2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #38615

Board 175: STEP E-Dragster: A Pre-college Partnership Program Pilot Model (WIP)

Mr. Erik James Schettig, North Carolina State University at Raleigh

Erik is a lecturer in the Technology, Engineering, and Design Education department and a Ph.D. student in the Learning and Teaching in STEM program at NC State University. He has served as a technology, engineering, and design education teacher and teacher educator whose research interests include developing engaging STEM experiences for students and teachers.

STEP E-Dragster: A Pre-College Partnership Program Pilot Model (WIP)

Introduction

Bringing together the forces of industry and university increases the ability of educators to develop engaging pre-college engineering education programs that expose students to early experiences involving engineering practices through real-world challenges. One such partnership between NC State University, the Future Renewable Electric Energy Delivery and Management (FREEDM) Systems Engineering Research Center, and Duke Energy provides secondary educators with resources for enhancing technological and engineering literacy using sustainable energy content. This partnership is the Sustainable Transportation Education Program (STEP). This paper details the partnership program's model of providing curriculum and equipment through STEP and students' work in a technology, engineering, and design education program integrating a pilot electric dragster (e-dragster) project as a work-in-progress. Furthermore, the paper will communicate initial challenges and successes with information on how the program can share resources with the pre-college engineering education community to enhance learner technological and engineering literacy.

STEM Partnership

Science, Technology, Engineering, and Math (STEM) partnerships demonstrate STEM concepts and provide pre-college engineering education experiences unavailable in several schools (1). Partnerships, such as the supporters of STEP, model a collaborative effort to solve significant real-world problems and strengthen the integration of knowledge, understanding, and practices of engineering within STEM (1). Another affordance of STEM partnership is bringing in STEM professionals to support content teachers are transferring to students (2). Many students have yet to learn first-hand how their math and science courses relate to careers they may be interested in pursuing (1). The engineering education partnership in this paper aims for the primary STEM education goals of ensuring students spark interest and excitement in STEM, understand STEM content and knowledge, engage in STEM reasoning and computational thinking, reflect on STEM, use the tools and languages of STEM, and identify with STEM Enterprise (1).

As technology advances and societal dependence on effective energy delivery and magement increases, the demand for technological and engineering literacy increases, along with the need for qualified STEM graduates (3, 4). To ensure student success beyond school and into the workforce, they should be able to identify connections to the content they learned while in school (1, 3). Doing so entails that students have an interest in their work, understand the concepts they are using, be engaged in their projects, and be able to use tools to be productive (1, 3). STEM partnerships envelop the goals of integrated STEM, such as providing supplementary classroom enrichment, integrating classroom resources, sustaining student learning communities, sustaining teacher learning communities, and contributing to infrastructure development to establish elements of success (1, p157.)

Universities, industries, and community-based organizations can establish STEM partnerships that promote these goals (1). STEM-integrated partnerships support what teachers do in the classroom and display how the 21st Century Skills apply to careers (5). Many schools cannot purchase or house equipment that students will use in the future (1). Partnerships can provide access to such tools while promoting their work and establishing prospective employees (1). STEM partnerships have impacted younger audiences in elementary and middle schools to inspire their development of interest in STEM careers and skills at a young age (4). High school students are a key audience in promoting interest in STEM careers and skills to prepare students for a pathway into post-secondary STEM education or workforce development.

Sustainable Energy for a Sustainable Pre-College Engineering Education Program

Pre-college programs must utilize industry and university partnerships to provide valuable, real-world, relatable equipment and experiences to teachers and students to develop interest and identity in engineering (1). Highlighted in this paper is a demonstration of how a STEM partnership provides an engaging and supportive real-world engineering education experience for students. Pre-college engineering education partnership programs must support underrepresented populations and rural communities to open the pipeline to STEM careers (6). University and industry partners can fund low-income students' equipment and provide instructional support via online learning management systems, digital guides, and web conferencing capability.

Electric vehicles (EVs) are a prominent example of evolving technology that is incredibly important to society, as evident through their numerous connections to the engineering grand challenges, encompassing multiple engineering applications (7,8). Using EVs in an educational environment can enhance learners' knowledge about electrical and transportation systems and their technological and engineering literacy (3,8). Pre-college project-based activities utilizing current technologies, such as electric vehicles, prepare students with skills for a successful function in a STEM career and society.

While teachers can learn and teach engineering-related content, they can only do so with funding and access to the equipment. This lack of resources is why industries and universities must partner with teachers to provide early student exposure to engineering practices and tools that can increase interest and identity for future post-secondary enrollment and workforce skill development.

Research Questions

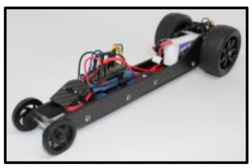
Q1. What are the experiences of pre-service technology, engineering, and design education students in a secondary-level engineering design project?

Q2. How can experiences of pre-service technology, engineering, and design education students in a secondary-level engineering design project inform the technology and engineering education community?

Method

A pre-college engineering education program provides an engaging experience in designing an electric dragster (e-dragster) (see Figure 1) through a documented problem-solving process using a STEM partnership. This partnership exists between a university research center, a major energy corporation, and public secondary schools. The e-dragster challenge is being piloted with five public secondary schools participating. The university member of the partnership is engaging pre-service technology, engineering, and design education students in the project to gain insight into experiences from a student perspective that can lead to project enhancements as the program continues to grow.

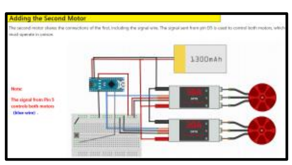
Figure 1: Example of E-Dragster Model



E-Dragster Model in Pre-College Environment

The e-dragster project provides pre-college engineering education students with instructional guides to establish foundational knowledge of using available resources and the engineering design process following project requirements (see Figure 2). Opportunity for open design exists in that students must construct a chassis to house all necessary components within a particular volume, distribute the weight appropriately within the vehicle, and construct a circuit for effective energy distribution. Significant engineering practices involve collaboration, modeling, programming, electric circuitry work, and digital documentation of the design process. Students also submit their digital notebooks as evidence of following each engineering design process step.

Figure 2: Example of Instructional Guide



Resources available through the partnership program includes a curriculum that provides step-by-step guides for significant elements of the design process and copy-paste programming for students to use as a foundation for their prototype. Teachers incorporate the pre-college engineering education program into their technology and engineering course or as an extra-curricular activity for student engagement. The partnership provides physical materials to each school, with each teacher receiving five kits, each suitable for one vehicle. The initial cost is $120 per kit, considering that most of the equipment can be reused by teachers multiple times, reducing future replenishment costs. Each kit includes an Arduino Nano, electric motors, electronic speed controllers, LiPo batteries, magnetic sensors, and additional components. Annual funding from the partnership program goes to replenishing worn equipment at participating schools and providing equipment to new schools, leading to program expansion.

Toward the end of the academic year, students convene at a large land-grant university in the southeast United States of America to exhibit their application of the engineering design process and receive recognition for designing an electric dragster prototype. The vehicles are raced using a lap timer system that identifies, in seconds, how long it takes for the dragster to travel 20 meters. The visit additionally allows for exploring a university campus and gaining information on engineering degree programs of interest.

E-Dragster in Pre-Service Education

For this work-in-progress paper, data was collected from eight participants in the technology, engineering, and design education course focused on applying technology through an engineering design process, including four pre-service teachers. Data collection methods include an anonymous survey of learner experience and a thematic analysis of student work after completing the relevant curriculum. All identities were kept anonymous and no direct identifying features were presented in the study.

Students completed the e-dragster project over four weeks, consisting of about 16 hours of course time. This period is very similar to what the public school teachers use for the project. At the end of the project, students raced their e-dragsters for the fastest time and presented their design features to the class. After the project, students participated in the anonymous survey feedback and submit de-identified work for analysis.

The anonymous survey of student experiences seeks to gain insight into how "real-world" and "challenging" the project was from a student perspective. Survey questions investigated students' input on positive and negative experiences from the project and sought to identify what resources are most advantageous for student success. The researchers analyzed results from the survey to identify themes related to student experiences, potential improvements to the project, and resourceful information for teachers to utilize when engaging students with the e-dragster challenge. Study participants submitted their engineering design notebooks documenting their collaborative experience designing and constructing an e-dragster. Student work was thematically analyzed to identify potential artifacts supporting survey responses and examples of how the project engages students in applying practices as identified in the standards for technological and engineering literacy through a problem-solving approach (3).

Researchers of this project are experienced technology, engineering, and design educators. Each author has experience teaching in a middle and/or high school setting, so they have an established insider relationship with participants in this experience. The students in the study are students of one of the authors so this can impact results.

Results

After experiencing the e-dragster challenge, student responses highlighted the following information and perspectives as shown in Table 1. Responses support that the e-dragster project is seen as a challenging experience relative to the "real-world". Additionally, information regarding positive and negative experiences demonstrate benefits, challenges, and areas of improvements.

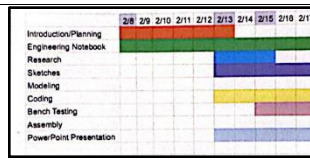
Table 1: Survey Question Responses	**Total Number of Responses**				
	S. Disagree	Disagree	Neutral	Agree	S. Agree
Do you feel the E-Dragster was a challenging experience?	0	0	3	1	4
Do you feel the E-Dragster project is a "real-world" project for a STEM Learning Environment?	0	1	1	3	3

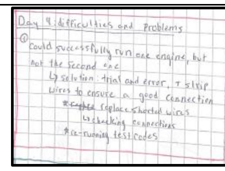
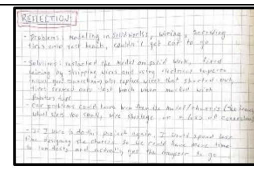
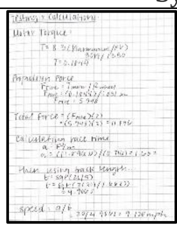
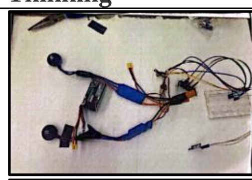
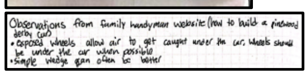
Question Topic	**Commonly Reported Themes**			
Positive Experience Themes	Following a Design Process	Challenging & Collaborative	Learning something new	Modeling
Negative Experience Themes	Challenging and experience with Failing	Initially overwhelming	A need to find solutions	
Most Challenging Aspect	Wiring electrical components	Attaching components	Overall challenge	Having a deadline
Most Helpful Resources	Instructor Provided Resources	Lab Space with Tools	Online sources	Peers
Future Improvements	Clearer Instructions with checkpoint deadlines	Increase guide on electrical components	Increase durability of components	Use with electrical focused curriculum

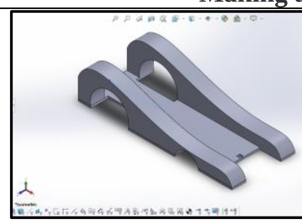
Throughout the analysis of the student e-dragster engineering design notebooks, four technological and engineering literacy practices were consistently demonstrated and supported by student survey responses as shown in Table 2. Collaboration is evident through the vocabulary use of "we", “our”, and “team” in addition to the planning of team roles and tasks. Communication is evident through daily goals, identification of problems and solutions, as well as reflections. Systems Thinking is evident using input, process, output, and feedback variables within the engineering design process. Making and Doing is evident using tools to solve problems and meet requirements.

Table 2: Technology and Engineering Practices Evident in Engineering Design Notebook

<table>
<tr><th>Collaboration</th><th>Communication</th></tr>
<tr><td>

</td><td>


</td></tr>
<tr><th>Systems Thinking</th><th>Making and Doing</th></tr>
<tr><td>




</td><td>


</td></tr>
</table>

Discussion

Real-World Relation

As the STEP E-Dragster Challenge continues to develop, it is beneficial to gain student input to maintain the student-centered approach of this collaborative pre-college engineering education. Student responses to the e-dragster project demonstrate that students view the project as a real-world relatable experience which supporting research demonstrates can lead to an increase in STEM content knowledge and skill development. This includes providing teachers the opportunity to exhibit applied mathematics and science content.

Along with the real-world relatable experience, the e-dragster challenge affords an opportunity to envelop professional resources into the learning environment. Student responses highlight how the most helpful resources were university provided including access to information, curriculum material, and lab spaces with tools. Each of these elements are partnership funded and provided via university instructors which can relieve the stress of teachers who need help in obtaining appropriate project materials and funding sources.

Students viewing the project as a real-world relatable project aligns with the supported goals of STEM partnerships where students spark interest and excitement in STEM, improve understanding of STEM content and knowledge, engage in STEM reasoning and computational thinking, reflect on STEM, and use the tools and languages of STEM. Positive experiences identified in student responses include the experience of modeling in a challenging and collaborative environment where they are provided a structure in learning new content in an applied manner. These responses support how the STEP E-Dragster project contributes to meeting STEM partnership goals.

Challenging

In addition to providing a real-world relatable experience to students, this pre-college engineering education partnership provides students with a challenging experience. Student responses highlight that positive aspects of the project involve a range of challenges including having to gain and apply new knowledge, meet deadlines while documenting a design process, in addition to correctly arranging and connecting components. While some of the challenging aspects of the e-dragster project are positive, there were challenges that lead to negative experiences. These negative experiences that students report include the project being overwhelming, an experience with failure, and the need to find answers that were not present in the instructor-provided resources.

With the increasing demand for technological and engineering literacy, students need exposure to challenging situations that promote problem-solving, critical thinking, communication, and collaboration. From student responses communicating positive, negative, and challenging experiences, the e-dragster project demonstrates an evolving STEM design challenge provided through a pre-college engineering education partnership. Such experiences allow for students to hone development of technological and engineering literacy practices

Practices

Analysis of engineering design notebooks revealed evidence of students demonstrating practices of technological and engineering literacy. The highlighted practices of collaboration, communication, systems thinking, as well as making and doing are characteristics of the desired incoming STEM workforce. Pre-college engineering education partnerships, as demonstrated through the e-dragster challenge, expose students to experiences in which they can fine-tune practices that can lead to success in future engineering work. Partnerships that provide resources that encourage engagement with course content and experience in using real-world tools foster a learning environment that leads to STEM knowledge and skill enrichment.

Using engineering design notebooks in conjunction with the e-dragster allows educators and pre-college engineering education programs to apply performance-based assessment that can lead to facilitative guidance of learning through supplemental materials as well as identified areas of improvement within programs and curricula. As STEM partnerships flourish, it should be kept in mind that resources provided to school promote practices of technological and engineering literacy while also remaining relevant and appropriately challenging.

Resources

Universities, industries, and community-based STEM partnerships are important resources of materials and information as identified through supported research and student responses. STEM partnerships support teachers and schools through the provision of equipment and curriculum. Student responses to the e-dragster project support that partnership-provided instructions and materials, along with an opportunity for collaboration with peers were the most helpful resources during experience. Opening access to these experiences through a STEM partnership encourages success in developing engineering related knowledge and skills. This can also lead to enhancement of interest and identity in technology and engineering to inspire future STEM workforce development.

Future Improvements

The continued evolution of the STEP E-Dragster Challenge through the STEM partnership between NC State University, FREEDM Systems Center, and Duke Energy will include future improvements such as increased curriculum structure and equipment durability. Students identified in the results that clearer instructions on prototype construction and guidance on electrical components will help in relieving stress and breaking components. Further improvements include aiming the pre-college engineering education program to high school related electronic or robotic courses that involve increased focus on electrical engineering and microcontroller programming.

Additional enhancements include expanding the program to reach more rural and underrepresented populations to establish interest in electrical vehicles and similar technologies. As alternative energy companies and manufactures make their way into communities, the STEP E-Dragster project can be a method of establishing foundational knowledge to prepare students for a post-secondary education and workforce. This project is fit to do so due to the decreasing cost of equipment along with STEM partnership instructional support via online learning management systems, digital guides, and web conferencing capability.

Conclusion

Research and student responses support that the pre-college engineering education program, STEP, provides a real-world related challenge that promotes technological and engineering literacy through a STEM partnership between NC State University, FREEDM System Center, and Duke Energy. Such partnership programs can provide authentic experiences to pre-college students to enhance interest and identity while also gaining knowledge. Limitations of the study include that while that project is for pre-college students, college students were the sample testing the project and providing feedback. This can impact how high school students may respond to the challenge. A second limitation is that this project is for technology and engineering courses and standards which can impact how science and math courses may incorporate the challenge.

Future studies include gaining secondary student and teacher input of the project as further development occurs. The E-Dragster Challenge is a student-centered project and therefore it makes sense to continue gaining student input to maintain relevancy to the goals of pre-college engineering education partnerships. STEM workforce pushes for critical thinking, collaboration, communication, and creativity which are all elements incorporated in the e-dragster challenge.

References

[1] D. B. Harlow, A. Hansen, J. Nation, R. Skinner, J.Pulgar, A. Spina, . . . A. Prud'homme-Genererux (2020). Creating stem learning opportunities through partnerships. In C. C. Johnson, M. J. Mohr-Schroeder, T. J. Moore, and L. D. English, *Handbook of Research on STEM Education*. Routledge, 2020.(pp. 152-165). New York, NY: Routledge.

[2] L. Fogg-Rogers and T. Moss, "Validating a scale to measure engineers' perceived self-efficacy for engineering education outreach," *PLOS ONE*, vol. 14, no. 10, p. e0223728, Oct. 2019, doi: 10.1371/journal.pone.0223728.

[3] International Technology and Engineering Educators Association (ITEEA), "Standards for technological and engineering literacy: The role of technology and engineering in STEM education," 2020. [Online]. Available: http://www.iteea.org/STEL

[4] E. Council, "Optimizing stem industry-school partnerships: inspiring Australia's next-generation final report." (2018) In *STEM Partnership Forum, Carlton South, Australia*.

[5] B. Trilling and C. K. Fadel, "21st century skills: learning for life in our times," *Choice Reviews Online*, vol. 47, no. 10, pp. 47–5788, Jun. 2010, doi: 10.5860/choice.47-5788.

[6] S.M Nesmith, S. Cooper (2020). Elementary stem learning. In C. C. Johnson, M. J. Mohr-Schroeder, T. J. Moore, and L. D. English, *Handbook of Research on STEM Education*. Routledge, 2020.(pp. 101-114). New York, NY: Routledge.

[7] National Academy of Engineering Grand Challenges for Engineering. http://www.engineeringchallenges.org/cms/challenges.aspx

[8] K. H. Tseng, C. C. Chang, S. N. Lou, and W. Chen, "Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment," International Journal of Technology and Design Education, vol. 23, no. 1, pp. 87–102, Feb. 2013, doi: 10.1007/s10798-011-9160-x.