knowledge and competence, collaborative problem solving, innovation success, and teamwork capabilities in diverse teams). Through the DBR approach, the $M^3$ project will generate knowledge about how this model can be broadly disseminated to the STEM education community. To inform the DBR approach qualitative and quantitative data are being collected from faculty, students, staff, and administration throughout the implementation of the M3 model to inform its revisions and document the institutional workarounds to its success. As shown in Figure 3, the DBR plan began with the initial implementation of the model in Year 1, whereas data were collected, analyzed, and used to redesign the model to be implemented in the next academic year. This iterative process has included identifying and addressing barriers to success and understanding how the educational experiences can help students to make connections among ideas and actions to synthesize and transfer learning toward innovation achievement.

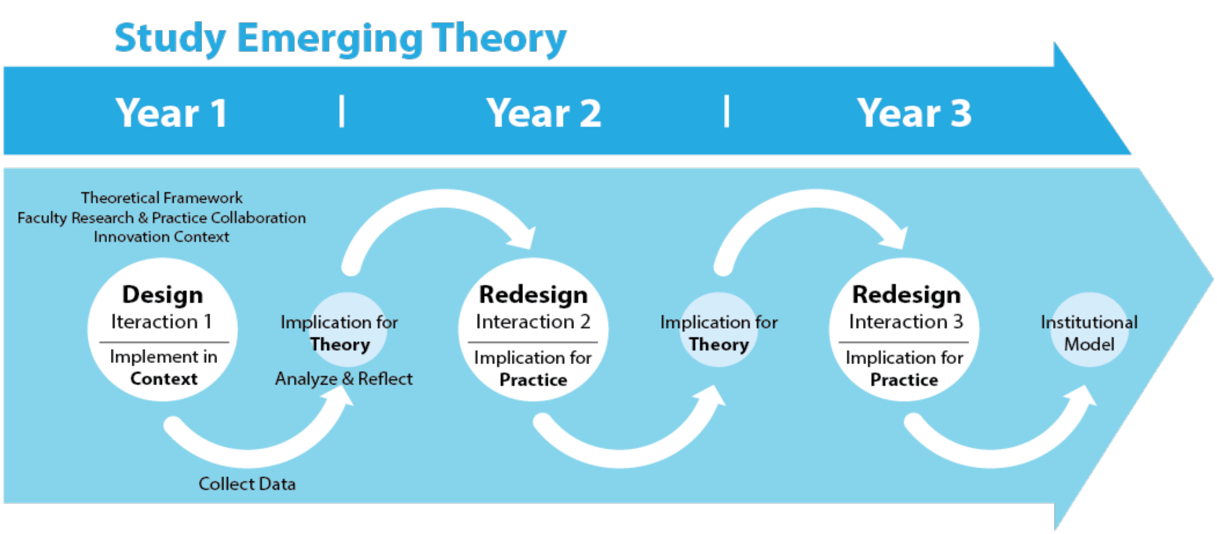


*Figure 3. M3 Design-Based Research Approach.*

**Current Results**

First, from an ETTE perspective there have been several positive results from the M3 programmatic approach. The D&I Minor introduced our pre-service engineering technology teachers to a broader audience of students and professors across disciplines/colleges. This has enabled them to learn the cross-disciplinary practices of innovation while sustaining required ETTE courses through increased enrollment. From 2 years of offering this program there are now 170 undergraduates, spanning across over 20 different majors enrolled in the D&I minor. Moreover, required ETTE courses have seen increased enrollment. For example, the *Designing Technology for People: Anthropological Approaches* course, which has been revised to be co-taught with ETTE and Anthropology faculty, has seen enrollment of over 300 students. The minor has also been built upon the *Designing Technology for People* course which is led by ETTE faculty and required as a first-year design course for all Polytechnic majors, which sees enrollment from hundreds of students each semester. By expanding to new audiences and working across colleges/majors, ETTE students, as well as others enrolled in the courses, have seemingly developed new mindsets and capabilities toward designing and innovating in ways that have potential impact beyond the classroom. For example, Briller, Kelley, and Wirtz (2016) found that through blending both technology and anthropology teachers and students was advantageous as respect for, and curiosity about, each other's disciplines and work grew. Students benefitted from mixed teams as they came to value and rely on each other's knowledge and skills and pushed the boundaries of their creative, analytical and cross-disciplinary thinking. While students highlighted the discomfort that comes with undertaking a new challenge and a nonlinear process, Briller, Kelley, and Wirtz (2016) saw how their successes, failures, and creative solutions were putting them on the path to be innovators and that the transformation process was seemingly working.

In addition, Kim and Strimel (2019) studied the influence of the co-taught innovation coursework in terms of cognitive abilities for problem framing. They believed that the integrated learning experience would influence students' knowledge structures, and those structures would then influence their problem framing to include a broader perspective. The study showed that participating students revealed more customer and social-oriented perspectives in a problem framing activity after the core coursework than before. This was an important finding as innovators must not only consider technological feasibility but also customer desirability, social impacts, and business viability (Brown, 2009). Kim and Strimel (2019) concluded that the co-taught course better enabled technology-oriented students to recognize the importance of customer and social aspects of innovative designs.

Lastly, through a preliminary analysis of D&I student interviews it was found that the participants felt a sense of freedom to explore project ideas, giving them confidence to move beyond the classroom and pursue personal and professional interests. For example, students within the D&I program have already won over $200,000 in awards to further their innovation ideas that they generated through the coursework, students have received external grants to support their start-up ventures, and others have sold their ideas or started their own online storefronts to sell their products. Notably, student teams from the pilot courses experienced success with their innovations that stemmed from effectively blending knowledge from the humanities, business development, and technology. To give examples, one student group received funding for their product to help those with movement disabilities eat independently. A second group licensed their innovative kit for teaching elementary students about IoT technologies to a local curriculum vendor. Additionally, a third group devised a promising solution for pediatric needle phobia that focuses on the parent and child patient experiences and has worked with Purdue's Office of Technology Commercialization to explore patent options. By having these experiences, interview data have also highlighted that student participants seem to be breaking down career silos, whereas they used their design and innovation experiences to obtain careers outside of their disciplines/majors. But, for ETTE majors specifically, these experiences are now what they bring into the classrooms during teaching careers. Furthermore, the preliminary analysis of the M3 stakeholder interviews revealed the following key aspects, or practices, to learning within an innovation-focused program 1) identifying/designing problems, 2) involvement in collaborative problem solving (innovative teamwork), 3) developing business acumen or an entrepreneurial mindset, 4) devoting time for iteration and rapid prototyping/experimenting, 5) learning from failure and building resiliency, 6) addressing personal/group biases, 7) valuing/understanding the view points and work styles of others, 8) taking creative risks, 9) networking with the right people and connecting with available resources, 10) establishing opportunities for professional/personal growth, 11) engaging in ethnography research, 12) becoming comfortable with sharing unfinished work, 13) embracing ambiguity, 14) promoting technology savviness, 15) developing a work ethic for getting things done, 16) designing for people through an empathetic approach, 17) applying different disciplinary lenses to problems or opportunities, and 18) being reflective and embracing criticism. These items can be refined to become a set of shared practices for innovation that bridge across disciplines that will be valuable for any future ETTE teacher to teach in their classrooms.

**Conclusion**

Although the concept of sustaining technology education programs with complimentary disciplines is not new. Many technology departments in the 1980s and 1990s included programs such as manufacturing technology, industrial or technology training, graphic communications, just to name a few and these programs and technology teacher education programs shared core courses with these programs; a similar approach to the design and innovation minor program at Purdue. So once again history repeats itself but to thrive in this every changing landscape known as higher education, we must locate new audiences to invite into our world and equality important to learn from in order to enhance technology education teacher programs. To sustain these efforts, engineering technology education faculty must understand the value structure of the university and play into that narrative. If successful in doing so, some engineering technology education programs will not only locate, recruit, and retain new audiences it can also draw attention from key university administration that may support, champion, and often fund these efforts because they offer examples transdisciplinary education and engineering technology education has often provided contextual learning that helps students see connections across STEM disciplines.

Unfortunately, it seems as though the technology education field has a history of “digging in its’ heals” desiring to retain traditional teaching practices, additionally we struggle to share practices, equipment, and expertise. Like any field, experts in technology education may feel that sharing our expertise opens a door to others stealing the best STEM education approaches from our field and using them for their gain. Kelley (2010) challenged the field to ‘sit’ at the STEM education table and build collaborations. Some programs have focused on collaborations with the other STEM fields on their campus and have thrived and others have not and some of those have as closed their doors. Those programs failing to locate necessary collaborations may have been a factor for their demise.

The example provided here leveraged design thinking with a focus on innovation. Other campuses, a focus on collaboration maybe be better to target integrated STEM education, additionally the recent maker movement might provide open doors for collaboration. Most important, understanding the needs of the students, community, and the value structure of the university should be considered for seeking collaborations for transdisciplinary education. The goal of this paper is to only provide an example of how to reach new audiences while simultaneously sustaining ETTE and presents a challenge for others to locate ways to build new partnerships with other programs on their campuses.

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