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Work-in-Progress: Enhancing the Student Experience in an Aerospace Engineering Program

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Introduction

There is a critical need to broaden participation in Aerospace Engineering to meet the growing demand [1], [2], [3]. As the scope of aerospace engineering expands to include cross-disciplinary advancements in areas ranging from environmental sciences to public health, enhancing the participation and retention of students is crucial to addressing global challenges in these areas. Achieving this goal necessitates large-scale reforms across all stages of the educational pathway, including identifying and mitigating the obstacles faced by students throughout their journey.

Some of these obstacles are well known, such as the large and prescriptive curriculum in many aerospace programs. A contributing factor is that the continual growth of course content and tools taught to students (and budgetary concerns) has often led to a reduction in experiential learning (lab assignments, experiments, hands-on projects) in courses. The time demands on students today, especially as more students are working 20+ hours per week to pay for school and/or support their families, are also a known problem. In addition, we know that student interactions with peers, staff and faculty are not always positive – particularly for women and non-white students.

One important aspect within aerospace engineering education is the student experience within the Aerospace Engineering department. A first step is to view this experience through a lens of students' sense of community [4], [5], as it has been shown to support student retention. One proven approach to increasing a student's sense of community is experiential learning [6], [7]. Be it undergraduate research, co-curricular student activities like design competition teams, or course-based activities, hands-on experience has proven to help students feel they belong. That motivated an attempt to increase the number of experiential learning opportunities available to our students, both inside and outside of the classroom.

Implementation

We began by soliciting feedback from all stakeholders in the Aerospace Engineering program at The Ohio State University. The feedback covered all aspects of the program and the student experience. After collating the feedback, the program began to design and implement changes. The process began in the two areas easiest to impact – the curriculum, and the facilities for experiential learning.

Curriculum

The curricular changes began after the previous cycle of ABET accreditation (in 2017) indicated that the program would benefit from additional space content. This opinion was shared by the External Advisory Board, the faculty, and the students so there were no groups resisting the change. Surveys of recent cohorts of students had shown a shift towards a majority enrolling in the major due to space rather than due to aircraft which had traditionally dominated. The growth of commercial space (SpaceX, Blue Origin, etc.) had changed what attracted our students, and we acknowledged the need to adjust our curriculum to better fit their interests. The old curriculum had a 2-semester sequence of introductory aerospace engineering courses in the second year (purple blocks in Figure 1: Top), with the first one focused on thermodynamics, aerodynamics, and aircraft performance while the second semester introduced stability and control, and propulsion. The new curriculum dropped the second course entirely (Figure 1: Bottom), moving the content into the later courses on those subjects. The first course on flight vehicle dynamics was then moved up from the third year to the second year and replaced with a course on foundational astronautics in the third year (Figure 1: Bottom). In addition, most of the aircraft performance material was removed from the first introductory course and replaced with five weeks of orbital mechanics and rocket propulsion content.

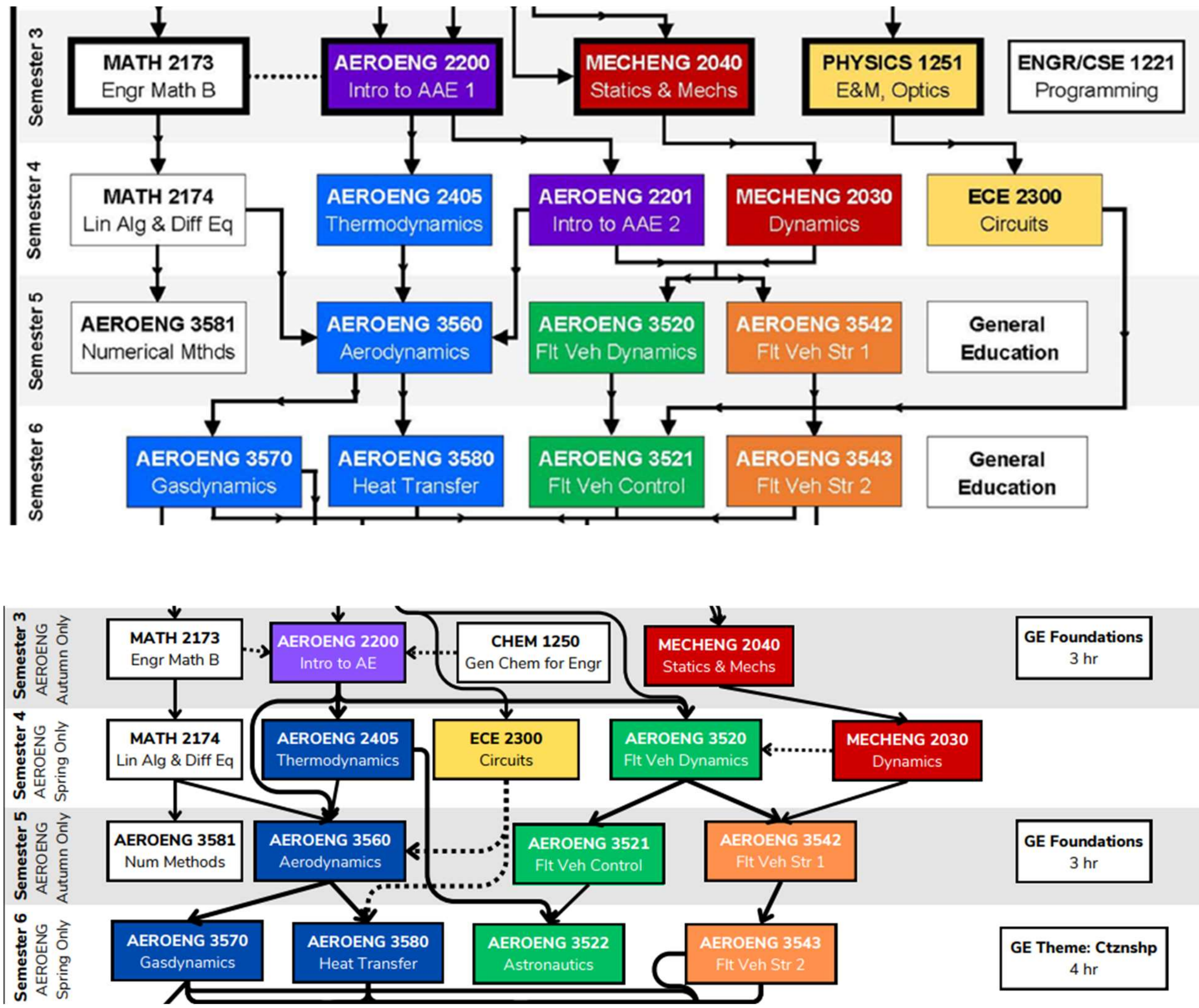

Figure 1. Top: A section of the "old" Aerospace Engineering Curriculum (Pre-2023) with two introductory courses (purple) on aerospace engineering: 2200 and 2201, with first exposure to flight mechanics and control (3520) appearing in the third year.
Bottom: Revised version, put into effect in 2023, with the second in the two course introductory sequence removed, allowing 3520 to move up to second year, and a dedicated course on foundational astronautics in the third year (3522).

A second aspect of the curriculum that students and academic advisors pointed out as a problem was the technical elective courses. The old curriculum required 3 courses of 5000-level (or higher) in the major or from Mechanical or Nuclear Engineering, both of which are part of our department. Aerospace Engineering would only offer ten 5000-level courses, so this was a limited pool to choose from especially since offerings depend on faculty availability. Any other course required a petition to the department to be counted. This resulted in many petitions every year, often for the same courses, translating to a significant amount of wasted time for the academic advisors and frustration among students. In addition, the faculty recognized that aerospace engineering is increasingly becoming an interdisciplinary field with electrification of propulsion and control systems (Electrical and Computer Engineering), autonomy and cybersecurity (also ECE, and Computer Science and Engineering), advanced materials and structures (Materials Science, Mechanical Engineering), and a broad range of fields of application (remote sensing, disaster management, bioengineering, modern agriculture, policy, etc.) that make courses in other branches of engineering and science relevant. In recognition of this, the program director went through the list of courses currently offered by every department in the College of Engineering. Every course that an Aerospace Engineering student might qualify to take (pre-requisites met) and was a high enough level (generally 5000-level, but some lower courses also) was added to the list of pre-approved courses – a total of 81 additional choices. In addition, the courses are listed both by department and by 18 focus areas that might be easier to understand for students looking for course (examples include Artificial Intelligence, Green Aviation, Machine Learning, Professional Skills, Policy, and Space Travel).

Experiential Learning Facilities

The Aerospace Engineering program at The Ohio State University takes pride in its reputation for experiential learning. It has long been a programmatic strength and is strongly supported by the External Advisory Board, faculty, alumni, and students. Unfortunately, the opportunities for quality experiential learning had decreased over the years for several reasons. The student body is growing faster than the faculty size is, leaving everyone stretched a bit thin and lacking the time to teach and grade lab assignments. The pandemic caused financial disruptions that reduced the availability of teaching assistants. In addition, the passing of the years had resulted in older equipment which did not always work properly placed in dimly lit rooms that needed to be renovated. The student dissatisfaction with existing lab assignments led some faculty to remove the assignments from their courses, resulting in even fewer experiential opportunities.

Feedback from students supported an increase in lab assignments, but only if paired with improvements to the facilities. Coincidentally, the College of Engineering was deciding at about the same time that it needed a centralized makerspace available to all students in the college. The location they chose was most of an entire hallway of academic lab space that was used by Aerospace Engineering but was being underutilized. This could have been viewed as a problem, but the Aerospace Engineering program chose to seize the opportunity. The college provided some funding for basic renovations (fresh paint, some new lights, addition of infrastructure AE had in their previous labs like shop air) to two large rooms and paid to remove one large wind tunnel and move another one down the hall to the new lab space.

This left the Aerospace Engineering program with an essentially blank slate to plan what we wanted our experiential learning facilities to look like. The goals were to retain all existing capabilities while adding those that would best support the curriculum while not being duplicative of existing facilities in research labs. The process began by deciding that one room would ideally be used for group work, both class projects and co-curricular student organizations that build vehicles for competition (like Design/Build/Fly, Buckeye Space Launch Initiative, etc.). The larger room would be utilized for course-based labs and capstone projects.

Mapping where the large pieces of equipment could fit in the lab room opened the idea of keeping the high bay half of the room primarily as flex space. The 20' x 60' long portion contained a 5' diameter fan from the old wind tunnel but otherwise had no fixed infrastructure. Due to the recent growth in drones, it was decided to enable indoor drone flight in this space. The key to the flex space was having casters on all the workbenches and chairs, so everything could quickly be moved out of the space when it was needed. Beyond that, the lab room effort focused on finding spaces along the walls for the necessary cabinets and shelving units so that it was ready to hold classes the next semester (this all had to be done over one summer).

After meeting the bare minimum of being able to run all the existing course labs, the program next sought input on how best to improve the space. Every member of the Aerospace Engineering faculty was given an individual tour of the two rooms, and the current capabilities of the lab room were explained. Then the discussion moved to how the lab room could better support their courses. What equipment would they suggest purchasing? What types of lab assignments interest them? What level of personnel support would they need to add experiential learning to their courses? The end result of these discussions was a prioritized wish list for new equipment based on broadly useful any one item was and how many courses it could serve. In addition, a faculty member was designated to manage the lab space and facilitate various courses using it. That could also include duties traditionally covered by teaching assistants (equipment setup, testing, running the lab, grading) if the course does not have one.

Because the Department and College value the undergraduate experience and want to increase opportunities for experiential learning (because of its benefits for all students, but especially those who are less sure about remaining in the major), it supported the lab renovation project with dedicated fundraising efforts led by the Office of Advancement. This approach allows alumni to help defray the costs of new equipment while strengthening their bonds with the program. Donations allow the program to purchase new equipment and implement it over time rather than trying to do it all at once but also provide a steady supply of funds that we know will be there.

The program had a strength in aerodynamics equipment in the lab facilities already. Though future additions are planned, especially re-installation of the supersonic wind tunnel, the focus was put on areas within the discipline where the program was lacking equipment and the instructors were eager to add experiential learning activities to their courses. The first two areas of focus were controls and space, as seen in the list of equipment added so far in Table 1. The most challenging area has been structures, as there are not as many choices for equipment that make sense for undergraduate labs and allow for labs the students will enjoy (unlike the old labs with strain gages on bars and such).

The innovative aspect of the process is that after starting to gather donations, the next step was to involve the undergraduate students in improving the infrastructure. An uncrewed aircraft system (UAS) research group was formed with a small seed grant in February 2025. A mid-semester solicitation yielded 40 inquiries about joining the unpaid research effort, with about 30 joining for weekly meetings. Part of the effort was for sub-teams in the group to design and build their own drones that could be used for outdoor research, but would also be used by future capstone teams and potentially in other courses (flight vehicle controls, etc.). After hearing about their success in the first few months, including helping acquire data at a prescribed wildland fire, the department chair requested a special flyoff event to demonstrate their vehicles as well as the new lab space. While the students continue building and refining their drones, they also are assembling and testing an indoor GPS-replacement system for vehicle tracking. Rather than an expensive motion-capture camera system, this system uses small ultrasonic beacons and sensors that can be flown on drones. The students have not only gained confidence and skills from the research group, but they show great pride in knowing that other students will benefit from their efforts directly.

Table 1. Additional lab equipment added so far

Equipment	Uses
New lab computers	All lab courses and capstone
Computer with GPU processor	Hi-fidelity simulations, machine learning
Inverted pendulums (set of 6)	Controls courses, capstone projects
6 DOF gyroscope	Controls and spacecraft dynamics related courses, capstone projects
Wi-fi enable electro-optical telescope for mapping space objects in LEO	Orbital mechanics courses, machine learning, capstone projects
Flight simulators	Flight vehicle dynamics courses, flight test course, capstone projects
Ultrasonic indoor tracking system	Controls and robotics related courses, capstone projects, research
Student-built drones	Controls, robotics, and autonomy related courses, capstone projects, research

The only available results at this stage are anecdotal. Student usage of the lab space has increased dramatically, especially in spring with capstone teams using the room in addition to course labs and student organizations. Four student design competition organizations work in the space, with at least 15 hours of scheduled meetings per week after normal class hours and on weekends. In addition, several students have worked on personal projects in the evenings or on weekends. Students are now inquiring whether additional opportunities will arise to work in the space over summer despite it lacking air conditioning. Experiential learning opportunities have been added to four courses, with at least three more courses planned for next year based on the current hardware available. Student response to the experiences has been very positive with request for even more.

Next Steps

While the infrastructure improvements are an ongoing process, the program has considered the next steps to take. After addressing the curriculum and the experiential learning opportunities, the program needs to consider other aspects of the student experience. This has begun by surveying students about their sense of community within the Aerospace Engineering program and in the College of Engineering, but it requires multiple cohorts to form a definitive picture. A small group of faculty have submitted a proposal for federal funding to complete this work in detail. If funded, the work should help elucidate the aspects of the student experience that need the most improvement and what components of the hidden curriculum are associated with them.

In addition, the impact of adding experiential learning opportunities on student achievement of learning goals should be studied. As laboratory assignments are added to additional courses, the effects can be studied. Longer term impacts may also be noticeable by student performance in internships, research labs, or later courses.

Conclusions

The student experience should be one of the primary concerns of any aerospace engineering program. There are currently many barriers to student success that prevent the broader participation that the industry needs to fill the workforce. While some of these may be beyond our control, there are some obvious obstacles we can remove. Removing unnecessary pre-requisites and restrictive technical elective programs makes the course registration process easier for students and academic advisors. Adding experiential learning opportunities helps students gain confidence and learn better, but it is also important to consider the quality of the experience. A fresh coat of paint and some new lighting can make an old lab look almost new, and both the students and the faculty respond better to the improved space. It is easy to neglect the infrastructure of undergraduate academic labs, especially in these turbulent times for academia with economic uncertainty on many fronts. But our alumni want to feel tied to their alma mater and often relish seeing directly how their contribution is helping students. Combining that with the energy of students eager to contribute increases everyone’s sense of investment in the department and improves their experience.

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