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# Analysis of Demographic and Experiential Interactions in Quantitative General Education

## USAFA Courses and Their Impact on STEM Attrition

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## Abstract

Science, technology, engineering, and mathematics (STEM) attrition occurs when undergraduates who are STEM-interested or initially declared STEM majors move away from these fields by switching majors or dropping out of college. This survey study examined this phenomenon at the U.S. Air Force Academy from the perspective of cadets who used to be STEM-interested or initially declared STEM majors and are graduating from non-STEM majors. The most impactful factors associated with STEM attrition were the accelerated pacing of instruction, the limitations in time and effort due to perceived excessive workload, and classroom experiences in Calculus I and II, General Chemistry I, and Mechanics Fundamentals. Cadets from certain demographic and socioeconomic groups reported experiencing significantly higher push factors away from STEM majors. The researchers discussed cadet recommendations to attract and retain STEM majors.

Higher education graduates with knowledge, skills, and abilities in STEM are essential for promoting innovation and economic growth as the United States faces many domestic and international challenges (Haslina & Karpudewan, 2019; Nadelson & Seifert, 2017), but universities are not graduating enough to meet current and future demands in federal, national defense, private, and nonprofit sectors (Iammartino et al., 2016; U.S. Government Accountability Office, 2018, 2022). The deficit of STEM professionals is especially a concern for the U.S. Department of Defense, including the U.S. Air Force and U.S. Space Force (DeLoatch et al., 2022; National Academies of Sciences, Engineering, and Medicine, 2015; National Research Council, 2010, 2012, 2014).

The availability of STEM graduates will depend on how many high school students decide to enroll in college to pursue these careers and how many complete a degree (Sithole et al., 2017; Xu, 2018). However, numerous academic and nonacademic factors influence enrollment and persistence, pushing students away from STEM careers (Funk & Parker, 2018; Malcom & Feder, 2016; Romash, 2019). STEM attrition is defined in terms of undergraduates who are STEM-interested or declared a STEM major but move away from these fields (Brewer et al., 2021; National Science Board, 2018; Seymour & Hunter, 2019; Singh et al., 2018). Leaving STEM is something that most students do not take lightly, as they need to weigh several extrinsic, intrinsic, and experiential factors (Chen, 2015; Chen & Soldner, 2013; Cohen & Kelly, 2020; Sjoquist & Winters, 2015; Wright, 2018). To better retain and graduate STEM-interested students, it is essential to consider how introductory STEM course structure is related to attrition.

Noncivilian postsecondary institutions also experience STEM attrition (Dwyer et al., 2020; O'Keefe et al., 2022, 2023). In the context of military academies, STEM-heavy academics provide the Armed Forces with the critical-thinking and quantitative-reasoning skills needed to fight increasingly technologically complex battles. However, questions remain about the perceived relative impact of academic and nonacademic factors leading to STEM departure.

## Purpose and Research Questions

This study examined factors linked to STEM attrition from the perspective of U.S. Air Force Academy (USAFA) cadets in the humanities and social sciences divisions (HSSD) who were initially STEM-interested or in the basic sciences and engineering divisions (BSED). There were several research questions:

1. To what extent were HSSD cadets interested in STEM majors in high school or as undeclared first-year USAFA students?
2. To what extent did cadets from HSSD initially choose STEM majors in BSED?
3. How did cadets rate the influence of conceptual understanding, final grades, classroom experience, time and effort invested in STEM coursework, and

instructor pacing in core STEM classes in their decision to switch to non-STEM majors?
4. Is there an association between the reported influence of academic and nonacademic factors in a cadet's decision to switch to non-STEM majors and demographic or socioeconomic variables?
5. What recommendations did cadets propose to attract and retain STEM-interested cadets?

The findings of this study can help the USAFA and other undergraduate programs develop and implement academic and nonacademic interventions to increase interest in STEM, improve student success in these majors, and minimize STEM attrition.

## Methodology

### *Participants*

During the fall 2022 semester, the dedicated survey and assessment time, USAFA sent a request to participate, a consent form, and a survey link to a random sample of 500 HSSD upper-level students. Of these, 187 agreed to participate in the survey, and the researchers included them in some of the analyses below (i.e., the "full sample"). The target sample of interest was obtained by excluding 35 cadets who reported never being STEM-interested nor originally majoring in STEM and 16 who submitted significantly incomplete surveys, resulting in 136 cadets for other statistical tests.

### *Survey*

The survey included three screening questions, asking whether the cadets had planned to major in STEM as high school students or undeclared cadets and wheth-

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er they declared a STEM major before switching to a non-STEM major. The following section asked cadets to rank 15 statements describing reasons that could have influenced their decision to declare a non-STEM major. The ranking used a Likert scale ranging from 1, representing factors that were not influential, to 10, for factors that were very influential in a cadet's decision to major in a non-STEM discipline. The statements referenced five STEM classes from the academy's core curriculum (Calculus I and II, Aeronautics Fundamentals, Mechanics Fundamentals, General Chemistry I, and Astronautics Fundamentals), subdivided into categories of classroom experience, understanding of the concepts covered in class, and final course grade. Additional ranking questions included broader factors of instructor pacing and invested time and effort.

The survey also asked cadets to recommend ways for USAFA to attract undecided cadets to declare a STEM major, allowing them to reflect on their own experiences and provide narratives to contextualize STEM attrition processes (Check & Schutt, 2012; Creswell, 2012). Finally, six demographic questions asked about a cadet's sex, race, ethnicity, preparatory school attendance (all of them, not just USAFA's), high school of origin, average annual family income, and whether participants were first-generation college students.

## *Analysis*

The quantitative ranking data were categorical, and sample sizes were small in a few cases. As a result, the researchers reported Kruskal-Wallis statistics when comparing three or more groups and Mann-Whitney U test, which follows a Z distribution, for pairwise comparisons and post hoc analysis. Due to the exploratory nature of this study, the researchers used a significance level ($p$-value) of 0.05 or less to balance the risks of Type I and Type II errors. The open responses were manually

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analyzed using thematic analysis (Braun & Clarke, 2021; Creswell & Creswell, 2018). This process included (a) reading the cadet answers multiple times, (b) searching for preliminary themes based on frequently used words or phrases, (c) applying a tabular format to identify codes and their corresponding quotations, and (d) reviewing the themes and quotations, revising as needed. The researchers selected representative cadet responses to illustrate the themes (Boyatzis, 1998; Saldaña, 2021).

## Results

### *Cadet STEM-Interest Before Declaring Non-STEM Majors (Full Sample,* n *= 187)*

The survey revealed that 139 of 187 (74%) of the participants began their STEM interest in high school. Many cadets then considered engineering majors, with aeronautical, astronautical, and mechanical engineering as the top three choices. Cadets also considered chemistry, biology, and physics as career paths. Before declaring a college major, 135 of 187 (72%) cadets were still STEM-interested, with 60% considering an engineering major. Cadets still frequently considered majoring in aeronautical, astronautical, and mechanical engineering at this time, while computer science displaced physics as the third most popular major in the science and mathematics category. In both cases, many cadets frequently listed multiple STEM majors of interest.

### *Factors Associated with STEM Attrition (Target Sample,* n *= 136)*

Although the ranking scale ranged from 1 to 10 (1 was not influential and 10 was very influential), the researchers grouped the ranking results into minor impact (mean rankings between 1 and 3), moderate impact (mean rankings between 4 and 7), and strong impact (mean rankings between 8 and 10). Table 1 shows the overall findings of this section.

Note the moderate and strong STEM attrition impacts of classroom experiences, mainly due to the Calculus I and II, General Chemistry I, and Mechanics courses. Final course grades, especially in Aeronautics and Astronautics Fundamentals, had the smallest impact on STEM attrition.

**Classroom Experience.** Almost two-thirds of cadets (65%) perceived that their classroom experience in Calculus I and II had a moderate or strong influence on their decision to move away from STEM majors. This percentage is much higher than those for Mechanics Fundamentals (53%) and General Chemistry I (51%). With 43% and 35%, the participants' classroom experiences in Aeronautics and Astronautics Fundamentals, respectively, were the least impactful when declaring a non-STEM major. Table 2 summarizes the classroom experience survey data.

**Table 1**

*STEM Attrition Impact Heatmap Matrix*

| Core Class | Level | Classroom Experience Impact | | | Content Understanding Impact | | | Final Grade Impact | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Minor | Moderate | Strong | Minor | Moderate | Strong | Minor | Moderate | Strong |
| Calculus I & II | Year 1 | 94 | 253 | 360 | 178 | 121 | 216 | 174 | 138 | 198 |
| General Chemistry I | Year 1 | 130 | 182 | 333 | 190 | 143 | 126 | 188 | 132 | 153 |
| Mechanics Fundamentals | Year 2 | 128 | 226 | 279 | 172 | 165 | 180 | 170 | 143 | 225 |
| Aeronautics Fundamentals | Year 3 | 154 | 171 | 243 | 194 | 149 | 99 | 220 | 110 | 45 |
| Astronautics Fundamentals | Year 4 | 172 | 198 | 135 | 200 | 143 | 63 | 202 | 154 | 36 |

*Note.* Values are weighted by an impact coefficient (2 for minor impact, 5.5 for moderate impact, and 9 for strong impact) and the sample size per cell.

**Conceptual Understanding.** About one in three cadets indicated that their mastery of content knowledge and skills in Mechanics Fundamentals (37%) and Calculus I and II (34%) was a moderate or strong push factor away from STEM and toward non-STEM majors. In contrast, 30%, 28%, and 25% of the cadets reported a moderate or strong influence on their content understanding in General Chemistry I, Aeronautics, and Astronautics Fundamentals, respectively. Table 3 summarizes the conceptual understanding data.

**Final Class Grades.** Like the previous content mastery factor, about one in three cadets perceived that their final grades in Mechanics Fundamentals (37%) and Calculus I and II (35%) had a moderate or strong influence on their decision to move away from STEM majors, followed by their grade in General Chemistry I (30%). The participants' final grades in Aeronautics and Astronautics Fundamentals were the least impactful when declaring a non-STEM major (24% and 19%, respectively). Table 4 summarizes the final grade survey data.

**Time and Effort Management and Instructor Pacing.** About 55% of the cadets indicated that time and effort commitments were a prominent push factor away from STEM, and 51% thought the pacing was also very influential. Table 5 summarizes the survey data for these two factors.

## *Statistical Analysis–Demographics (Target Sample,* n = *136)*

In this section, the researchers compared the median influence rankings in the previous 15 categories (three academic reasons multiplied by five core courses) with demographic and socioeconomic variables. The statistical analysis revealed that

**Table 2**

*STEM Attrition Impact Rankings of Classroom Experience in Five Core Classes*

| Class | Mean +/- St Dev | Med | How much did your classroom experience influence the decision to ultimately declare a non-STEM major? | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Calculus I & II | 5.23 ± 3.11 | 6 | 30 22.6% | 9 6.8% | 8 6.0% | 4 3.0% | 14 10.5% | 9 6.8% | 19 14.3% | 20 15.0% | 9 6.8% | 11 8.3% |
| General Chemistry I | 4.50 ± 3.22 | 4 | 41 30.4% | 11 8.1% | 13 9.6% | 6 4.4% | 15 11.1% | 5 3.7% | 7 5.2% | 18 13.3% | 7 5.2% | 12 8.9% |
| Mechanics Fundamentals | 4.46 ± 3.16 | 4 | 40 29.4% | 12 8.8% | 12 8.8% | 8 5.9% | 12 8.8% | 5 3.7% | 5 3.7% | 9 6.7% | 3 2.2% | 15 11.1% |
| Aeronautics Fundamentals | 3.73 ± 3.29 | 2 | 66 48.9% | 6 4.4% | 5 3.7% | 9 6.7% | 12 8.9% | 5 3.7% | 5 3.7% | 9 6.7% | 3 2.2% | 15 11.1% |
| Astronautics Fundamentals | 2.91 ± 2.71 | 1 | 79 59.4% | 5 3.8% | 2 1.5% | 4 3.0% | 22 16.5% | 6 4.5% | 4 3.0% | 3 2.3% | 2 1.5% | 6 4.5% |

the average ranking of academic reasons that influenced cadets to move away from STEM majors was similar for all five courses regardless of cadet status as first-generation college graduates. The researchers found that cadets from families with $65,000–$100,000 annual incomes reported larger push factors due to their grade in Calculus I and II (4.10 mean impact ranking) and conceptual understanding of Aeronautics Fundamentals (3.29 mean impact ranking) compared with cadets from more affluent backgrounds (2.81 and 2.11 mean impact rankings, respectively; $z = 2.15$, $p = 0.032$ and $z = 2.067$, $p = 0.039$). Also, cadets who graduated from private schools or home-school reported a larger impact due to their classroom experience (6.04 mean impact ranking) and final grade (5.08 mean impact ranking) in Mechanics Fundamentals. Rankings for public school cadets were 4.20 and 3.45, respectively ($z = 2.75$, $p = 0.006$ and $z = 2.72$, $p = 0.007$). Cadets who attended preparatory schools and those from low socioeconomic backgrounds experienced the strongest push away from STEM due to academic factors. Tables 6 through 9 summarize these findings.

## *Recommendations to Minimize STEM Attrition*

The last survey question asked cadets to provide recommendations for increasing the number of cadets graduating in STEM. Cadets used their experiences as context to provide actionable items for attracting undecided cadets to STEM majors and retain those who declared them. Twenty-four themes were identified, the top five of which are discussed below.

**Table 3**

*STEM Attrition Impact Rankings of Conceptual Understanding in Five Core Classes*

| Class | Mean +/- St Dev | Med | How much did your level of understanding of the concepts taught in class influence the decision to ultimately declare a non-STEM major? | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Mechanics Fundamentals | 3.71 ± 2.92 | 3 | 45<br>33.1% | 19<br>14.0% | 22<br>16.2% | 4<br>2.9% | 8<br>5.9% | 9<br>6.6% | 9<br>6.6% | 7<br>5.1% | 4<br>2.9% | 9<br>6.6% |
| Calculus I & II | 3.56 ± 3.15 | 2 | 56<br>41.5% | 22<br>16.3% | 11<br>8.1% | 4<br>3.0% | 5<br>3.7% | 5<br>3.7% | 8<br>5.9% | 8<br>5.9% | 4<br>3.0% | 12<br>8.9% |
| General Chemistry I | 2.96 ± 2.73 | 1 | 70<br>51.9% | 15<br>11.1% | 10<br>7.4% | 5<br>3.7% | 10<br>7.4% | 3<br>2.2% | 8<br>5.9% | 6<br>4.4% | 3<br>2.2% | 5<br>3.7% |
| Aeronautics Fundamentals | 2.70 ± 2.49 | 1 | 76<br>56.3% | 12<br>8.9% | 9<br>6.7% | 8<br>5.9 | 9<br>6.7% | 3<br>2.2% | 7<br>5.2% | 7<br>5.2% | 2<br>1.5% | 2<br>1.5% |
| Astronautics Fundamentals | 2.40 ± 2.33 | 1 | 87<br>65.4% | 8<br>6.0% | 5<br>3.8% | 1<br>0.8% | 18<br>13.5% | 5<br>3.8% | 2<br>1.5% | 3<br>2.3% | 1<br>0.8% | 3<br>2.3% |

**Modify the Core Classes.** The most frequent recommendation was to modify the core curriculum, the equivalent of general education classes at USAFA. Although many cadets did not provide specific suggestions to improve the core, others mentioned making these classes easier, slower-paced, manageable, and accessible. A few cadets suggested reducing the number of core classes or removing specific classes. One cadet noted that because of the substantial number of required core courses, classes in the major are out of reach until the fourth semester. An opposite recommendation was to add classes to the core, like a freshman-level engineering design process class. Other recommendations were to adjust the mix of STEM and non-STEM core classes based on the cadet's majors (less STEM core classes for non-STEM majors and vice versa) and to front-load core STEM classes to create an exposure bias toward STEM. "A cadet in their incoming year should be taking more STEM classes if only to put them in a STEM-oriented mindset for those majors," a cadet explained.

**Advise First-Year Students About the Benefits and Perks of Majoring in STEM.** Cadets recommended USAFA provide first-year students with additional information and better advice about the benefits of completing a STEM degree and specific major requirements, including the following:

- "[Providing] weekly email highlights for freshmen on the different majors."
- "[Planning and implementing] a summer engineering design program."
- "Bringing in graduates of those degrees to inform cadets."

**Table 4**

*STEM Attrition Impact Rankings of Final Grade in Five Core Classes*

| Class | Mean +/- St Dev | Med | How much did your final class grade influence the decision to ultimately declare a non-STEM major? | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Mechanics Fundamentals | 3.74 ± 3.10 | 2.5 | 51 37.5% | 17 12.5% | 17 12.5% | 4 2.9% | 8 5.9% | 10 7.4% | 4 2.9% | 9 6.6% | 4 2.9% | 12 8.8% |
| Calculus I & II | 3.35 ± 3.08 | 1.5 | 67 50.0% | 14 10.4% | 6 4.5% | 5 3.7% | 9 6.7% | 4 3.0% | 7 5.2% | 7 5.2% | 8 6.0% | 7 5.2% |
| General Chemistry I | 3.01 ± 2.83 | 1 | 73 54.1% | 10 7.4% | 11 8.1% | 5 3.7% | 10 7.4% | 4 3.0% | 5 3.7% | 7 5.2% | 4 3.0% | 6 4.4% |
| Astronautics Fundamentals | 2.28 ± 2.18 | 1 | 90 67.7% | 5 3.8% | 6 4.5% | 3 2.3% | 18 13.5% | 4 3.0% | 3 2.3% | 1 0.8% | 0 | 3 2.3% |
| Aeronautics Fundamentals | 2.14 ± 1.92 | 1 | 84 62.2% | 16 11.9% | 10 7.4% | 3 2.2% | 14 10.4% | 2 1.5% | 1 0.7% | 4 3.0% | 0 | 1 0.7% |

- "Letting undeclared cadets spend time with the instructors and cadets in a classroom or laboratory."

Cadets also encouraged enhancing special events like Open House, Majors Night, or STEM Night oriented toward first-year cadets and providing recruitment incentives (including financial ones) for high-demand STEM majors.

**Reduce Workload for STEM Majors.** Cadets perceived majoring in STEM comes with an increased workload. Those who major in STEM "have no free time and seem like they are always struggling." One cadet mentioned that USAFA should be transparent about "how rigorous the academic course load is [because] some may not be able to handle it." Athletes and engineering cadets perceived the STEM workload as being particularly intense. A cadet proposed that these students should receive excusals from some military training requirements.

Two cadets mentioned that the U.S. Military Academy addressed workload issues by modifying the semester schedule, either by making it last longer but having a day off midweek to catch up on academics or by providing additional weekend time for academics. Other suggestions to reduce the workload included:

- "[Reducing the number of] core [classes], thus decreasing the pace."
- Decreasing the amount of homework since "cadets do not have the time to teach themselves the material outside of class and then only be able to ask questions in class."
- "[Modifying STEM classes to] go a little slower but explain the material in more depth."

**Table 5**

*STEM Attrition Impact Rankings for Instructor Pacing and Workload Factors*

| Reason | Mean +/- St Dev | Med | How much did these reasons to do well in a STEM major influence your decision to ultimately declare a non-STEM major? | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| I would have needed instructors who could cover the material at a moderate pacing. | 5.57 ± 3.45 | 6 | 32<br>23.7% | 8<br>5.9% | 9<br>6.7% | 5<br>3.7% | 7<br>5.2% | 11<br>8.1% | 12<br>8.9% | 10<br>7.4% | 18<br>13.3% | 23<br>17.0% |
| I would have needed to spend more time and effort than I could afford. | 5.44 ± 3.53 | 6 | 34<br>25.0% | 8<br>5.9% | 10<br>7.4% | 8<br>5.9% | 7<br>5.1% | 9<br>6.6% | 11<br>8.1% | 8<br>5.9% | 12<br>8.8% | 29<br>21.3% |

Interestingly, cadets noted that if reducing the workload of STEM cadets is not possible, they will be at a disadvantage for competitive opportunities tied to GPA and overall performance average, causing STEM attrition. Overall performance average determines graduation order of merit by weighing GPA at 50%, military performance average at 40%, and physical education average at 10%. Cadets provided two options to reduce GPA disparities:

- "[Rewarding] cadets better for selecting difficult majors, through grade balancing." This system sounds like those in high schools, where advanced placement and honors classes are weighted more than regular ones.
- "Making [non-STEM] majors more challenging. The Academy could evaluate whether the workload for a [STEM] major is significantly above that of fuzzy [non-STEM] majors."

**Attract and Maintain High-Quality Instructors.** Cadets perceived the content knowledge of STEM instruction as excellent. They did argue that some instructors could do a better job helping cadets understand the content knowledge and skills they are teaching, making it more likely for cadets to avoid STEM attrition. Other cadets thought instructors should be more considerate, understanding, approachable, and motivated. Instructors should be discerning in recognizing that some students may be struggling academically. On the other hand, instructors should not

**Table 6**

*STEM Attrition Impact Rankings by Caucasian and Asian Minority Demographics*

| Academic Reason | Impact Ranking (mean ± St Dev) | | Z | p |
|---|---|---|---|---|
| | Caucasian | Asian Minority | | |
| Conceptual Understanding in Aeronautics Fundamentals | 2.41 ± 2.36 | 4.22 ± 2.94 | 2.89 | **0.004** |
| Conceptual Understanding in Mechanics Fundamentals | 3.39 ± 2.84 | 5.09 ± 2.95 | 2.45 | **0.014** |
| Final Grade in Mechanics Fundamentals | 3.33 ± 2.92 | 5.00 ± 3.41 | 1.99 | **0.046** |

be intimidating, condescending, or make cadets "feel dumb" for asking questions. Cadets recommended providing additional professional development opportunities in pedagogy and teaching strategies.

**Improve the Curriculum for Non-Core Classes.** One cadet stated that some courses appeared designed to filter people out of STEM majors. Cadets differentiated between classes that were "well-structured" and did not add anything unnecessary, and those that appeared to go out of their way to make [the content] more difficult. Further recommendations included the following:

- "[Making] the learning environment more collaborative."
- "[Making] the focus of classes more on learning than difficulty."
- "[Making] them relevant to being warfighters and officers [by focusing] on the future fight."
- "[Avoid suggesting] summer STEM courses. Three weeks for any STEM course is too fast."

Other strategies to retain STEM majors included (a) expanding research and graduate school opportunities, (b) informing about STEM career opportunities in the Air Force and the civilian workforce, and (c) creating STEM minors.

## Discussion and Recommendations

The transition to higher education is challenging, regardless of whether the universities are civilian or military (Conley et al., 2014; González-Espada & Napoleoni-Milán, 2006). Add a strict adherence to a four-year STEM program, military, leadership, and physical education tasks, and it is not difficult to understand the multiple push factors away from STEM experienced by participants.

Cadet responses may reveal that, although the curriculum designed and prepared by USAFA is adequate to meet their needs, they perceive implicit messages that not all cadets work hard enough, are intelligent enough, or can multitask effectively enough to enter the culture of science or engineering. The perception that

**Table 7**

*STEM Attrition Impact Rankings by Caucasian and Asian Minority Demographics*

| Academic Reason | Impact Ranking (mean ± St Dev) | | Z | p |
|---|---|---|---|---|
| | Caucasian | Asian Minority | | |
| **Final Grade in Mechanics Fundamentals** | 3.33 ± 2.92 | 4.77 ± 3.19 | 2.35 | **0.019** |
| **Final Grade in Calculus I & II** | 3.09 ± 3.04 | 4.83 ± 3.35 | 2.02 | **0.043** |
| **Conceptual Understanding in Aeronautics Fundamentals** | 2.17 ± 2.11 | 3.07 ± 1.89 | 2.31 | **0.021** |
| **Final Grade in Astronautics Fundamentals** | 2.11 ± 2.06 | 3.46 ± 2.15 | 2.82 | **0.005** |

non-STEM programs result in higher GPAs also leads some cadets to leave STEM programs. Although many of the cadets' recommendations to attract and retain their peers in STEM majors echo those identified in civilian universities (Seymour & Hewitt, 1997; Seymour & Hunter, 2019), there are a few actionable items that USAFA could implement without significantly affecting the formal curriculum's rigor.

## *Revising the Calculus Sequence*

One of the more salient findings of the study was the cadets' perceived impact of the classroom experience in Calculus I and II in their decision to depart STEM majors. Their recommendation to revamp the calculus sequence is consistent with recent studies at USAFA related to STEM attrition (Dwyer et al., 2020; O'Keefe et al., 2022) and similar studies that identify these courses as leading cause of STEM attrition (Ellis et al., 2014; Núñez-Peña et al., 2013; Seymour & Hewitt, 1997).

The Mathematical Sciences Department at USAFA recently started to modernize its core calculus courses to emphasize modeling and pattern visualization with actual data, using current technology for computations unrealistic by hand, and promoting student exploration and experimentation (Saxe & Braddy, 2015; Schumacher et al., 2015). Early evidence suggests promising results (Horton, 2023; Johnson et al., 2024).

## *Provide Enhanced Academic Support to Cadets from At-Risk Demographic Groups*

The socioeconomic status of families is associated with children's achievement in school and degree attainment, causing low-income and first-generation college students to become less likely to finish STEM degrees (Estrada et al., 2016; Ferrare & Lee, 2014; Jackson, 2018; Knight, 2017; President's Council of Advisors on Science and Technology, 2012). Uncovering that classroom experiences, conceptual understanding, and final grades in core classes are disproportionally impacting some so-

**Table 8**

*STEM Attrition Impact Rankings by Preparatory School Attendance Demographics*

| Academic Reason | Impact Ranking (mean ± St Dev) | | Z | p |
|---|---|---|---|---|
| | Direct Enrollment | Prep School | | |
| Conceptual Understanding in Mechanics Fundamentals | 3.21 ± 2.66 | 5.38 ± 3.16 | 3.59 | **0.001** |
| Conceptual Understanding in Calculus I & II | 3.20 ± 2.97 | 4.90 ± 3.46 | 2.75 | **0.006** |
| Final Grade in Calculus I & II | 2.99 ± 2.93 | 4.56 ± 3.31 | 2.43 | **0.015** |
| Conceptual Understanding in Aeronautics Fundamentals | 2.32 ± 2.17 | 3.94 ± 2.99 | 3.01 | **0.003** |
| Conceptual Understanding in Astronautics Fundamentals | 2.10 ± 2.06 | 3.32 ± 2.90 | 2.27 | **0.023** |

cioeconomic and demographic groups should motivate USAFA to design and plan a more detailed tracking of STEM attrition.

Preparatory school graduates deserve a separate mention. These programs remediate academic deficiencies so that their course performance at USAFA will be like nonpreparatory school graduates. The findings suggest that preparatory school graduates are experiencing disproportionate push factors away from STEM, confirming the conclusion of a recent study (O'Keefe et al., 2022). The Air Force should critically examine the preparatory schools' STEM curriculum to better align it with best practices in STEM education (Hallström & Schönborn, 2019).

## *Reducing Workload for STEM Majors*

An option suggested by cadets was to follow a midweek study day without scheduled classes, reportedly in place at the U.S. Military Academy (USMA) at West Point. Communication confirmed that a version of this scheduling system was in place but will soon be cancelled by USMA. At USAFA, a weekly "Wednesday off" model would lengthen the semester, negatively impacting many other activities on campus, especially those scheduled for the summer.

A second alternative to address the perceived excessive workload would be to statistically weigh USAFA STEM coursework to compensate for the additional difficulty. A model like this does not exist at the college level, only in high schools with advanced placement and honors classes. If USAFA considers STEM course weighing, additional research like Tomkin and West (2022) is needed to (a) confirm that graduation GPAs per USAFA division are significantly disparate and (b) identify weights that could produce statistically similar graduation GPAs for all divisions.

Although cadets suggested avoiding summer STEM courses, a recommendation to reduce workload would be for USAFA to revise the current summer course lottery

**Table 9**

*STEM Attrition Impact Rankings by Average Annual Cadet Family Income*

| Academic Reason | Impact Ranking (mean ± St Dev) | | Z | p |
|---|---|---|---|---|
| | > $100,000 | < $65,000 | | |
| Classroom Experience in Calculus I & II | 5.06 ± 3.14 | 6.63 ± 2.50 | 1.98 | **0.048** |
| Conceptual Understanding in Mechanics Fundamentals | 3.32 ± 2.87 | 4.30 ± 2.52 | 2.28 | **0.022** |
| Final Grade in Mechanics Fundamentals | 3.11 ± 2.94 | 4.90 ± 2.85 | 3.09 | **0.002** |
| Classroom Experience in Astronautics Fundamentals | 2.85 ± 2.78 | 4.30 ± 2.77 | 2.30 | **0.022** |
| Conceptual Understanding in Aeronautics Fundamentals | 2.11 ± 1.95 | 3.30 ± 2.62 | 2.35 | **0.019** |
| Conceptual Understanding in Astronautics Fundamentals | 1.97 ± 1.82 | 3.00 ± 2.20 | 2.51 | **0.012** |
| Final Grade in Aeronautics Fundamentals | 1.85 ± 1.68 | 2.55 ± 2.01 | 1.96 | **0.050** |
| Final Grade in Astronautics Fundamentals | 1.80 ± 1.61 | 3.00 ± 2.08 | 2.93 | **0.003** |

system and expand the offerings of non-STEM courses. This alternative would free up time for STEM cadets during their regular semester. The impact on the many military, survival, airmanship, and leadership requirements cadets complete during the summer is unknown.

## *Keeping Interest for STEM*

Cadets were savvy in pointing out that STEM-interested cadets must have multiple sources of quality information to make a well-informed decision about the benefits of completing a STEM degree and specific major requirements. In addition to providing additional opportunities for STEM majors to engage in research and STEM-related outreach, USAFA should promote frequent, informal peer-to-peer interactions (Drane et al., 2014; Micari et al., 2010). These can be events like Open Houses, Majors Night, or STEM Showcases with first-year cadets, graduating seniors in STEM, and graduating seniors in non-STEM majors who experienced push factors away from STEM.

USAFA should avoid the opposite of peer learning, which is peer misinformation. One researcher shared his experience with basic cadet training cadre alerting first-year cadets to avoid Calculus III, "poisoning the well" of undecided STEM-interested cadets and adding stress to those who already decided to major in STEM. USAFA should expose cadets to various perspectives on academic majors during basic training, which should minimize peer misinformation.

Another way to keep cadets interested in STEM is to challenge the misconception that Air Force officers rarely use their undergraduate STEM degrees in their duties.

USAFA should continually inform cadets about the importance of STEM majors for the expected technological sophistication of future conflicts, especially cyber sciences, space systems, complex systems, and research and development (Rempfer, 2019).

One cadet recommendation to retain interest in STEM was to develop a first-year engineering foundations class. Research supports introduction to engineering courses in the first year of college (Patangia, 2003; Sable et al., 2014; Watson et al., 2015). The Department of Civil and Environmental Engineering, the Department of Management, and the Office of Diversity and Inclusion piloted an introduction to engineering design courses in the fall 2023 semester, and they are evaluating its effectiveness.

## Conclusion

This study examined academic and nonacademic factors linked to cadets switching out of STEM majors. The researchers concluded that about three-fourths of the participants reported interest in STEM (high school and during their first year), and about two-thirds of them even initially declared STEM majors. The accelerated pacing of instruction, the limitations of time and effort due to the workload, and the classroom experience in Calculus I and II were the most impactful factors related to STEM attrition. Two factors, instructor pacing and excessive workload, also emerged in the analysis. The researchers identified moderate impacts in classroom experiences in General Chemistry I, classroom experiences in Mechanics Fundamentals, conceptual understanding and final grade in Mechanics Fundamentals, conceptual understanding and final grade in Calculus I and II, and final grade in General Chemistry I.

The researchers also found that cadets from lower-income families, who attended preparatory schools, who are racial or ethnic minorities, and who attended private schools or were home-schooled experienced stronger push factors toward STEM attrition. Cadets provided numerous ideas to prevent STEM attrition; however, some are more feasible than others in the context of the legal and curricular realities of USAFA.

Despite various study limitations like cadet self-selection for completing the survey, low overall survey response rates, not including other introductory core classes like Physics I and Biology I, and the lack of data associated with the revamped Calculus I and II sequence, the findings significantly expand previous studies at USAFA (Dwyer et al., 2020; O'Keefe et al., 2022, 2023) that point to STEM attrition as an ongoing, concerning challenge for the U.S. Department of Defense.

Although this study was completed in the context of USAFA, the problem of STEM retention and attrition is broad enough that this study's findings can inform similar ones in other contexts such as military postsecondary institutions other than USAFA and civilian colleges and universities, both public and private. Some factors

are common to these groups. For instance, the accelerated pacing of instruction in introductory STEM courses has been widely reported by both cadets and civilian students; opportunities to apply research methods to revamp these courses in light of new technologies and instructional approaches should be a priority. The limitations in time and effort due to perceived excessive workload are a similar consequence for cadets and students, although the causes may be different for both groups (e.g., physical education and military leadership duties for cadets; part-time jobs and family responsibilities for civilians). The role of persistence or grit as a personality trait that differentiates cadets or civilian students who finish STEM degrees from those who leave is an additional factor worth researching. In fact, a future research study that examines persistence among USAFA's graduating cadets in STEM is in the data collection stage.

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