Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #49508

Design of a Micro Class Airplane for SAE 2024 Competition: Fostering Engineering Self-Efficacy and Collaboration in Capstone Education

Dr. Iftekhar Ibne Basith, Sam Houston State University

Dr. Iftekhar Ibne Basith is an Assistant Professor in the Department of Engineering Technology at Sam Houston State University, Huntsville, TX, USA. Dr. Basith has a Ph.D and Masters in Electrical and Computer Engineering from University of Windsor, ON,

Syed Hasib Akhter Faruqui, Sam Houston State University

Assistant Professor, Department of Engineering Technology

Dr. Ali Dinc, Sam Houston State University
Joice Hill, Sam Houston State University
Emma Elizabeth Robles
Addym Paul Jackson, Sam Houston State University
Francis Coker, Sam Houston State University

Design of a Micro Class Airplane for SAE 2024 Competition: Fostering Engineering Self-Efficacy and Collaboration in Capstone Education

Ali Dinc, Emma Robles, Addym Jackson, Joice Hill, Francis Coker, Syed Hasib Akhter Faruqui and Iftekhar Ibne Basith
Engineering Technology, Sam Houston State University, Huntsville, TX

Abstract

This paper presents a multidisciplinary capstone project centered on the 2024 SAE Aero Design Micro-Class competition, emphasizing both technical achievement and educational outcomes. Students were tasked with designing, building, and testing a radio-controlled electric aircraft with a wingspan under two meters and capable of carrying a two-liter liquid water payload, in accordance with competition rules. While meeting these technical constraints, the project was also structured to support measurable student growth in systems integration, interdisciplinary collaboration, and engineering communication. The project integrates mechanical, aerospace, electrical, and electronics engineering disciplines to develop critical systems such as aerodynamics, control systems, and power distribution. Key challenges include aerodynamic optimization, weight distribution, and structural integrity. A structured educational framework guided the experience, integrating iterative design reviews, simulation-based analysis, and prototype testing. The outcome is a functional prototype that not only meets competition requirements but also enhances the students' understanding of engineering principles and real-world problem-solving skills. To evaluate student learning, the team implemented pre/post self-efficacy surveys with a custom rubric used to assess growth in problem-solving, teamwork, and system-level thinking. Preliminary results suggest that this competition-based approach enhances engagement, deepens conceptual understanding, and provides students with realistic engineering design experience. This work contributes evidence-based insights into the effectiveness of competition-based learning in capstone courses, underscoring its role in preparing students for professional engineering careers by fostering both technical proficiency and teamwork. The experience gained through this project will prepare the students for future professional roles in engineering, equipping them with both technical and collaborative skills to tackle real-world challenges.

Introduction

This project is part of the undergraduate senior design requirement in the Engineering Technology Program at Sam Houston State University. The objective is to design and fabricate an unmanned aircraft for the SAE Aero Design competition, with a focus on creating a radio-controlled electric airplane capable of carrying at least two liters of water within a two-meter wingspan. Similar design challenges have been addressed in other SAE competitions, such as the high-performance designs of WPI UAV teams [1], and the use of lightweight yet durable materials by previous SAE Aero Design participants [2]. The capstone project is designed to emphasize systems thinking, interdisciplinary collaboration, and practical application of engineering knowledge. This project will serve as an educational tool for students to learn professional engineering processes and provide practical insights into weight distribution, structural integrity, and power constraints. However, the team will not participate in the official competition due to time constraints.

The capstone project emphasizes systems thinking, interdisciplinary collaboration, and practical application of engineering knowledge. This educational approach aligns with the framework proposed in [3], which highlights the integration of systems engineering concepts in student projects. The team will develop critical collaboration skills as each member takes on specific responsibilities—such as aerodynamic design, structural analysis, or electronics integration—while ensuring all components work cohesively. Effective communication and teamwork will be vital to overcoming challenges and meeting deadlines. Moreover, the project aligns with methodologies used in [4] for structuring problem-solving processes in engineering design. Effective communication and teamwork will be vital to overcoming challenges and meeting deadlines. In addition to teamwork, project management will be a core component. The team will learn to manage time, allocate resources, and prioritize tasks throughout the project's lifecycle. Regular progress reviews and adjustments will help keep the project on track, fostering adaptability and resilience. Moreover, the team will face numerous technical challenges that require innovative problem-solving strategies. This iterative process of testing, analysis, and refinement will enhance their ability to handle complex engineering tasks and improve critical thinking skills. The project will also help them develop critical skills in teamwork, project management, and problem-solving. Working under real-world constraints, such as weight, power, and structural limitations, will simulate industry-standard engineering processes. By the end of this project, the students aim to have not only a fully functional aircraft but also a greater capacity for handling complex engineering tasks in future professional roles. The interdisciplinary nature of the project ensures that students develop critical communication, adaptability, and collaborative skills essential for their future careers.

Hypothesis Question: Will students who engage in competition-based capstone projects, such as the SAE Micro-Class design challenge, exhibit greater improvements in engineering self-efficacy, teamwork, and systems integration skills compared to traditional project-based learning experiences?

Methodology

Educationally, the methodology integrates active learning strategies and project-based learning principles, encouraging students to apply theoretical knowledge to practical challenges. The design process involves a structured approach to research, planning, and prototyping. The team has adhered to SAE Micro-Class rules and regulations while breaking the project into manageable phases. Initial steps included literature review, problem definition, and identification of key design parameters. The iterative approach mirrors methodologies discussed in [5], which emphasize the importance of early-stage simulations and testing. The team performed studies for design and simulation to optimize configurations for aerodynamics, lift, drag, and thrust, similar to the modeling techniques employed in [6]. After production of prototype stress testing of wing structures will ensure the aircraft's ability to carry the payload efficiently. The application of load testing will be guided by findings from [7], which discuss preliminary sizing and performance calculations.

When beginning the proposal for a micro class airplane that would abide by limitations set forth by the Society of Automotive Engineers (SAE), it was apparent that this process would need to be comprised of multiple sub-processes if it were to break the next year of research, planning, and prototyping into their simplest forms. It was decided that these three major parts of the project would need to be planned thoroughly in order to produce the best result for this Capstone plane. Before broaching the methodology used since the Fall semester of 2024, it is imperative that the reader is aware of the following: although this group intends on abiding by the SAE micro-class plan rule and regulations set forth for the 2024 competition season, it was not entered and will not be competing in any competitions, but will still be evaluated based on the criteria the SAE has provided in their rulebook from prior years.

At the outset, when the group was first formed, it was understood that the project would involve the development of a remote-controlled (RC) plane. However, it was not until Dr. Ali Dinc, a mentor from the Mechanical Engineering Department at Sam Houston State University, introduced the idea of participating in the SAE competition that the project's direction began to solidify. Dr. Dinc encouraged the team to align their efforts with the competition's rigorous standards, thus providing an opportunity for all four members to surpass expectations for this Senior Project. With his guidance, the group was able to initiate the first phase of research.

In the early stages of the project, each team member was assigned specific tasks based on their individual strengths. Emma Robles conducted a literature review on previous SAE designs [8], Joice Hill designed and 3D printed key components such as the fuselage, nose, and tail holders, and led the calculations for benchmarking [5]. The group as a whole referred to [9] for UAV design guidelines. Francis Coker served as the editor and coordinator, overseeing revisions to both the initial and final proposals, and managing group meetings. Addym Jackson took on the role of secretary, documenting project progress, and was also responsible for the construction and assembly of non-3D-printed materials.

Through the delegation of these tasks, the team was able to develop a more comprehensive understanding of the challenges ahead. The final proposal not only enhanced the group's preparedness but also fostered adaptability to unexpected challenges that arose throughout the project.

The following generic formulas are used to calculate the aerodynamic lift and drag forces for the airplane where parameters such as lift coefficient and drag coefficient were calculated based on guidelines in [10]. The iterative refinement process, which included theoretical calculations and simulation, reflects approaches from [11].

$$\mathrm{L} = \frac{1}{2}\rho V^2 c_l S \tag{1}$$

$$\mathrm{D} = \frac{1}{2}\rho V^2 c_d S \tag{2}$$

The formula for lift force includes air density (ρ), flight speed (V), lift coefficient (c_l), and wing area (S). It is typically assumed that the lift force is equal to the UAV's instantaneous weight during cruise and loiter phases. The lift coefficient can be calculated at a specific speed and altitude of the UAV using the following formula:

$$c_l = \frac{2W}{\rho V^2 S} \tag{3}$$

The calculation of drag force follows a similar approach to the lift formula, but it includes a drag coefficient. The drag coefficient (c_d) is composed of two components: parasite (zero lift) drag (c_{d_0}) and lift-induced drag.

$$c_d = c_{d_0} + \frac{c_l^2}{\pi ARe} \quad (4)$$

$$c_{d_0} = c_{f_e} \frac{S_{wet}}{S} \quad (5)$$

The below equations are used for sizing of the airplane:

$$F_{pl} = \frac{W_{pl}}{Wo} \quad (6)$$

$$W_o = \frac{W_{pl}}{F_{pl}} \quad (7)$$

$$\mathrm{S} = \frac{W_o}{W_l} \quad (8)$$

$$\mathrm{b} = \sqrt{AR * S} \quad (9)$$

$$\mathrm{C} = \frac{S}{b} \quad (10)$$

where : W_{pl} is payload weight; F_{pl} is payload fraction; S is wing area; W_l is wing loading; W_o is the total weight of the aircraft; AR is aspect ratio; b is wingspan and C is wing chord (width).

Design and Development Process

The design and development of a micro class aircraft for the SAE competition involves numerous system level considerations. All of which are aimed at optimizing the aircraft's performance as well as adhering to the competition guidelines. The approach also incorporates innovative solutions to enhance educational outcomes. For example, team-based learning activities are structured to foster collaboration and communication skills, while regular progress reviews emphasize adaptability and resilience which aligns with the findings in [12].

The aircraft will be devised of several systems that are critical for its function. These systems include the airframe, control, propulsion, and payload. These systems must be carefully considered and adjusted to ensure an optimal balance between weight, stability, and overall aerodynamic efficiency as discussed in [13]. This balance also must be optimal in making certain of receiving a satisfactory flight score. The plan is to design a lightweight but durable airframe, the propulsion should be able to deliver a reliable amount of thrust, and the control system must allow for precise maneuvering during flight. Figure 1 below details the block diagram filled with the necessary systems needed for the plane's function.

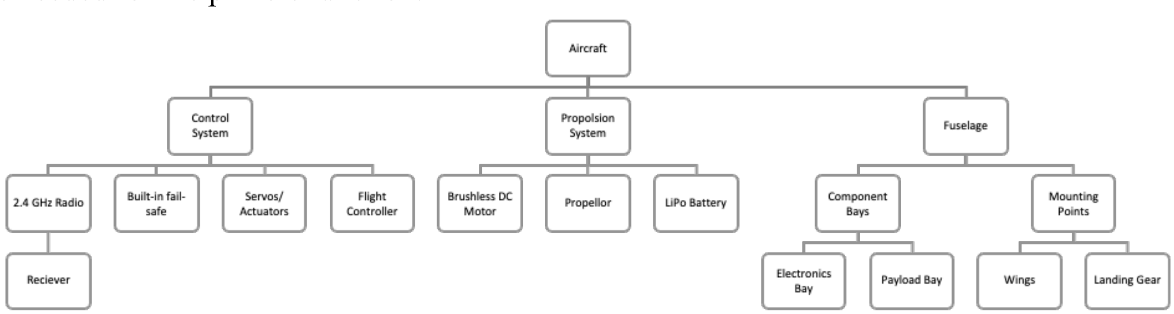

Figure 1. Functional Block Diagram

At an early point in the planning process, the design is leaning toward a monoplane configuration which is characterized by having a single set of wings. A monoplane is a conventional design choice in the SAE competition. A monoplane is best known for its high efficiency and low drag, which is essential for overall performance [14].

SAE Micro-Class Airplane Benchmarking													
Weight Calculation			Wing Calculation					Horizontal Tail			Vertical Tail		
$W_{payload}$ (kg)	F_{pl}	Total Weight	Wing loading (W_l)	Wing Area (S)	Aspect Ratio	Wing Length (b)	Wing Width (C)	S_{HT}	b_{HT}	C_{HT}	S_{VT}	b_{VT}	C_{VT}
2.25 kg	0.7	3.21 kg	6.5	0.495 m^2	7	1.86 m	0.27 m	0.039 m^2	0.29 m	0.13 m	0.025 m^2	0.16 m	0.15 m
2.25 kg	0.7	3.21 kg	4	0.804 m^2	7	2.37 m	0.34 m	0.063 m^2	0.37 m	0.17 m	0.040 m^2	0.21 m	0.19 m
2.30 kg	0.7	3.29 kg	4	0.821 m^2	7	2.40 m	0.34 m	0.064 m^2	0.38 m	0.17 m	0.041 m^2	0.21 m	0.19 m
2.35 kg	0.7	3.36 kg	4.5	0.746 m^2	7	2.29 m	0.33 m	0.058 m^2	0.36 m	0.16 m	0.037 m^2	0.20 m	0.18 m
2.40 kg	0.7	3.43 kg	4.5	0.762 m^2	7	2.31 m	0.33 m	0.059 m^2	0.36 m	0.16 m	0.038 m^2	0.20 m	0.19 m
2.45 kg	0.7	3.50 kg	5	0.700 m^2	7	2.21 m	0.32 m	0.055 m^2	0.35 m	0.16 m	0.035 m^2	0.20 m	0.18 m
2.50 kg	0.7	3.57 kg	5	0.714 m^2	7	2.24 m	0.32 m	0.056 m^2	0.35 m	0.16 m	0.036 m^2	0.20 m	0.18 m
2.55 kg	0.7	3.64 kg	5.5	0.662 m^2	7	2.15 m	0.31 m	0.052 m^2	0.34 m	0.15 m	0.033 m^2	0.19 m	0.17 m
2.60 kg	0.7	3.71 kg	6.5	0.571 m^2	7	2.00 m	0.29 m	0.045 m^2	0.31 m	0.14 m	0.029 m^2	0.18 m	0.16 m
2.65 kg	0.7	3.79 kg	6.5	0.582 m^2	7	2.02 m	0.29 m	0.045 m^2	0.32 m	0.14 m	0.029 m^2	0.18 m	0.16 m
2.70 kg	0.7	3.86 kg	7.5	0.514 m^2	7	1.90 m	0.27 m	0.040 m^2	0.30 m	0.14 m	0.026 m^2	0.17 m	0.15 m
2.75 kg	0.7	3.93 kg	7.5	0.524 m^2	7	1.91 m	0.27 m	0.041 m^2	0.30 m	0.14 m	0.026 m^2	0.17 m	0.15 m
2.80 kg	0.7	4.00 kg	8	0.500 m^2	7	1.87 m	0.27 m	0.039 m^2	0.29 m	0.13 m	0.025 m^2	0.17 m	0.15 m
2.85 kg	0.7	4.07 kg	8	0.509 m^2	7	1.89 m	0.27 m	0.040 m^2	0.30 m	0.13 m	0.025 m^2	0.17 m	0.15 m
2.90 kg	0.7	4.14 kg	8.5	0.487 m^2	7	1.85 m	0.26 m	0.038 m^2	0.29 m	0.13 m	0.024 m^2	0.16 m	0.15 m
2.95 kg	0.7	4.21 kg	9.5	0.444 m^2	7	1.76 m	0.25 m	0.035 m^2	0.28 m	0.13 m	0.022 m^2	0.16 m	0.14 m
3.00 kg	0.7	4.29 kg	10	0.429 m^2	7	1.73 m	0.25 m	0.033 m^2	0.27 m	0.12 m	0.021 m^2	0.15 m	0.14 m

Figure 2. Benchmarking Data

To fine tune the design and select the best configuration, our team evaluated a range of possible designs based on the payload weight. According to the SAE competition guidelines our design needed to have the ability to carry a minimum two-kilogram payload weight. Adding weight to the payload gains competitors more points to the overall flight score which competitors use to understand how "successful" their flight had been by SAE standards which change from year to year. Figure 2 details these configurations which have been narrowed down to choose a more practical range for our use. The range has been reduced by determining which data is worth pursuing in depth. This allowed the team to concentrate on configurations with a higher potential for success. Each configuration offers its own unique advantages and disadvantages.

The data in Figure 2 focuses on several critical design parameters that are essential to optimizing our aircraft's performance for the SAE competition. The most important factors include payload weight which directly impacts our flight score. Heavier payloads result in higher points. Wing loading is also directly impacted by the payload. It measures how much weight each unit of wing area must support to carry the aircraft. Proper wing loading is vital for maintaining an efficient lift and efficient maneuverability. Additionally, the wing area also plays a key role in determining the amount of lift generated. Larger wing areas are great for adding more lift but have the potential of generating more drag. The aspect ratio is the ratio of wingspan to the wing's chord or wing width. The aspect ratio is also very crucial in considering the plane's design. Higher aspect ratios can improve aerodynamic efficiency by reducing the drag but must be chosen in moderation. While a higher aspect ratio can be theoretically advantageous, it is very possible that it will not be viable in a real-world application. Such designs that focus on higher aspect ratios can introduce structural challenges. It can make the wings more susceptible to bending and difficult to manufacture within the weight and material constraints. The areas of the horizontal, S_{HT}, and vertical tails, S_{VT}, combined with the other variables contribute to the overall stability and control of the aircraft. Finding a balance of these elements is key to achieving a design that maximizes the payload capacity and flight performance within the competition's class guidelines.

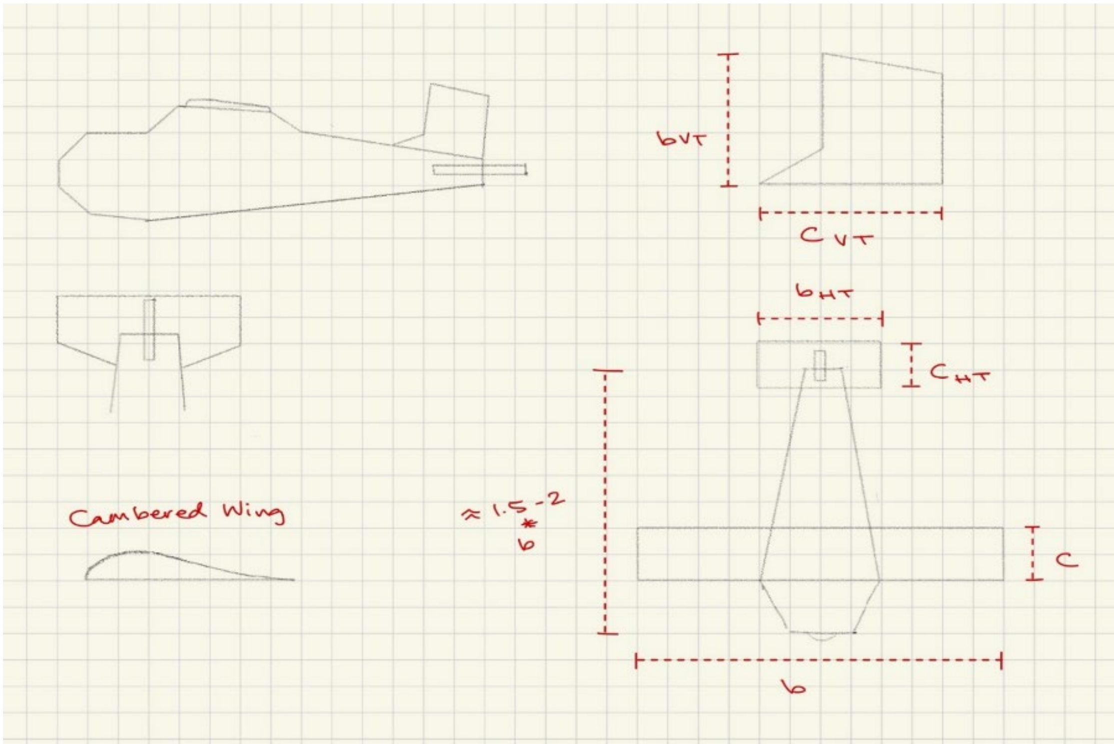

Figure 3. Initial Sketch Design

Figure 3 above presents our initial conceptualization draft that highlights the key variables within the design. Each team member took this design into account and utilized it as an outline for their individual interpretation of an efficient plane design. Critical design elements such as the wing shape and fuselage design were tailored to enhance the aircraft's performance goals. This includes optimal lift generation and structural integrity throughout flight. Depending on the configuration the fuselage can be fifty percent or larger than the wings for overall stability of the aircraft. The fuselage also needs to allocate space for a bay to host the electronics, the payload, as well as a clearly visible fail-safe mechanism in accordance with the SAE competition guidelines. These elements are key in finding an effective design that maximizes aerodynamic performance as well as net the most amount points possible per trial in the competition.

Final Team Member Benchmark Values																
Team Members	Weight Calculation			Wing Calculation					Horizontal Tail			Vertical Tail			Flight Score
Member Name	$W_{payload}$ (kg)	F_{pl}	Total Weight (kg)	Wing Loading (W_l)	Wing Area (S)	Aspect Ratio	Wing Length (b)	Wing Width (C)	S_{HT}	b_{HT}	C_{HT}	S_{VT}	b_{VT}	C_{VT}	Highest Score Value
Emma	2.60 kg	0.7	3.71 kg	6.5	0.571 m^2	7	2.00 m	0.29 m	0.045 m^2	0.31 m	0.14 m	0.029 m^2	0.18 m	0.16 m	56.581 pts
Joice	2.75 kg	0.65	4.23 kg	7	0.604 m^2	6.5	1.98 m	0.30 m	0.047 m^2	0.32 m	0.15 m	0.030 m^2	0.18 m	0.17 m	58.745 pts
Francis	2.50 kg	0.7	3.57 kg	6	0.595 m^2	6.5	1.97 m	0.31 m	0.046 m^2	0.32 m	0.15 m	0.025 m^2	0.16 m	0.15 m	55.557 pts
Addym	2.85 kg	0.7	4.07 kg	8	0.509 m^2	7	1.89 m	0.27 m	0.040 m^2	0.30 m	0.13 m	0.025 m^2	0.17 m	0.15 m	57.888 pts

Figure 4. Final Team Benchmarking Values

Figure 4 above contains the team member benchmarking data. This Figure has the values that team members considered when creating their individual designs. These benchmarks were critical in guiding our team's design process, as they reflected factors such as weight, payload capacity, wing area, and overall performance expectations. Alongside these values, the practicality of the build, potential for achieving a high final flight score, and the overall conceptualization of the design were considered. By carefully evaluating these aspects, the team was able to make an informed decision in selecting the final design that would be developed into a prototype. This thorough evaluation ensures that the prototype meets both the competition requirements, and the performance goals set by the team.

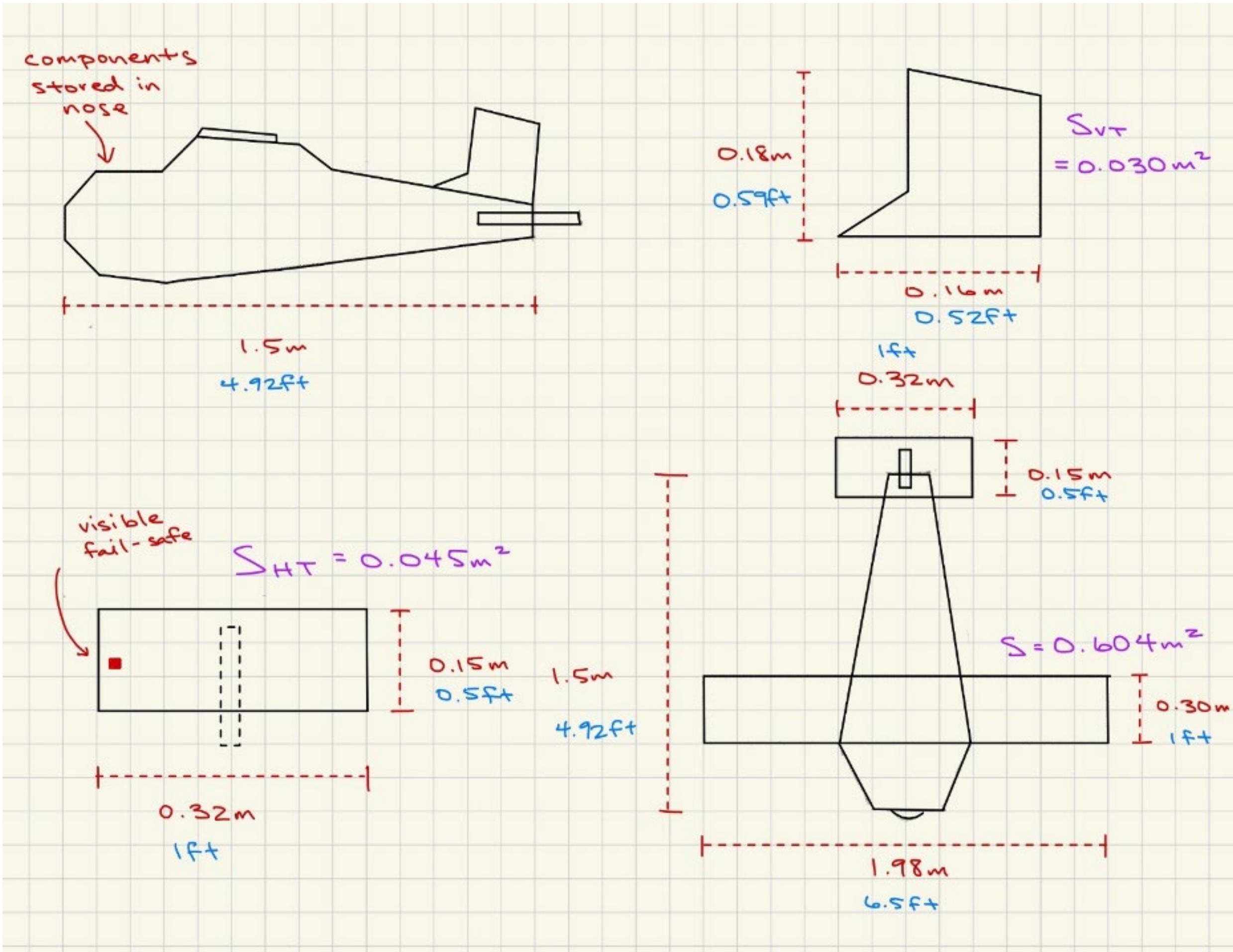

Figure 5. Final Design Sketch

Figure 5 above contains the final sketch our team decided to go forward with, designed by team member Joice Hill. The plane is engineered to carry a maximum payload of 2.75 kilograms. The design follows the standard monoplane design featuring a wingspan of 1.98 meters. Our team chose this design for its practicality and potential for stable, efficient flight performance. Our team chose this design for its practicality and potential for stable, efficient flight performance. The design achieves a balanced ratio of total aircraft weight to payload weight, with a payload fraction of 65%. The wings are designed to support this load efficiently, with calculated wing loading optimized for the expected flight conditions. The wings dedicate 70% of their weight-bearing capacity specifically to carrying the payload, ensuring an effective lift and overall performance. These conditions have contributed to this design, achieving the highest projected flight score earning 58.745 points across three runs with the most optimal conditions.

The plane design also features mostly rectangular wing shapes allowing for the rapid production of an initial prototype within a short time frame. These wings provide sufficient lift and aerodynamic efficiency relative to the aircraft's size and weight [15-17]. The horizontal tail features a visible fail-safe mechanism, a critical component that aligns with the requirements outlined in the SAE competition guidelines.

In the initial stages of the project, the team planned to test various modifications of the wings and fuselage shape. These tests would evaluate the viability of design adjustments and identify potential improvements in performance and efficiency [18]. By systematically analyzing these changes, the team aimed to determine the most effective configuration for future iterations of the prototype.

The final prototype closely matched the illustration shown below, particularly in its rectangular wing design, which was chosen for ease of rapid reproduction in the event of crash landings. The four-member team used carbon fiber spar rods to reinforce both the main wing and tail airfoils. The wing spars were inserted through precision-cut holes in the airfoils, created during the laser cutting process, to provide structural support and maintain consistent airfoil alignment along the wingspan.

Two different spar sizes were used to accommodate the smaller surface area of the tail section. Specifically, the front carbon fiber spar consisted of four connected rods, each with dimensions of 18 mm outer diameter (OD), 500 mm in length and a 1 mm thickness. The rear spar measured 10 mm OD, 420 mm in length, with a 1 mm thickness. To secure the spar assemblies, the team designed and 3D printed custom connectors that fit inside the spars. These were bonded with instant adhesive to ensure structural integrity and minimize unwanted movement during flight.

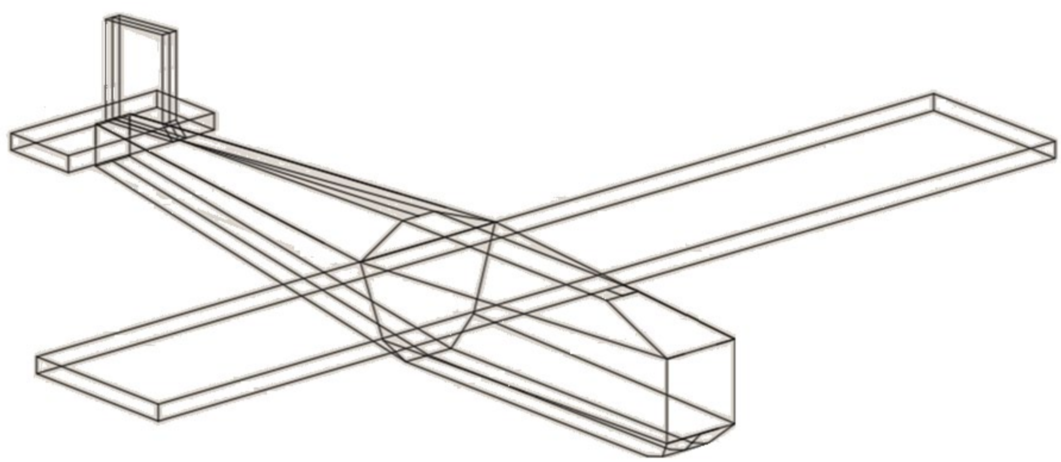

Figure 6. Selected Initial Concept Plane CAD Sketch

The CAD design shown in Figure 6 has been carefully developed to represent the team's chosen concept, incorporating essential elements such as the rectangular wing shapes, fuselage layout, and horizontal tail mechanism. The design has been updated to flatten the body of the plane to further reduce drag. This design has an influence in shape from Vestel planes. It serves as a detailed blueprint for constructing the prototype and allows for further refinement during the testing and evaluation phase. This design also adheres to the specifications outlined in the SAE competition guidelines, ensuring compliance while maximizing the aircraft's potential for stable and efficient flight performance.

By iterating through the design, our team improved the configuration (Figure 7) that provides the best balance between payload capacity and aerodynamic performance while abiding by the confines of the competition’s design constraints.

Figure 7. Improved Concept Plane CAD Sketch

In order to significantly reduce the weight of the aircraft frame, the team redesigned the fuselage using a windowed structure resembling a squirrel cage. This updated design minimizes the amount of material required to carry the payload while substantially lowering the overall system weight. The fuselage was segmented and fabricated using modular 3D-printed components, allowing for a highly configurable structure.

Polylactic acid (PLA) filament was selected due to its ease of use and structural rigidity—representing a major improvement over the original PVC pipe-based design. This new approach enhances the consistency and repeatability of manufacturing over time. In addition to weight reduction, the redesigned fuselage offers improvements in manufacturability, efficiency, and adaptability. Leveraging 3D printing technology, the team was able to control key design parameters, including wall thickness and material placement. This enabled more efficient filament usage and reduced production waste. Overall, the updated fuselage contributes to a lighter, more sustainable, and more easily refined airframe as the project evolves.

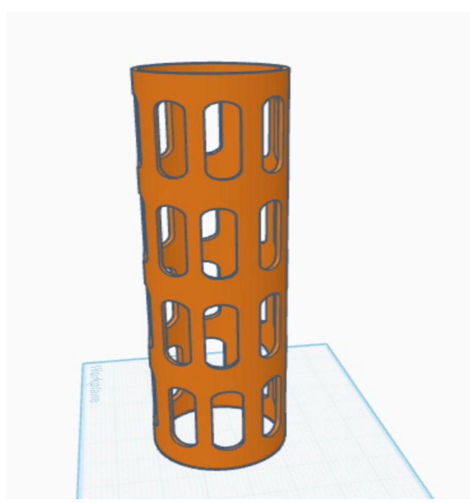

Figure 8. Squirrel Cage Fuselage CAD Model

Figure 8 illustrates the intended appearance of the redesigned fuselage. It features equidistant circular openings to enhance both structural integrity and aerodynamic performance. Rounded shapes are known to disrupt airflow less than angular geometries, thereby reducing drag and improving overall efficiency. For testing purposes, this design is significantly more effective than the initial PVC-based configuration. The rounded contours of the fuselage also help distribute mechanical stresses more evenly, reducing the likelihood of cracks or structural failure during flight. This airframe geometry enables the material to better withstand vibrations and dynamic loads, thereby maintaining structural integrity throughout operation.

The fuselage dimensions were optimized to minimize unused internal space. This ensures that the available volume is efficiently allocated to essential components such as the payload and electronics. The compact layout of the squirrel cage design eliminates unnecessary bulk and contributes to overall weight reduction while preserving strength. The evenly spaced window pattern enables material removal without compromising the structural cohesion of the aircraft. This careful balance between form and function ensures that the fuselage remains both lightweight and resilient under the aerodynamic and mechanical stresses of flight.

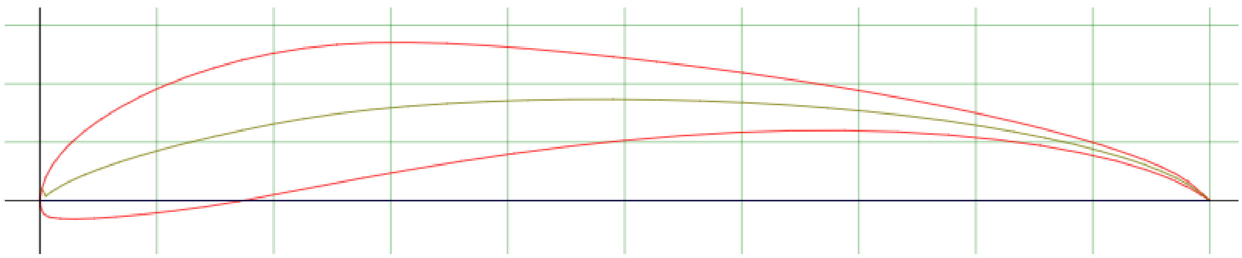

Figure 9. S1223 Airfoil

The team selected one of the following airfoils: S1223, S1223 RTL, and S1210, based on their high lift-to-drag ratios. After a detailed evaluation, the team chose the S1223 (Figure 9) as the most suitable option for the main wing airfoils. For the tail airfoils, the decision was more straightforward, as symmetrical airfoils were required to ensure stability during flight. Consequently, the team opted for the NACA 0012, a commonly used and well-suited airfoil for unmanned aircraft, as well as other applications beyond the scope of this project.

The airfoils were fabricated using a precision laser cutter at Sam Houston State University's Annex C, a woodworking facility, under the supervision of Mr. Kevin Von Rosenberg. Utilizing a Kern Laser System with pressurized air, Mr. Von Rosenberg cut the airfoils according to the specifications provided by the team. Balsa wood, chosen for its lightweight properties and sufficient structural integrity to support the aircraft, was selected as the fabrication material.

To develop a reliable and efficient propulsion system for the SAE RC aircraft, a systematic approach was used to identify and source each component required for power generation, distribution, and propulsion. The process involved evaluating performance requirements, compatibility constraints, and regulatory compliance, followed by the selection of commercially available, competition-approved components. The power system was designed to comply with SAE rules, which mandate electric propulsion only. Based on the projected maximum takeoff weight, desired thrust-to-weight ratio, and expected flight duration, the following key performance criteria were established: continuous power output, motor kV rating, battery capacity (mAh), discharge rating (C rating), maximum current draw, and system voltage.

For the motor selection, a 1000kV brushless motor was chosen for its high power-to-weight ratio and proven reliability in RC aircraft applications. This motor was selected based on the optimal kV rating for compatibility with the chosen propeller size and the electronic speed controller (ESC).

The propeller selection was based on the required RPM and the aircraft's wingspan. Initially, a 14-inch propeller was selected for the front of the nose. However, after design changes to the aircraft, the configuration was updated to two 5-inch propellers, each mounted under the wings. Complications arose with wiring the ESC to both motors, so the design reverted to the 14-inch propeller.

A 1000mAh 6S LiPo battery was selected to power the entire electronic circuit, based on the required weight and thrust to achieve takeoff. Additionally, a 30A ESC was chosen for its ability to meet the peak current demands of the motors, with an added safety margin of 20%.

Several challenges and obstacles were encountered throughout the project, including scheduling conflicts, 3D printing time constraints, and electrical component failures. One of the most significant challenges was the extended printing time required for the fuselage, compounded by the reliability issues of the available 3D printers. On occasion, the printers were in use for other team projects, limiting access to the equipment. A breakthrough occurred when it was discovered that the college possessed a Method X 3D printer, which proved to be faster and more reliable than the other MakerBot Replicator+ models available to students. However, despite this improvement, the printing time remained excessive, and the extruder—responsible for melting and guiding the material to form the models—frequently jammed. This issue resulted in multiple reworks and faulty prints, further delaying an already constrained project timeline. To mitigate these delays, a team member would remain near the Method X printer for extended hours to ensure proper file processing and address any potential errors, serving as a preventative measure against extruder jamming.

Another challenge arose when our lead circuit designer and expert were unable to attend meetings due to an unforeseen injury, resulting in fewer team members available to contribute to the project during that period. Despite this setback, the team demonstrated resilience and continued to make progress under increasingly stressful conditions.

Lastly, several electrical components and manufacturing machines experienced malfunctions throughout the project. Some components failed to operate as intended, while others exceeded the expected specifications. For example, during testing of the speed controller connected to the receiver, initial calculations indicated the need for a 22.2V battery. This voltage was determined based on the circuit design, as it was projected to provide sufficient power for the entire aircraft. However, this voltage led to damage to the receiver. It took several days to order and receive a replacement, during which time power requirements were recalculated. A fellow student, who had encountered a similar issue with their own circuit, suggested using a 9V battery.

Educational Outcomes

To assess changes in engineering self-efficacy, a 15-item Likert-scale survey [19-21] was administered to four students both before and after completing the SAE Micro-Class capstone project, as shown in Table 1. It presents a set of 15 Likert-scale survey statements that were used to assess changes in engineering self-efficacy among the four students who participated in the capstone project. These items were selected to cover a broad range of competencies necessary for successful participation in a multidisciplinary engineering design project. The statements focus on core engineering principles, systems integration, technical tool proficiency, communication skills, project management, and interdisciplinary collaboration—all of which are key components of the student learning experience in the capstone project.

The survey results were collected both before and after the completion of the project to gauge how the students' self-assessment of their engineering abilities evolved through the process. This approach provides a clear picture of how the capstone project contributed to their development of specific skills and their overall confidence in handling engineering challenges.

Table 1. Pre/Post Survey Statements applied in the project

Item	Question/Statement
1	I can apply core engineering principles (e.g., mechanics, fluid dynamics, thermodynamics, and electronics) to solve real-world design challenges.
2	I understand how to effectively integrate mechanical, electrical, and aerospace systems into a cohesive aircraft design.
3	I feel confident using technical tools such as CAD software, flight simulation platforms, and prototyping equipment to support design and testing activities.
4	I am comfortable collaborating and contributing in a multidisciplinary engineering team environment.
5	I can clearly communicate technical concepts through written reports, oral presentations, and visual design materials.
6	I understand how to balance competing design constraints and make informed trade-offs between factors like weight, performance, and structural integrity.
7	I am familiar with industry-standard practices and procedures for aircraft design, fabrication, and testing.
8	I can plan and manage time, tasks, and resources effectively across the lifecycle of a long-term engineering project.
9	I feel well-prepared to enter the professional engineering workforce and contribute meaningfully in technical roles.
10	I am confident in analyzing test results, assessing design performance, and using feedback to drive iterative design improvements.
11	I can evaluate the feasibility of multiple design concepts and select solutions based on analysis, data, and stakeholder input.
12	I understand how to apply safety, regulatory, and ethical considerations within the context of an aerospace engineering project.
13	I can lead or support structured design reviews and justify design decisions using quantitative analysis and engineering reasoning.
14	I am capable of documenting engineering work in a format suitable for technical audiences, including competition judges, instructors, and industry professionals.
15	I have developed a deeper appreciation for the value of interdisciplinary collaboration in solving complex engineering problems.

Figure 10 presents a comparison of pre- and post-survey mean scores across 15 Likert-scale items designed to assess engineering self-efficacy. Error bars indicate the standard error of the mean (SEM). The post-survey results demonstrate consistent improvement across all items, suggesting a positive educational impact from participation in the SAE Micro-Class capstone experience.

Figure 11 depicts individual pre- and post-survey response trends for each of the four participating students. Dashed lines represent pre-survey scores, while solid lines indicate post-survey scores. All students exhibit upward trends across the majority of items, reflecting increased confidence and perceived competence in both technical and team-based engineering tasks.

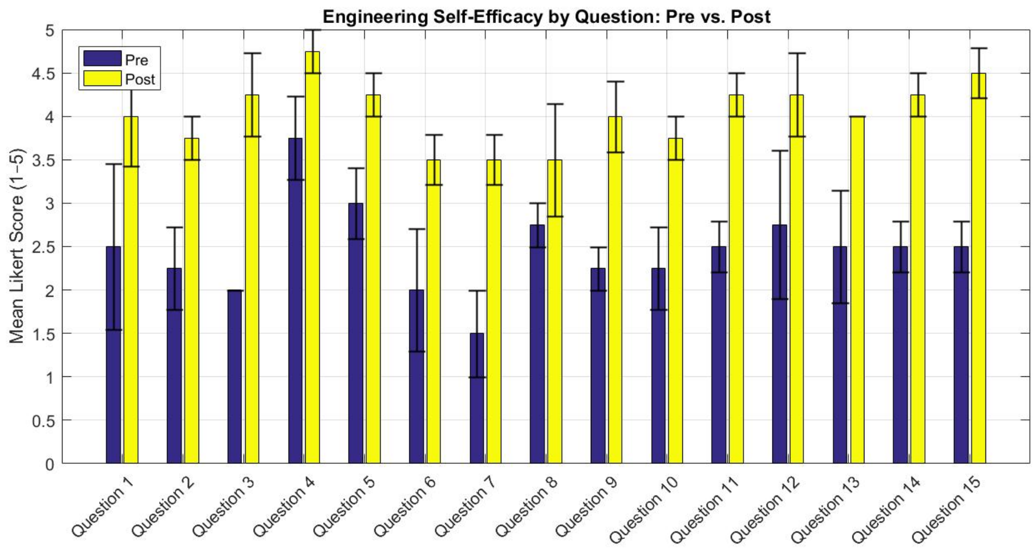

Figure 10. Mean Likert Score of Survey

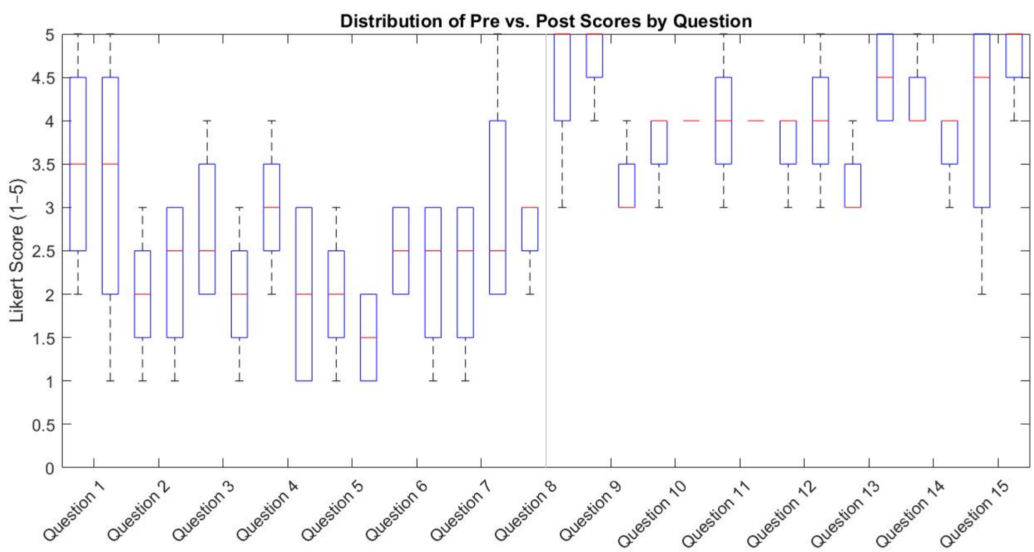

Figure 11. Distribution of Mean Likert Score

The findings presented in Figures 10 and 11 further validate the use of competition-based frameworks as effective pedagogical tools for enhancing engineering self-efficacy. The data show significant improvements in various areas, particularly in the integration of mechanical, electrical, and aerospace systems, as well as technical communication and collaborative skills, contributing valuable insights to the engineering education literature. The results demonstrated a consistent and substantial improvement across all items, with the average pre-survey score increasing from 2.47 to 4.03 on a 5-point scale. Notable gains were observed in specific items, including questions 3, 7, and 15, with several items showing an increase of more than 2 full points. These findings suggest that the competition-based, multidisciplinary learning environment significantly enhanced students' perceived engineering competencies. This supports the value of incorporating hands-on, real-world challenges into senior design curricula to foster engineering self-efficacy.

The highest changes observed in self-efficacy scores are particularly noteworthy. Question 3, which focuses on confidence in using technical tools such as CAD software, flight simulation platforms, and prototyping equipment, showed a significant change of 2.25. This demonstrates that the project had a notable impact on students' technical capabilities and their confidence in utilizing these tools to support design and testing activities—key aspects of aerospace engineering.

Question 7, which focuses on familiarity with industry-standard practices for aircraft design, fabrication, and testing, exhibited the largest improvement, with a change of 2.0 (Post - Pre). This suggests that students gained considerable confidence and expertise in understanding professional engineering processes, likely due to the hands-on nature of the project and its alignment with real-world industry standards.

Similarly, Question 15, which addresses interdisciplinary collaboration, showed a change of 2.0, underscoring the importance of team-based activities in engineering education. The project appears to have fostered a greater appreciation for the value of cross-disciplinary cooperation in solving complex engineering problems—an essential skill in modern engineering environments.

Furthermore, several other questions showed substantial improvements, including Questions 1, 2, and 14, each showing a change of 1.75. These results highlight the effectiveness of the competition environment in enhancing students' abilities not only to lead and make decisions but also to communicate their ideas effectively to diverse technical audiences, including competition judges and industry professionals.

Other notable changes include Question 6 (balancing competing design constraints), which also showed a change of 1.5. These results reflect the ability of students to connect theoretical knowledge with practical application in a design environment.

The outcomes of this project align with research suggesting that project-based learning and real-world applications, such as SAE competitions, provide students with opportunities to develop critical skills that are often challenging to teach through traditional classroom methods alone. These findings support the integration of competition-based projects in capstone courses, which can help students build the technical and interpersonal competencies required for success in the professional engineering workforce.

Conclusion

By the end of the project, the team demonstrated significant growth across various dimensions of self-efficacy, including problem-solving, technical competency, and teamwork. This SAE student competition project not only resulted in a functional, competition-ready micro-class airplane, but also served as a powerful model for integrating key engineering education practices into a hands-on, multidisciplinary project. The experience provided students with a deep understanding of how to manage complex systems and solve engineering problems in a collaborative environment.

The capstone project allowed the students to apply theoretical knowledge to real-world engineering challenges, particularly in the areas of aerodynamics, weight distribution, and structural integrity. Through the iterative process of design, prototyping, and testing, students were able to experience firsthand the dynamic nature of engineering design, where theory and practice often diverge. This process enhanced their critical thinking skills and gave them the confidence to make informed decisions when faced with complex trade-offs.

In conclusion, the SAE Micro-Class project served as a powerful example of how capstone design projects, particularly those involving real-world competition, can play a transformative role in preparing students for the engineering workforce. By promoting systems integration, enhancing technical communication, and fostering effective teamwork, this project exemplifies how multidisciplinary projects can holistically enhance engineering education, ensuring that students are not only prepared to solve complex technical problems but are also equipped with the skills needed to collaborate and innovate in a professional setting.

Acknowledgement

The team would like to express their sincere gratitude to the American Society for Engineering Education (ASEE) for hosting this conference and facilitating the publication process. We also extend our thanks to the Society of Automotive Engineers (SAE) for providing the project specifications that guided our work. Special appreciation is extended to Dr. Ali Dinc and Dr. Iftekhar Basith for their invaluable supervision and guidance throughout the duration of the project and to Mr. Kevin Von Rosenberg for his supervision of woodcutting and outreach efforts.

References

[1] R. Bellitto, K. Blackstock, C. Blomquist, M. Umbricht, David J. Olinger, and Jagannath Jayachandran, “A high performance aircraft for the 2020 WPI UAV competition,” report, Apr. 2020.

[2] B.M.S COLLEGE OF ENGINEERING, “SAE AERO DESIGN WEST – 2015,” 2015.

[3] S. T. Sorensen, A. Hopman, M. Petersen, R. Basko, and S. Ochsner, “SAE Aero Design East: BYU-Idaho Aero Team 326 – Final Report Document,” SAE Technical Papers on CD-ROM/SAE Technical Paper Series, Jul. 2017, doi: 10.4271/2017-01-6000.

[4] A. Bushehri, F. Al-Sarraf, A. Al-Ali, A. M. A. Al-Saidi, and A. Al-Ruwayeh. “Preliminary design, sizing and flight performance calculations of a Radio-Controlled aircraft,” Capstone Project. 2021

[5] A. Dinc, Preliminary Sizing and Performance Calculations of Unmanned Air Vehicles, in: T. Shmelova, Y. Sikirda, N. Rizun, D. Kucherov, K. Dergachov (Eds.), Autom. Syst. Aviat. Aerosp. Ind., IGI Global, 2019: pp. 242–272. https://doi.org/10.4018/978-1-5225-7709-6.ch009.

[6] J. Ni, “SAE Aero Cargo aircraft Design Report,” Michigan Technological University, Feb. 2011.

[7] A. Dinc, Sizing of a Turboprop Unmanned Air Vehicle and its Propulsion System J. Therm. Sci. Technol., vol. 35, pp. 53–62, 2015.

[8] B. Czapor, SAE Aero Design Rules. 2024.

[9] A. Dinc, Y. Gharbia, A. Bushehri, F. Al-Sarraf, A. Al-Ali, A. M. A. Al-Saidi, and A. Al-Ruwayeh, "A sizing tool for the preliminary design of an unmanned aerial vehicle for student projects," Int. J. Res. Publ., vol. 77, no. 1, pp. 68–72, 2021, doi: 10.47119/IJRP100771520211951.

[10] C. Miller, E. Perleberg, Z. Simmons, and The Prop Dogs, “NAU Mechanical Engineering Senior Capstone SAE Aero Micro Design Final Report,” report, Apr. 2020.

[11] A. Dinc, Y. Gharbia, M. Alshammari, A. Alrasheedi, S. Alqallaf, M. Alibrahim, S. Alobaid, Preliminary design of a radio-controlled micro aircraft for student competition, Glob. J. Eng. Technol. Adv. 2020 (2020) 64–069.

[12] A. Cárdenas, A. Patel, and N. Paz, “EML 4905 Senior Design Project,” 2014.

[13] D. Fox Jr., W. Landacre, C. Peterson, S. Stuart, and G. Tokuyama, “Team 21 – SAE Aero Design Micro Class.”

[14] A. J. Frewin, A. B. Wilson, D. D. Celaj, H. L. Cummings, M. A. Oswald, and Worcester Polytechnic Institute, “Design of an MAV for the 2019 SAE Aero Design Competition,” 2019. [Online]. Available: https://digitalcommons.wpi.edu/mqp-all/7034

[15] J. Lojek, J. Koryan, J. Sommer, R. Ghaly, and Stevens Institute of Technology, “2007 SAE Aero Design East Report,” May 2007.

[16] B. Waller, D. Chandpen, J. Travaglini, M. Maberry, T. Cushman, and Z. Veilleux, “Design, construction and testing of a remote Operation Heavy-Lift model aircraft,” May 2013.

[17] D. Raymer, Aircraft Design: A Conceptual Approach, Sixth Edition. Washington, DC: American Institute of Aeronautics and Astronautics, Inc., 2018.

[18] M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.

[19] R. C. Chong, "Examining the Relationship of Active Team-based Learning and Technology and Engineering Students' Research Self-efficacy in a Cybersecurity Traineeship Class," *Proc. 2019 ASEE Annual Conf. & Exposition*, Tampa, FL, USA, Jun. 2019, Paper 32783. [Online]. Available: https://doi.org/10.18260/1-2--32783.

[20] R. P. Bringula, "Development of capstone project attitude scales," *Educ. Inf. Technol.*, vol. 20, pp. 485–504, 2015. doi: 10.1007/s10639-013-9297-1.

[21] M. Khan and M. Ibrahim, "Impact of Project-based Learning on Self-Efficacy of Students in Engineering Modeling and Design Courses," *2019 IEEE Integrated STEM Education Conference (ISEC)*, Princeton, NJ, USA, 2019, pp. 281-286, doi: 10.1109/ISECon.2019.8882059.