WIP - Outreach and Entrepreneurial Mindset Learning (EML) in STEM

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Ghina Absi is an Assistant Professor in the Civil and Environmental Engineering department at Vanderbilt University. She teaches classes at the freshmen, sophomore and junior classes in Civil Engineering (Intro to Engineering, Statics, Mechanics of Materials, Civil Engineering Lab and several electives including travel classes) . She earned her BE and ME from the Saint Joseph University (ESIB) in Beirut, Lebanon, and worked for 5 years as a steel structures design engineer at a multinational firm (Dar Al-Handasah Shair and Co) based in Beirut. Absi then joined Vanderbilt University to pursue her PhD in Civil Engineering at Vanderbilt University (graduated 2019), focusing her research on risk and reliability of hypersonic structures. Absi is a licensed professional engineer in the state of TN.

Absi is passionate about education and promoting diversity in engineering. She serves as the advisor for the ASCE student chapter, the EDI liaison for the civil engineering department. A 2023 KEEN Engineering Unleashed fellow, Absi incorporates EDI as well as entrepreneurial mindset learning fostering curiosity, connections and creating value in design into her core classes with project-based learning techniques. She continually spearheads K-12 initiatives, especially for girls and underserved youth, to get them excited about engineering.

Outside work, Absi loves spending time with family. She enjoys traveling, hiking, mountain biking, and the outdoors. Absi is trilingual in English, French and Arabic.

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Introduction:

This Work-In-Progress paper seeks to study the correlation between a STEM outreach effort and math literacy among middle and high-school students. It aims to show that an early hands-on engineering project intervention would capture students' interest in civil engineering as they navigate theoretical math content that could lead otherwise to alienation from STEM. The project has an Entrepreneurial Mindset Learning (EML) objective as well as an Equity, Diversity and Inclusion (EDI) application.

Civil Engineering as a career is currently in high demand [1] to cater for our ailing infrastructure and design for a sustainable and innovative future for our planet. This profession has an extensive impact on society and the global environment [2]. It is primordial for us to train ethical and innovative budding engineers to cater for the need of our communities and environments and design the cities of the future. It has been shown that students who are exposed to STEM before college have a greater chance of selecting engineering as a major, and that visits to engineering schools had an impact on the students' decision to enter engineering [3]. Phelps et al. [4] showed that many factors across life stages are associated with engineering major choices, and highlighted the importance of pre-college experiences in guiding students in that choice. This demonstrates that interactions with undergraduate programs have a measurable influence on major selection, which provides a great argument for STEM outreach from engineering schools to middle and high-school students.

STEM interest in middle and high-school students is sometimes difficult to predict. It relies on many socio-economic variables, as well as academic settings in schools. Some studies have attempted to link these variables to success of students in STEM fields: Betancur et al. [5] have studied how disparities in science achievement across elementary and middle school are related to parental income and education, highlighting the influence of socioeconomic status on students' performance in STEM subjects. Tuner et al. explore in their paper [6] how socioeconomic status (SES) and gender influence high school students' STEM career interests, goals, and actions, utilizing Social Cognitive Career Theory (SCCT) as a framework. Other studies have shown that some introductory classes negatively impact interest in STEM, especially in under-represented groups: Ellis et al. [7] found that women are 1.5 times more likely than men to leave the STEM pipeline after taking Calculus I, with a lack of mathematical confidence identified as a significant factor. Other studies [8] provide evidence that introductory STEM courses may disproportionately drive underrepresented minority students out of STEM (this case in undergraduate programs), even after controlling for academic preparation in high school and intent to study STEM. With respect to primary education, a report from the National Academy of Engineering discusses how difficulties in Algebra I contribute to high dropout rates and hinder students' progression in STEM education[9]. It emphasizes the need for innovative teaching methods to improve comprehension and retention as math without a context application can become a barrier to success in STEM. Leyva et al. [10] show that when students understand the relevance of math in their career choice, their interest in STEM careers peaks. These findings highlight the need for supportive learning environments and targeted interventions to maintain and enhance interest in STEM among all student groups.

Students' interest in STEM is increased when social justice work is integrated in engineering projects. A study by Vance-Chalcraft et al. [11] examines how incorporating social justice and

community engagement into STEM curricula can enhance student participation. It suggests that when students work on projects with tangible social benefits, their motivation and commitment to STEM fields are strengthened. Many undergraduate programs [12] [13] [14] are incorporating more projects dealing with social justice work. These studies provide valuable insights into the integration of social justice in engineering education, demonstrating its significance in developing engineers who are not only technically proficient but also socially conscious and ethically responsible.

This work aims to show that a hands-on real-world problem intervention at a specific time during a student's academic development could affect their interest in STEM subjects. We explore the effect of an immersive STEM outreach program in civil engineering with a social justice aspect to it on a group of 23 juniors in high school. The author designed an academically appropriate project based on a civil engineering core statics course application centering on one of the largest infrastructures investments in national history: the Federal-Aid Highway Act of 1956.

Two other implementations of this projects are in the works for middle and high school students differentiated by their math curriculum (specifically Algebra 1). By comparing the data collected from these different groups, the author will study whether interventions of socially oriented STEM projects with students of different math levels would influence their understanding of how math is used in engineering and increase their interest in pursuing a future career in STEM.

Completed Work:

As part of an outreach work to local middle and high schools in Nashville, TN, the author designed an academically appropriate civil engineering project based on a sophomore level undergraduate course: Statics [15]. The project helps students study the effects of civil infrastructure on communities – specifically the Federal Highway Act (FHA) of 1956 – and guides them in designing a balsa bridge by producing a cut list (mirroring basic shop drawings), calculating reactions, manufacturing the bridge using glue and pins, and testing it to capacity.

Inspired by the visit President Eisenhower made to Germany in the first half of the 20th century, the FHA aimed to develop and grow the links between the major cities in the US. It was designed to enhance national security and improve the economy by facilitating transportation across the country. While funded by the federal government, cities had the power to decide where to run their highways and many within the city limits were purposefully routed though under-represented minoritized communities [16]. This led to the destruction of many thriving neighborhoods, notably the Jefferson Street community in Nashville, TN. Currently, a national effort to alleviate the effects of the Highway Act is driving the design of many interstate caps to reconnect the affected communities.

Based on this real-world problem, students were tasked with researching the FHA of 1956 and designing a bridge to cap interstate 40 that runs under Jefferson Street. The bridges would span the interstate and create a green space to reconnect the two sides of the community. To spur creativity and design a structure that speaks to the public they would serve, students used an ideation process called "bisociation". Bisociation, a concept introduced by Arthur Koestler in his 1964 book "The Act of Creation" [17], refers to the process of connecting two previously unrelated matrices of thought to produce new insights. Some students used local street art (murals) as inspiration, others diverse objects like busses or pianos.

In groups of 3 or 4, students designed their bridges and presented them to their peers and other community leaders, as shown by the pictures below.

Figure 1: (a) A group of students showcases a bridge inspired by the music scene of Jefferson Street – A piano, and (b) A group of students showcase a "connections" bridge, with gravel that will mix the more people walk across.

To incorporate math in their designs, students were taught to calculate the reactions on a K'NEX bridge by moving a point load on the top arch. This translated into solving a system of equations with 2 unknown parameters: The vertical reactions on the supports. Students validated their calculations by using scales to measure the weight on the edges of the bridge as they move the load along the bridge, as shown in Figure 2.

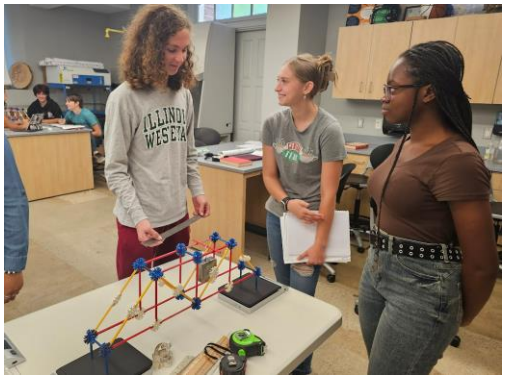

Figure 2:A group of students validates their calculations using a simple experiment with K'NEX.

After that simple exercise, students started exploring bridge designs and drawing sketches on graph paper. When they agreed on a shape, they drew it on an online truss calculator (https://ei.jhu.edu/truss-simulator/) to explore which elements would have the highest internal forces in tension or compression. The next step was creating a cut list of their design on the graph paper: Students used the balsa wood to incorporate the thickness of the wood and find the correct lengths to cut. They used toolboxes provided by the author and the Civil engineering Department at Vanderbilt University to cut the wood and drill holes in it for the connections.

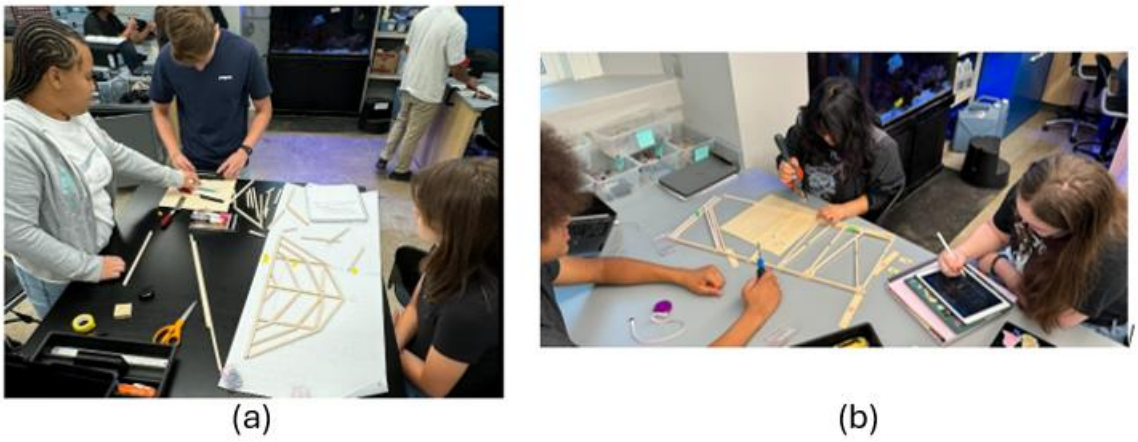

Figure 3: (a) Students create their cut list and start building their trusses, and (b) Students use the hand drill to assemble the bridges using pins.

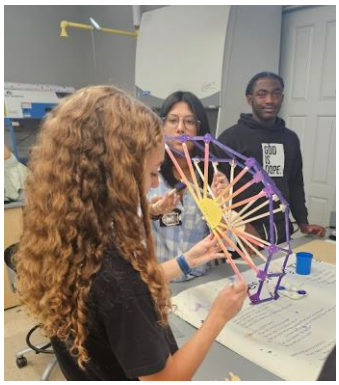

Figure 4:The sunset bridge getting a final esthetics touch

Preliminary Results:

This intervention project was very positively received by all the students. It allowed them to channel their scientific knowledge in basic math and physics and merge it with an artistic flair and social justice awareness. Feedback from the students was the following:

- 100% of students felt like they learned a lot about civil engineering,
- 87% of students shared their appreciation for the real-world application and its ties to social justice and EDI,
- 78% of students were excited about the math calculations and their parallel to their math curriculum,
- 65% of students shared that they are now more interested in becoming an engineer, and that looking at this project from start to finish gave them the insight of an entrepreneur working with clients,

This group of students is a STEM-oriented group, so these results were welcome, but also not surprising. It will be used as a benchmark to compare the responses from two other groups from the general student population (no direct STEM inclination) at two different levels of math

curriculum: During and before taking Algebra I. Using data from a pre-survey, the author will try to answer the following questions: Do math classes help or deter students from STEM careers? Do these inclinations change after the project intervention? How does Algebra I affect the responses from both groups? Would this inform when this project would be more appropriate to use in middle/high school?

Future Work:

Intervention group (2) is currently ongoing (8^{th} graders taking Algebra), and intervention (3) will start a few months after (8^{th} graders taking pre-Algebra). The data from these two interventions will be analyzed for trends and correlations to inform how and when these interventions are the most appropriate.

The author hopes this work is a precursor to studying how STEM interventions affect the communities where they are applied and would help personalize the project types and the level of content needed to maximize interest in STEM.

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