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Authentic Engineering Experience: An Electromagnetic Induction Powered Illuminated Fine Art Sculpture

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I'm currently a sophomore at a Community College, working towards a degree in mechanical engineering.

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I was apart of the first group to began working on the Electromagnetic Induction Powered Illuminated Fine Art Sculpture. Through many long hours, countless fails, and many small victories along the way, our project has evolved into a successful product with a happy client. I have taken many classes at Raritan Valley Community College and at Rutgers University School of Engineering where I completed my bachelors degree, but no other class has taught me the hands on skills and real life applications quite like the Authentic Engineering Experience Class instructed by Professor Peter Stupak. It has been a privilege to been involved in this project and I am looking forward to seeing what the future holds for this project and the many other projects that will continue to be produced by future participants in the Authentic Engineering Experience Class at Raritan Valley Community College.

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Darren McManus is an Associate Professor of Graphic Design and Co-Chair of the Arts and Design Department at Raritan Valley Community College in New Jersey. He teaches Visual Design 1, Visual Design 2, Digital Artmaking, Portfolio Development, and Typography within the Graphic and Interactive Design Program. He is an award-winning artist and professional graphic designer specializing in visual identity and branding. McManus has earned numerous grants, awards, and residency fellowships while working between the contemporary art and design worlds. He received his BFA from the Hartford Art School, where he completed a double major and spent his junior year studying at the Glasgow School of Art in Scotland; and an MFA from Cranbrook Academy of Art.

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Peter Stupak is President and Founder of the non-profit organization Main Engine Start that is dedicated to project-based learning for students of all ages to discover their passion for Science and Engineering and to increase their self esteem and confidence. Prior to creating his non-profit organization, Peter was an Associate Professor of Engineering and Physics at Raritan Valley Community College from 2014 to 2021, and before that he enjoyed a 22-year career in the fiber-optics manufacturing industry, living, and working in 7 countries. Peter's work involved him in R&D, Engineering, and Manufacturing culminating in the construction, start-up, and operation of an optical fiber factory in Suzhou, China where he was also the Chief Technology Officer. He holds a B.S. in Chemistry and M.S. and Ph.D. in Mechanical Engineering from the University of Massachusetts at Amherst.

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Introduction:

A collaboration between an engineering education nonprofit and a Raritan Valley Community College's service-learning program led to a practical, project-based learning initiative named the "Authentic Engineering Experience" (AEE). In this program, student teams, each composed of two members, were tasked with designing, prototyping, manufacturing, and delivering a real product to a real customer. The precise request for this project was an electromagnetic induction-powered "Light Box," intended for illuminating translucent sculptures at an art exhibition, as proposed by a college art professor.

The concept of the AEE was inspired by the author's (Stupak) professional experience in forming manufacturing engineering teams across different countries. A significant observation was that, while new engineering graduates often exhibit academic excellence, there is a marked disparity in their grasp of real-world business operations. This gap considerably affects their ability to contribute effectively to business success in their early months of employment. The AEE addresses this gap by providing second-year community college students with a hands-on experience that mirrors a real-world engineering work environment. The project's goals were to acquaint students with the essentials of business operations within an engineering context, enhance their problem-solving skills, and improve their chances of securing internships.
The students were placed in small teams to simulate working within a compact engineering solutions company, mentored by industry-experienced professionals, including the author. This setup allowed students to engage directly with the customer, understand and negotiate requirements, brainstorm solutions, prototype, and accept and react to critical feedback. Leadership roles within each team were rotated weekly to grow leadership skills, and teams were responsible for presenting their progress to the customer.

The overarching aim was to expose students early in their academic careers to the practices, motivations, and methods used in the engineering industry. A critical lesson was the importance of perseverance, and understanding that overcoming challenges is a part of the engineering process. This experience not only equipped students with valuable technical and soft skills but also provided them with a unique narrative to share with potential employers, demonstrating their readiness and capability to contribute effectively in a professional setting.

The AEE differs from many Capstone projects because of its focus on industry methods and it is offered in the second year of community college instead of the Senior year of many 4-year engineering programs.

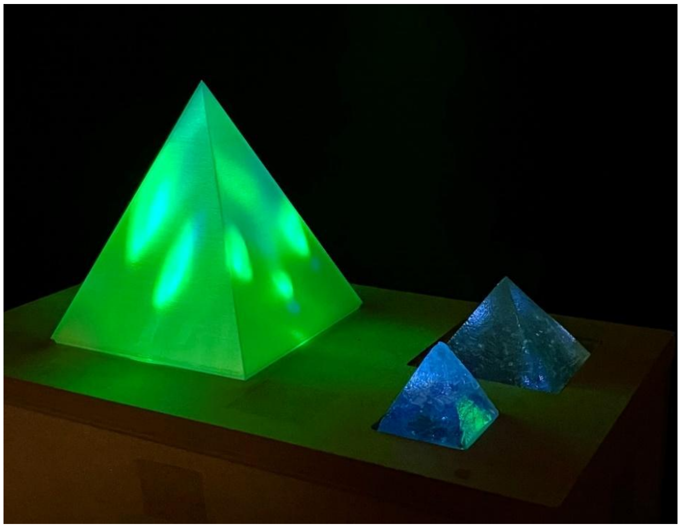

Figure 1: The “Light Box” with LED lights illuminating elements of the sculpture.

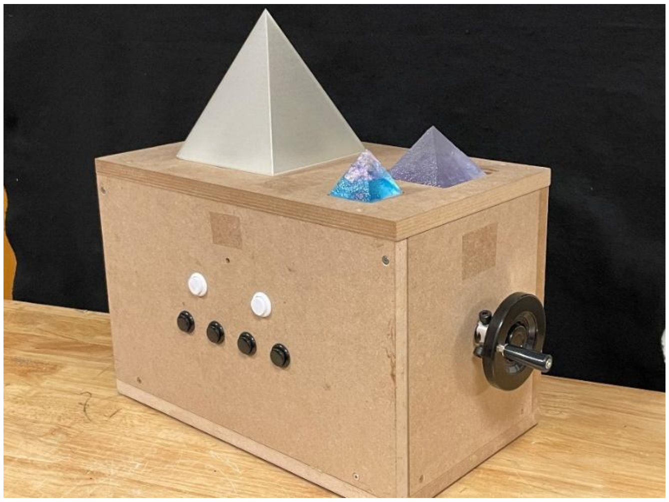

Figure 2: The Final Product- “Light Box” with hand-crank, pushbuttons, and cast glass and 3D-printed pyramidal elements.

Learning Objectives and Assessment:

This section outlines the specific learning objectives and assessment methods for the "Authentic Engineering Experience" (AEE) project. The AEE project was conducted entirely through hands-on, practical work, with an emphasis on learning through direct experience rather than traditional classroom lectures or labs. The objectives were designed to align with industry practices, providing students with skills relevant to the professional engineering environment. Assessment of these objectives was based primarily on the level of customer satisfaction, the product feasibility demonstration, the functionality of the prototype, and the quality of the final product.

Additionally, the experienced industry professionals mentoring the student teams assessed internal team dynamics and the application of learned skills throughout the project.

Upon successful completion of the AEE project, students would be able to:

Customer Focus and Satisfaction:

- Effectively communicate with the customer to understand and negotiate requirements.
- Perform interim project demonstrations to showcase progress.
- Respond constructively to feedback and incorporate it into project revisions.
- Deliver a fully functional prototype and final product that meets or exceeds customer expectations, within agreed timelines.

Project Management:

- Collaborate within a team, clearly defining roles and responsibilities.
- Develop and adhere to a project plan, including task allocation and scheduling.
- Demonstrate leadership skills through rotating leadership roles, ensuring project continuity and team coordination.
- Manage project resources effectively, staying within budget constraints.

Fail-Fast Prototyping:

- Generate initial ideas and rapidly develop prototypes to test concepts.
- Identify and address high-risk areas early in the design process.
- Employ a fail-fast approach to evaluate multiple solutions in parallel, minimizing resource expenditure on unviable options.
- Analyze each design iteration in detail to mitigate risks and refine the solution.

Skills:

- Master technical skills necessary for project success, including soldering, circuit design, and component selection.

Voice of the Customer:

The project’s customer, a college art professor, requested the creation of three specialized "Light Boxes" called "The Oracle" to highlight his translucent sculptures at art exhibitions. These light boxes were designed with specific features: two square and one circular opening on the top, each housing LED lights to cast light on sculptures placed above them (Figure 3). The square openings contained four white LEDs each, and the circular opening was surrounded by 32 LEDs in total—eight each of blue, green, red, and white—arranged in concentric circles. This setup required a total of 40 LEDs per light box, activated by pushbuttons for user control, designed to keep the LEDs lit for 30 seconds upon activation.

The customer required that only “Green Electricity” be used and generated at the moment by the user and that no batteries or wall-plug electricity be used. The customer did not specify how to generate the required electricity, only that the time to generate the required electricity is about 15 seconds to maintain the interest of the user.

Finally, the electricity generation and circuits were required to be rugged to withstand the shipping of the “Light Boxes” to various venues for Art Exhibitions and to be easy to access and repair if needed.

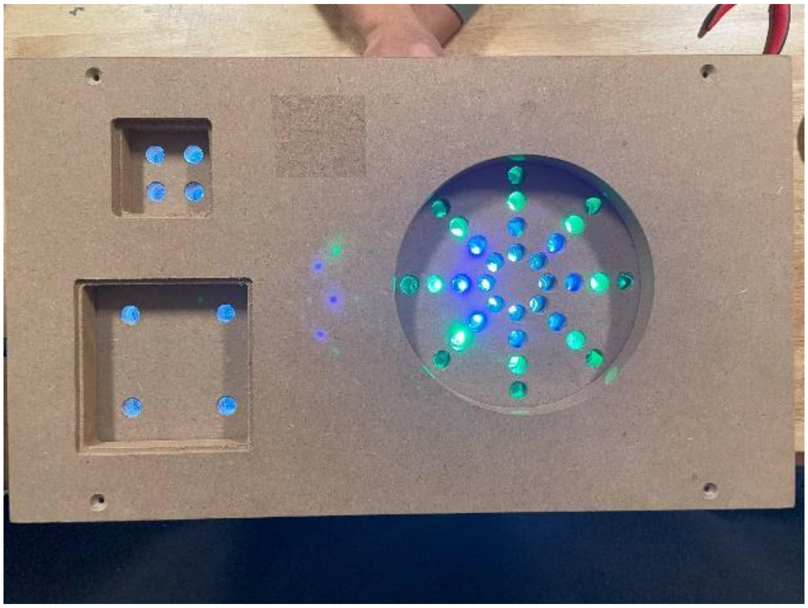

Figure 3: A top view of the “Light Box” showing the two square and one circular opening with LED lights embedded. The translucent elements are positioned on top of each opening.

Project Timeline Overview:

Over a span of two years, three Authentic Engineering Experience (AEE) teams, each comprising two students, dedicated their efforts to advancing the project. The first team demonstrated the feasibility of the project. The second team developed a fully functional prototype approved by the customer. The third team “industrialized” the fully functional prototype and fabricated three final products “Light Boxes”.

Energy Generation:

Electromagnetic induction, the principle that moving an electrical conductor through a magnetic field results in an electrical current, was used to generate the energy for this project. Specifically, direct current (DC) motors were used as generators. A DC motor is composed of a wire coil mounted on a rotating shaft within a ring of permanent magnets (Figure 4). Typically, powering the motor causes the shaft to spin. However, by manually rotating the shaft, the movement of the coil through the magnetic field induces an electric current. A greater rate of rotation results in a greater voltage and current produced. The motor's output was maintained below 5 volts to protect the LEDs, and a comfortable rotation speed of about 60rpm was chosen for the user.

The initial attempt involved a large DC motor connected to a hand-crank mechanism, where a large wheel turned a smaller wheel attached to the motor, generating enough power for the LEDs (Figure 5). Despite achieving the necessary power, the setup required excessive effort to start due to the large wheel's rotational inertia and suffered from vibration and noise issues caused by misalignment of the motor and wheels.

A change was made to smaller DC motors equipped with gearboxes, designed to decrease the shaft's rotation speed when powered electrically. Manually rotating the motor shaft resulted in significant increases in rotation speed and, consequently, power generation. This setup not only addressed the initial torque and vibration issues but was also more user-friendly.

After further discussions with the customer, a 300 rpm/12V DC motor with a gearbox and a circular crank handle were selected as the solution. This combination effectively balanced aesthetic appeal with operation.

The motor was installed inside the "Light Box," connected via a flexible coupler to compensate for any alignment discrepancies. An aluminum shaft extended from the coupler through a support bearing and the light box's wall, with the hand-crank securely attached, ensuring reliable and efficient energy generation for illuminating the LEDs (Figure 6).

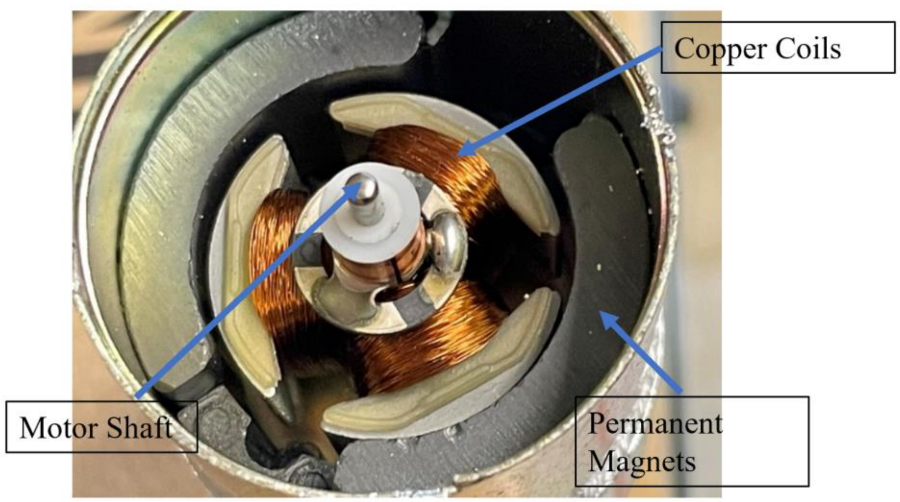

Figure 4: A top view of a DC motor showing the central coil of copper wire attached to the shaft and the ring of permanent magnets surrounding the coil.

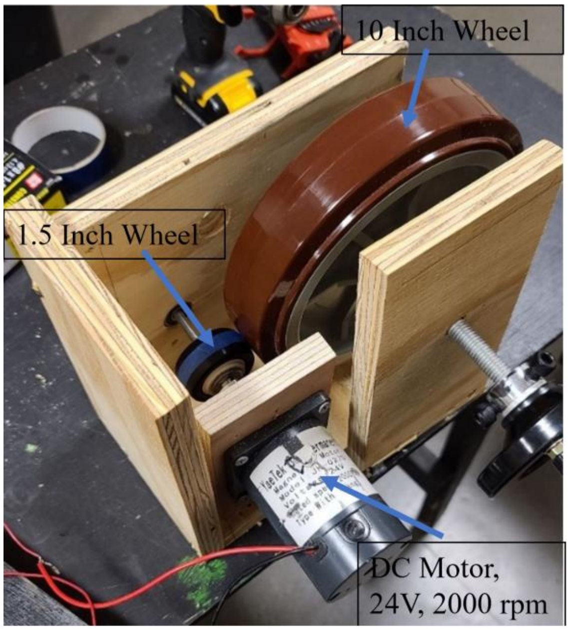

Figure 5: View of the first team’s “Light Box” DC motor and fabricated “gear-train” assembly consisting of a hand-crank rotated 10-inch diameter wheel driving a 1.5-inch wheel attached to the DC motor shaft.

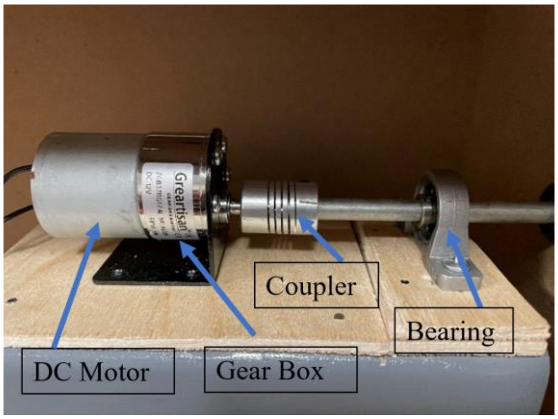

Figure 6: Side view of the mounted DC motor and attached gearbox with flexible coupler, aluminum shaft, and bearing.

Circuit Design:

The “Light Box” circuit was designed to store the electrical energy generated by the DC motor and to provide it to the LEDs by using pushbuttons to close the appropriate circuit. The circuit was assembled and soldered onto a circuit board (Figure 7). The electrical energy from the DC motor entered the circuit through a detachable connector. A rectifier was used to allow the electrical energy created by the motor to be used whether the hand-crank was rotated clockwise or counterclockwise by the user. The electrical energy was stored in a 5V, 4F supercapacitor. Three 5V diodes were connected in series to serve as over-voltage protection. Voltage greater than 5V passed through the diodes and converted into waste heat.

The output to the pushbuttons and LEDs was through detachable cables attached to pin headers mounted to the circuit board. This design facilitated straightforward disassembly, accommodating potential future repairs. Given the operational voltage disparities among LED colors, with red and green LEDs functioning at voltages below the requisite 3V for blue and white LEDs, resistors were integrated into the circuitry—22 Ohms for red and 10 Ohms for green—to standardize the operating voltage at 3V across all LED colors.

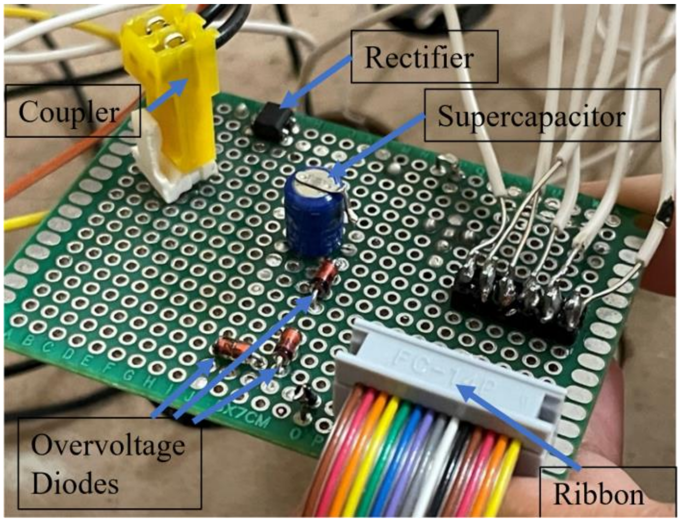

Figure 7: View of the final circuit board showing the power input connector, rectifier, Supercapacitor, over-voltage-protection diodes, and pinout and ribbon cable

Learning Objective Assessment:

The assessment of the learning objectives for the "Authentic Engineering Experience" (AEE) was two-fold, involving both customer feedback and evaluations by the industry-experienced staff mentoring the student teams.

Customer Feedback and Assessment:

The primary assessment of customer-facing objectives came directly from the client, who evaluated the project at the interim and final stages. Throughout the project, student teams engaged in regular communication with the client, receiving and incorporating feedback to refine their designs and approaches. This iterative process culminated in the client expressing satisfaction with the delivered "Light Boxes," indicating that the teams successfully met the external objectives of the project.

Internal Team Assessment:

The internal assessment was conducted by the mentors through structured weekly meetings. Each team developed a "Horizon Plan" detailing tasks for the upcoming week, which served as a roadmap for project activities. These plans were reviewed in weekly meetings, providing a forum for accountability and progress tracking. The weekly rotation of leadership roles ensured that each student gained experience in project management, communication, and logistical coordination, such as parts ordering.

A key strategy employed by the teams was "Fail Fast Prototyping," where ideas were quickly tested and evaluated to identify viable solutions, allowing for efficient use of time and resources. This approach resulted in a culture of innovation.

Conclusions:

By engaging students in real-world challenges that simulate the professional engineering work environment, the AEE successfully imparted valuable skills and insights to students early in their academic careers. Through this authentic experience, students learned both the technical aspects of engineering projects and the importance of perseverance, teamwork, and effective communication.

A critical insight derived from the Authentic Engineering Experience (AEE) is the students' acknowledgment of the significance of resilience and adaptability in surmounting challenges within engineering projects. This practical methodology affords students a distinctive comprehension of problem-solving and project management, competencies highly valued by employers.

The AEE program provides students with early exposure to authentic engineering scenarios and significantly enhances a student's readiness for the professional world. It prepares them for the challenges and opportunities they will face in their careers. As a result, participants of the AEE emerge as more competitive candidates for internships and job opportunities, armed with not just knowledge and skills, but with real stories of innovation and persistence that resonate with potential employers.

Acknowledgements:

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