Hands-on Learning Modules to Increase Community College Students' interests in Aerospace Engineering

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Abstract

The U.S. aerospace industry faces a critical talent shortage due to aging workforce, increased retirement rates, and fewer skilled STEM professionals in training. This industry is especially vulnerable because it relies heavily on advanced technical talent to support complex missions and foster innovation. It is essential to increase the number of graduates in STEM fields, especially in Aerospace Engineering field. With the support from NASA, Del Mar College partnered with Texas A&M University-Kingsville to develop and implement a series of hands-on learning modules aiming to increase students' interests in Aerospace Engineering and the number of students pursuing Aerospace related majors, which would create a talent pipeline for the aerospace industry. Most of the hands-on learning modules were created by integrating NASA-relevant concepts or contents with existing kits available in the market. In the last three years, ten different learning modules were implemented in seven different Del Mar College courses, which impacted more than 600 community college students. In this paper, the detailed design of each learning module is introduced. Each learning module normally lasts one to two weeks allowing required processes to be completed by the students. The implementation process of the learning modules in different classes is also discussed. The authors collected students' feedback after they completed the learning modules, which focused on the learning modules' impacts on students' interests in Aerospace Engineering. In addition, the authors collected student data, including GPA (before and after completing the learning modules), course grades, retention rate, and graduation rate and timeline. This paper presents a comprehensive analysis of students' feedback on different learning modules and students' academic performance before and after completing the learning modules. A group of Del Mar College students who were from the same departments but did not participate in the learning modules are used as a control group in analysis the impact of the learning modules. The results show that most learning modules had positive impacts on both students' interests in Aerospace Engineering and students' academic performance. However, the impacts vary among different learning modules, which may be related to the module itself or the way the module was implemented. Finally, the authors share the lessons learned during the last three years related to module implementation and continuous improvements.

Project Background

In late August 2021, Texas A&M University Kingsville (TAMUK) and Del Mar College (DMC) received a NASA grant, which supported classroom activities and materials with NASA-relevant content, student summer research internships, career readiness through paid internship opportunities, and outreach initiatives such as high school campus visits and industry webinars. The proposal was submitted to NSF because U.S. aerospace sector faces persistent talent constraints due to retirements, an aging workforce, and competition for skilled STEM workers. U.S. Bureau of Labor Statistics (BLS) projects aerospace engineer employment to grow 6% (2024–2034) with about 4,500 openings/year, largely driven by replacement demand [1]. STEM occupations overall are projected to outpace average job growth over the decade [2]. Industry studies indicate continuing hiring and retention challenges with 76% of firms reporting sustained

difficulty hiring engineers, and attrition remains near 15% [3], [4]. National indicators show the STEM workforce totals 36.8 million (24% of U.S. workforce), and more than 50% of those workers lack a bachelor's degree, underscoring the role of community colleges in the talent pipeline [5]. Early success metrics of persistence and retention are improving nationally: for the fall 2022 cohort, first-year persistence reached 76.5% and retention 68.2%; community colleges recorded 55.0% retention—highest gain in a decade [6]. Targeted support can yield strong effects; one two-year college program achieved 87% quarter-to-quarter persistence vs. 67% for a matched cohort [7].

Del Mar College is a designated Hispanic-Serving Institution (HSI) in south Texas with approximately 71% Hispanic enrollment and 91% local residency [8]. Texas A&M University Kingsville similarly serves a diverse, regionally rooted student population Embedding NASA-aligned, hands-on modules into core courses at these institutions respond to national workforce signals while advancing regional equity and transfer outcomes [9].

Learning Modules Design and Implementation

The project team designed a series of NASA-aligned learning modules for both high school and community college students. A comprehensive list of modules was shared with participating teachers and faculty, who selected options that best aligned with their course objectives and student needs. Each module featured hands-on activities and included detailed instructions for both educators and learners. To support successful implementation, the project team supplied all necessary materials and provided video tutorials for selected activities.

The project offered seven core types of learning modules, each with multiple engagement options, resulting in a total of 20 choices:

1. Design an Artemis II mission patch using 2D CAD software.
2. Space launch system modeling with 3D CAD drawings (two variations).
3. Recycled bottle rocket constructed from household items.
4. Solar system representation using everyday materials.
5. Commercially available kits enhanced with additional hands-on activities (13 options, ranging from paper airplanes to drones and from rockets to robotic cars).
6. Aerospace engineering video report based on 16 curated videos.
7. Aerospace engineering magazine report using five selected magazines.

This study centers on Del Mar College, a key community college partner, to evaluate the impact of learning modules on STEM students' interest in aerospace engineering and their academic performance. Located in Corpus Christi, Texas, Del Mar College is a comprehensive institution serving a diverse student body, including a large proportion of Hispanic and first-generation college students. The college offers a wide range of academic and technical programs and plays a critical role in preparing students for transfer to four-year universities and careers in STEM fields. Over the four-year project, nine DMC instructors participated, bringing expertise in engineering, engineering technology, computer science, geographic information systems, artificial intelligence, and mathematics. More than 600 students engaged with the learning modules, most of which were integrated into required coursework and aligned with established student learning objectives.

This paper presents the detailed design and implementation of five selected courses and their associated learning modules. Each course was taught twice by the same instructor, once with the learning modules integrated and once without, to enable a comparative analysis of the

modules' impact. Most activities were assigned as group projects to promote teamwork, problem-solving, and communication skills. The five courses were as follows.

- ITSE1329 Programming Logic and Design
  This pre-programming course introduces structured problem-solving techniques and algorithm representation using design tools. Students learn to create hierarchy charts, flowcharts, pseudocode, and explore basic Python concepts. As part of the learning module, a commercial robot car kit is incorporated into the course. Students assemble, program, and test robot cars, simulating their role as landing units in a space mission project.
- COSC1437 Programming Fundamentals II
  This Level II programming course uses C++ to introduce fundamental algorithm analysis, searching and sorting techniques, and an overview of software engineering processes. As part of the learning module, students participate in a 50-minute webinar presented by a NASA systems engineer. Following the session, students complete a set of questions and write a reflective summary addressing topics such as deep space travel challenges, verification and validation processes, hardware and software testing, the role of artificial intelligence in space missions, and essential engineering soft skills. Figure 1 below displays a webinar presented by Mr. Salazar, a lead systems engineer at NASA.

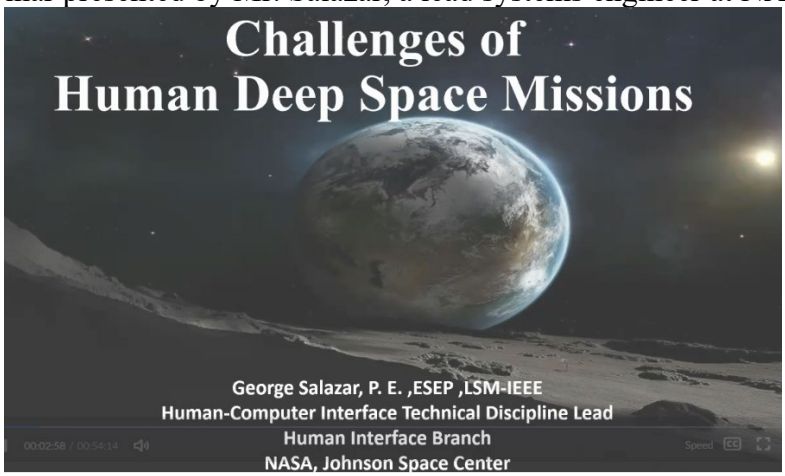

Figure 1. A Webinar Presented by Mr. Salazar, Lead Systems Engineer, NASA.

- ENGR1201 Introduction to Engineering
  This course introduces engineering as both a discipline and a profession, emphasizing the application of mathematical and scientific principles to solve practical problems for societal benefit. As part of the learning module, students worked in teams to assemble and launch two types of rockets, water powered and solid fuel, using kits provided by PITSCO Education. The hands-on project enabled students to connect engineering principles with real-world aerospace applications. Figure 2 below was taken in the DMC Engineering Lab while students worked on their rocket projects.

Figure 2. Hands-On Rocket Projects in the DMC Engineering Lab

- ENGR1304 Engineering Graphics
  This course introduces essential engineering graphics concepts, including sketching, geometric constructions, multiview projections, and CAD modeling, equipping engineers to interpret and create these essential technical visuals. The learning module included designing a patch logo for Artemis mission or modeling a space launch system using AutoCAD. These projects provided opportunities for students to practice technical visualization skills while engaging with NASA mission themes. Figure 3 below shows students' drawings and models from the Engineering Graphics class.

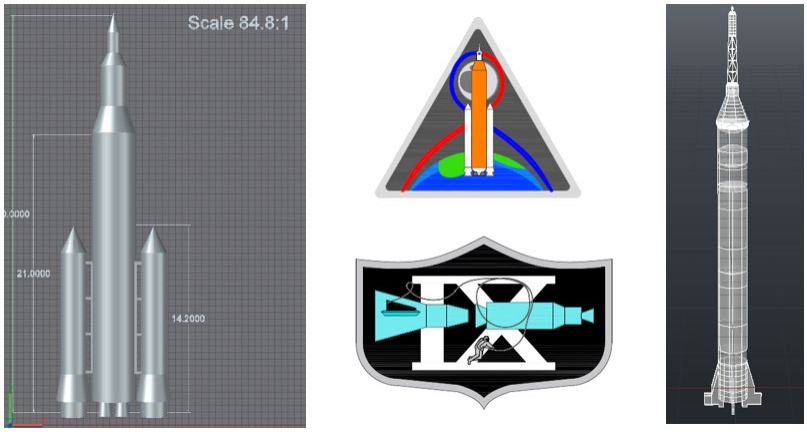

Figure 3. Examples of Student Work from the Engineering Graphics Class.

- GISC1372 Introduction to Artificial Intelligence
  This course provides a broad overview of Artificial Intelligence (AI) with its application to a variety of industries. The use of unsupervised and supervised machine learning for creating AI solutions is explored. The ethical collection and use of data is explained and demonstrated. The module projects included mapping NASA space facilities and integrating the new ChatGPT AI bot into research projects focused on Mars colonization.

In addition to embedding modules within college courses, the project expanded outreach efforts to local high schools. Del Mar College hosted six on-campus STEM and aerospace-focused camps at its Windward Campus, where 92 students participated in activities such as designing and launching rockets and building and flying drones. These outreach sessions extended the project's impact beyond college students and supported early engagement in STEM and aerospace pathways.

Learning Module Results

To assess the effectiveness of the learning modules, a set of survey instruments was developed, with one version tailored for instructors and a similar version for community college students who experienced the modules in their courses. The student surveys began with demographic questions and asked students to identify the learning modules they experienced. Other topics on the student survey included the following.

- Overall rating of the learning module.
- Likelihood to recommend the module to other students.
- Level of interest in the module.
- Whether the module aided the student in learning STEM concepts.
- Whether the module increased the student's interest in STEM.

By early summer 2024, the pool of student respondents for the modules had grown significantly. A total of 292 students accessed the survey, with 215 providing usable responses (some discontinued after completing only demographic questions). Overall, student ratings reflected strong satisfaction, with mean scores ranging from 7.50 to 9.15 on a ten-point scale. Students consistently strongly agreed that the modules increased their interest in STEM. Previous research has compared and analyzed both instructor and student responses and published those findings [10]. This paper focuses specifically on examining class performance and course-level outcomes associated with module implementation at Del Mar College. A brief description of implementation as follows.

The project received NASA funding in September of 2021. From spring 2022 through spring 2025, the learning modules were integrated into multiple courses within the Computer Science, Engineering, and Advanced Technology (CSEAT) Department at Del Mar College. Seven CSEAT faculty members and two faculty members from the Mathematics Department with Engineering background participated, incorporating modules into courses in engineering, programming, computer information systems (CIS), geographic information systems (GIS), and artificial intelligence (AI). These efforts impacted on more than 600 students. Beyond classroom activities, the project supported 12 DMC students in completing eight-week summer internships across four years at sites including Corpus Christi Army Depot, FAA Lone Star UAS Center of Excellence and Innovation, Southwest Research Institute (San Antonio and Utah locations), Horton Automatics in Corpus Christi, and the University of Texas at Austin through the Texas Space Grant Consortium. Additionally, six high school aerospace/STEM camps were hosted at the DMC Windward Campus, serving 92 students who participated in rocket-building, drone activities, and other hands-on projects.

As outlined in the previous section, five courses were selected for this study. Table 1 compares students' cumulative GPAs before and after completing each course. The "prior GPA" refers to cumulative GPA at the end of the preceding term, and the "after GPA" refers to cumulative GPA at the end of the target term. Each course was taught twice by the same

instructor, once with the learning modules integrated and once without, to enable a direct comparison of their impact. Figure 4 shows the comparison of GPA change (%) with and without learning modules.

Table 1: Comparison of students' GPAs before and after the courses

	Prior GPA	After GPA	GPA Change (%)
ITSE1329 with module	1.383	2.315	+41.85%
ITSE1329 without module	1.363	2.221	+21.45%
COSC1437 with module	2.837	3.121	+7.10%
COSC1437 without module	3.327	3.367	+1.01%
ENGR1201 with module	1.823	2.419	+14.88%
ENGR1201 without module	2.392	2.574	+3.86%
ENGR1304 with module	1.445	2.763	+32.96%
ENGR1304 without module	2.378	2.550	+4.08%
GISC1372 with module	3.199	3.247	+1.19%
GISC1372 without module	3.319	3.353	+0.84%

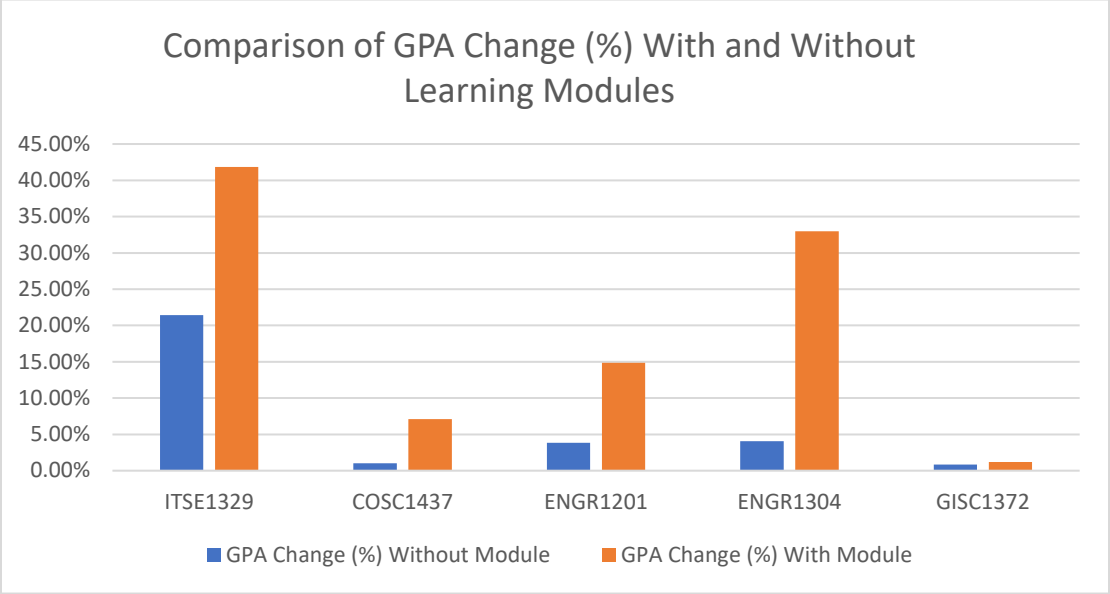

Figure 4: Comparison of GPA Change (%) With and Without Learning Modules

The data clearly demonstrates that courses incorporating learning modules produced greater GPA improvements compared to those without modules, suggesting a positive impact on academic performance. The magnitude of GPA improvement varied significantly across courses, suggesting that the effectiveness of learning modules may depend on both course content and student preparedness. Courses such as ITSE1329 and ENGR1304 showed the largest gains (+41.85% and +32.96%, respectively), likely because these modules introduced highly interactive, project-based activities that complemented foundational skills and boosted engagement among students with lower starting GPAs. In contrast, courses like GISC1372 and COSC1437, which had higher baseline GPAs, exhibited smaller improvements (+1.19% and +7.10%). This may indicate a ceiling effect, where students already performing well experience limited measurable benefit. Additionally, the complexity of the module and its alignment with

course objectives may influence outcomes; modules that directly reinforce core competencies appear to yield greater academic impact.

Table 2: Comparison of Courses' Retention Rates

	Enrolled	F Grade	W Grade	Retained	Retention Rate
ITSE1329 with module	17	5	3	9	52.94%
ITSE1329 without module	16	4	6	6	37.50%
COSC1437 with module	6	0	2	4	66.67%
COSC1437 without module	18	0	2	16	88.89%
ENGR1201 with module	11	0	0	11	100%
ENGR1201 without module	16	2	2	12	75%
ENGR1304 with module	5	1	1	3	60%
ENGR1304 without module	10	1	5	6	40%
GISC1372 with module	18	0	0	18	100%
GISC1372 without module	9	0	0	9	100%
Courses with modules	57	6	6	45	78.95%
Courses without modules	69	7	15	47	68.12%

In Table 2 above, for each section, retention was computed by total enrollment minus Grade F and W then divided by enrollment. The retention rate for course sections with modules was higher than for the sections without in three of the five cases, was the same for one, and was lower in one instance. When considered as a combined set, the overall retention improved with modules compared to those without modules at 78.95% vs. 68.12%. Attrition followed the same pattern, down from 31.88% to 21.05%. Withdrawals dropped substantially with modules. The modules appear to help students stay in the course (lower W's), which is often the most direct lever for retention. Effects on F's are smaller but still favorable. Some findings are:

- Strong gains in ENGR1201 (+25%), ENGR1304 (+20%), and ITSE1329 (+15.44%) suggest hands-on, project-based activities (rockets, graphics/CAD, robotics) likely increase engagement and course "stickiness," especially for cohorts with more modest baseline preparation.
- No change in GISC1372 (100% both ways) reflects a ceiling effect—retention can't improve when it is already perfect.
- COSC1437 shows lower retention with modules. It could be caused by the small section size with module (enrolled = 6) which one or two withdrawals materially shift the percentage. The module (webinar + reflection) may be less directly performance-reinforcing than build/test activities.

Due to course scheduling and faculty availability, not all participating faculty or their courses were included in the project every semester. Table 3 summarizes course enrollments and graduation counts for the five selected courses across terms.

It is important to note that graduation counts in Table 3 reflect only students who had completed their programs by the time of data collection (Fall 2025). Several module-integrated courses occurred in recent terms (2023–2024), so many students remain actively enrolled and pursuing their degrees. Therefore, these figures should be interpreted as preliminary rather than final graduation rates. A longitudinal follow-up is planned to capture the full impact of module participation on degree completion.

Table 3: Course Enrollment and Graduation

	Term	Enrolled	Graduated
ITSE1329 with module	2023FA	17	3
ITSE1329 without module	2024FA	16	1
COSC1437 with module	2023FA	6	3
COSC1437 without module	2023SP	18	8
ENGR1201 with module	2024SP	11	1
ENGR1201 without module	2021SP	16	2
ENGR1304 with module	2024FA	5	1
ENGR1304 without module	2021FA	10	6
GISC1372 with module	2024SP	18	7
GISC1372 without module	2024FA	9	5
Total Students		126	37

Across all sections, 37 of 126 students graduated, representing an overall graduation rate of 29.4%. Courses with modules show mixed graduation outcomes compared to those without. COSC1437 had the highest graduation ratio with modules (50%) versus without (44%), suggesting strong alignment of the webinar-based module with student persistence. ITSE1329 and ENGR1304 show lower graduation counts with modules, likely due to timing, as recent terms mean students are still enrolled and have not yet graduated. GISC1372 demonstrates strong graduation outcomes with modules (39%) compared to without (55%), though both are relatively high. These patterns indicate that graduation data should be interpreted cautiously because time-to-degree varies widely among community college students, and many students in recent module-integrated courses have not yet reached the point of program completion. A follow-up study is suggested to capture long-term trends.

Discussion and Conclusions

The findings from GPA, retention analyses, and graduation rate, combined with student survey responses, provide strong evidence that NASA-aligned, hands-on learning modules positively influence student engagement and academic outcomes in community college STEM courses. Across five courses examined, sections with modules consistently demonstrated greater GPA improvements compared to those without, with the most substantial gains observed in ITSE1329 (+41.85%) and ENGR1304 (+32.96%). These courses incorporated highly interactive, project-based activities, robotics and CAD modeling that appear to reinforce foundational skills promote active learning and increase students' sense of ownership over course content. In contrast, courses with higher baseline GPAs, such as GISC1372 and COSC1437, exhibited smaller or negligible gains. These results point to a likely ceiling effect among already high-performing students and underscore the importance of aligning module complexity with student readiness. The variation across courses also suggests that module type—highly applied versus reflective—plays a meaningful role in determining academic impact.

Retention analysis further highlights the benefits of module integration. Overall retention improved by 10.83 percentage points (78.95% vs. 68.12%), and attrition decreased by approximately 34%, driven primarily by a reduction in withdrawals. This pattern suggests that hands-on modules not only enhance academic performance but also help students persist through the term which is a critical factor in community college success. Notably, ENGR1201 and

ENGR1304 achieved retention rates of 100% and 60%, respectively, when modules were integrated, compared to 75% and 40% without modules. COSC1437 was the only course where retention declined with modules, likely due to small sample size and the module's reflective nature rather than performance-based engagement. In the future, the authors will consider incorporating applied coding tasks tied to webinar content to strengthen alignment with course objectives.

Survey data reinforce these quantitative findings. Students rated modules highly (mean scores 7.50–9.15 on a 10-point scale) and strongly agreed that modules increased their interest in STEM. These results align with prior research emphasizing the role of experiential learning in improving motivation, self-efficacy, and persistence in STEM pathways.

Overall, this study demonstrates that integrating NASA-aligned, hands-on learning modules into community college STEM courses can significantly improve student outcomes. Modules were associated with higher GPA gains, increased retention, and strong student satisfaction, particularly in courses where activities reinforced core competencies through tangible, project-based experiences. While impacts varied by course, the overall trend supports the effectiveness of experiential learning as a strategy to strengthen the STEM talent pipeline—especially for underrepresented populations served by Hispanic-Serving Institutions like Del Mar College, where such interventions can support equity and broaden participation.

Future work should focus on scaling these modules across additional courses and semesters, refining module design to ensure alignment with learning objectives, and conducting subgroup analyses to examine equity impacts—particularly for Hispanic and first-generation students. Incorporating performance-based components into reflection-heavy modules and expanding internship and outreach opportunities will further enhance the program's ability to prepare students for aerospace-related careers. Additionally, longitudinal tracking of graduation and transfer outcomes is essential to fully assess the long-term impact of module participation. Ultimately, these findings contribute to a growing body of evidence that authentic, hands-on learning experiences are a powerful lever for improving STEM education and workforce readiness at the community college level.

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