Peer Reviewed

A Mixed Methods Analysis of STEM Major Attrition at the U.S. Air Force Academy

Daniel S. O'Keefe and David Meier

Department of Physics and Meteorology, United States Air Force Academy

Jorge Valentine-Rodríguez

Ana G. Méndez University at Gurabo and Puerto Rico Science, Technology & Research Trust

Lachlan T. Belcher

Intituto Tecnológico de Aeronáutica, São José dos Campos, Brazil

Wilson González-Espada

Department of Physics, Earth Science & Space Systems Engineering, Morehead State University

Abstract

Science, technology, engineering, and mathematics (STEM) professionals are indispensable for a robust economy and a strong military in evolving U.S. national security contexts. However, from high school to graduate school, the STEM pipeline loses up to 50% of its potential workforce, particularly in quantitative disciplines. This national trend is observed at the U.S. Air Force Academy (USAFA), where STEM recruitment and STEM major attrition are consistent challenges. Our mixed-methods study examines factors associated with STEM attrition and persistence at the USAFA using two years of academic data from the USAFA's Registrar's Office and a thematic analysis of the narrative responses obtained from surveyed cadets. STEM *Departers* were statistically more likely to have low GPA and SAT Math scores and to have attended a preparatory school before enrolling at USAFA. Also, undecided cadets with higher GPA and SAT scores, secondary majors, and *Scholars* statuses were more likely to major in STEM. Survey data reveals that a lack of information about occupation and labor markets, coursework cognitive load and quantity, and instructor interactions may be linked to STEM attrition. Recommendations to reduce STEM attrition include (a) developing an early-warning, data-driven system to monitor and support STEM-interested freshmen cadets within specific SAT score ranges and whose GPA decrease below a certain threshold; (b) critically reviewing and strengthening the STEM curricula at preparatory schools; (c) providing additional information and peer-led focus groups on the academic expectations of STEM and non-STEM majors; (d) recruiting STEM instructors with pedagogical content knowledge to teach introductory STEM courses; and (e) enhancing the curricula of introductory STEM courses at USAFA with teaching methods supported by research, including project-based and authentic learning, and data-driven modeling.

Graduates from science, technology, engineering, and mathematics (STEM) majors are essential for many professions and for a robust economy (Fayer et al., 2017; Piatkowski, 2020). STEM graduates and a vigorous science and technology workforce have also been identified by the U.S. Department of Defense (National Research Council, 2012a, 2012b, 2014) as essential for a strong military and for an evolving U.S. national security environment that demands greater scope and depth from science and technology. Specifically, the U.S. Air Force has prioritized scientific discovery and has relied on a highly skilled workforce to manage the discovery, development, and integration of STEM to advance its mission (National Research Council, 2010).

The number of college graduates in the United States exceeded 61 million in 2017 and nearly half of employed college graduates earn their highest degree in a science and engineering field (Foley et al., 2020). There is a robust debate among STEM education and policy researchers about the extent to which the output of STEM professionals is adequate for meeting workforce needs or not. Researchers like Camilli and Hira (2019), Carnevale et al. (2014), Hira and Hira (2008), and Piatkowski (2020) have argued that shortages in the STEM workforce are not widespread but dependent on which disciplines are under scrutiny and the methodologies used when mining job posting data. Nevertheless, there seems to be a generalized accord that the United States is not close to meeting the need for the Nation's science and technology talent, and that attrition from the field may be a contributing factor (Apriceno et al., 2020; Belser et al., 2018; Hrabowski & Henderson, 2017; Sithole et al., 2017). STEM shortages seem to be more evident in quantitative disciplines (Duncheon, 2018; National Science Board, 2018).

STEM attrition is defined as enrollment choices that result in students interested in STEM leaving their academic programs by switching majors to non-STEM fields or dropping out of college (Green & Sanderson, 2017; Jelks & Crain, 2020; Shedlosky-Shoemaker & Fautch 2015; Xu, 2018). In the United States, STEM attrition has been reported to be as high as 30-50% (Chen, 2013; National Science Board, 2018).

On the road to becoming STEM professionals, high school graduates struggle at two main points in time: during the transition from high school to college (DeVilbiss, 2014) and when students are completing their science coursework. Students struggle with following the fast pace of science coursework (Seymour & Hunter, 2019), exposure to science lectures that are broadly critiqued for transmitting information without promoting understanding (Petrovic & Pale, 2015; Singh & Phoon, 2021; Wolff et al., 2015; Zhao & Potter, 2016), and applying mathematics and numeracy to solve scientific problems (Bowen et al., 2019; Bressoud, 2015; Brewer et al., 2019; Gottfried, 2015; Hilgoe et al, 2016; Jacobs & Pretorius, 2016). Unfortunately, STEM attrition is found to be more prevalent among college students who are minorities, first-generation, or those coming from low-income backgrounds (Chen, 2015).

Students leave collegiate STEM programs for reasons other than grades (Chen, 2013). The literature also considers the importance of attitudinal factors associated with STEM attrition, like motivation and beliefs about their future professional occupations (Cabell, 2021; Morgan et al., 2013), student self-regulation habits (Park et al., 2019), career value-expectancy (Appianing & Van Eck, 2018), and STEM self-efficacy (Cohen & Kelly, 2020).

Maj. Daniel O'Keefe graduated from the United States Air Force Academy in physics and mathematics, and then earned his MS in physics from Purdue University and PhD in applied physics from the Air Force Institute of Technology. He has served as a physicist in the U.S. Air Force since 2010, with assignments at the Air Force Research Lab Weapons Directorate and the Air Force Nuclear Weapons Center. He is currently an assistant professor in the Department of Physics and Meteorology at the United States Air Force Academy.

Jorge A. Valentine-Rodríguez currently works as the STEM and workforce director for the Puerto Rico Science, Technology and Research Trust, a nonprofit organization tasked to foster innovation and research in the fields of science, technology, and socioeconomic development on the island. He holds a BA in business administration from the University of Puerto Rico and an MA in humanities from Sagrado Corazón University in San Juan. As part of his leadership duties at the Science Trust, Valentine develops and leads research projects in general STEM Education as well as STEM career selection, persistence, and attrition among university freshmen. In 2021 he completed his first year as an Air Force Research Lab Summer Faculty Fellow with the Center for Physics Education Research, Department of Physics and Meteorology, United States Air Force Academy, Colorado.

In the case of the United States Air Force Academy (USAFA), Dwyer et al. (2020) reports factors associated with cadets completing their bachelor's degree in STEM compared with data from a survey of cadets' interest in STEM majors four years prior. The survey, offered by the Basic Sciences Division, was completed by cadets the summer before their freshman year. According to the survey, 56.5% of cadets were STEM-interested and 30.0% were non-STEM-interested (the rest were undecided). Four years later, 36.4% of the cadets who were STEM-interested switched majors and graduated with a non-STEM major. In contrast, only 6.3% of the non-STEM-interested switched majors and graduated with a STEM major. Most cadets changed their intention to major in STEM before declaring a major (González-Espada et al., 2020a, 2020b, 2021; O'Keefe et al., 2021).

Purpose and Research Questions

The researchers were interested in improving the graduation rates of STEM majors at USAFA by analyzing the factors associated with cadets becoming STEM *Departers* or STEM and non-STEM *Persisters*. The researchers used two academic years' worth of data (AY 2019-20 and AY 2020-21) and a qualitative analysis of data from a survey designed to explore attitudinal factors associated with STEM attrition. Table 1 summarizes which USAFA majors were classified as STEM and non-STEM.

The research questions for the study were:

- Is there a significant difference in the demographic and academic factors for STEM *Departers* and STEM *Persisters* in the AYs 2019-20 and 2020-21?
- Which data-based models can best identify cadets at risk of becoming STEM *Departers*?
- According to cadets, what practices can USAFA implement to improve recruitment into STEM or prevent attrition from STEM majors?

Maj. Lachlan Belcher graduated from the United States Air Force Academy (USAFA) in physics and mathematics (2003) and then earned his MS in physics from the Air Force Institute of Technology (2005). He then served as the system survivability program manager for intercontinental ballistic missiles at Hill Air Force Base, Utah. Belcher returned to the Air Force Institute of Technology (2007) to earn his PhD in physics. Afterward, Belcher was a deputy branch chief and lead test director of the Starfire Optical Range at Kirtland Air Force Base, New Mexico (2011). In 2014, Belcher was reassigned to the National Reconnaissance Office in Chantilly, Virginia, as part of the Imagery Intelligence directorate and subsequently the Survivability Assurance Office. In 2018, Belcher was selected as an assistant professor at USAFA and later as the director of the Center for Physics Education Research. In the summer of 2021, Belcher joined the physics faculty at Brazil's Instituto Tecnológico de Aeronáutica as a military exchange officer.

These research questions were selected because even though military higher education institutions differ from traditional public/private universities in that their curricula focus on key components of military careers such as Military and Strategic Studies and physical training (Kennedy, 2017), the literature associates STEM attrition with both quantifiable aspects of academic life and attitudinal factors that apply to both military and civilian institutions. By exploring answers to these research questions, the body of research-based knowledge on STEM pathway persistence will grow, which could result in improved interventions to address STEM attrition.

Methodology

The quantitative portion of the study relied on data pulls from the USAFA Registrar's Office: eight monthly pulls from AY 2019-2020 and 10 monthly pulls from AY 2020-2021. Independent variables collected included cadet gender, race, class rank (based on graduation year), presence of a secondary major, number of declared minors, status as preparatory school graduate, participation in the *Scholars Program*, GPA at the end of the academic year, SAT Math (SAT-M) scores, and SAT Reading and Writing (SAT-RW) scores.[1] The dependent variable was major status, which was classified as either STEM *Arrivers* (those cadets who switched from a non-STEM major to a STEM major), STEM *Departers* (those cadets who switched

Wilson González-Espada is a professor in the Department of Physics, Earth Science and Space Systems Engineering at Morehead State University. His academic background is in physics (BA in physics education, University of Puerto Rico at Río Piedras) and science education (MA, Interamerican University of Puerto Rico at San Germán; and PhD, University of Georgia). He teaches courses in physical science for K-8 teachers and general education, science methods, history of science, introductory physics, and research methods. González-Espada's scholarly interests include physics education, multicultural STEM education, educational assessment, and STEM attrition, and he has published extensively in these and other topics. In 2021, he completed his third year as an Air Force Research Lab Summer Faculty Fellow with the Center for Physics Education Research, Department of Physics and Meteorology, United States Air Force Academy, Colorado.

Lt. Col. David Meier graduated with a BS in physics from the United States Air Force Academy in 1996 and served as an operational C-130 pilot for twelve years. He returned to physics and earned his MS in applied physics in 2010 and PhD in applied physics in 2015, both from the Air Force Institute of Technology. He is currently an assistant professor of physics and the director of core programs for the Department of Physics and Meteorology at the United States Air Force Academy. His research interests include atmospheric effects on laser propagation, curriculum development, and physics education research.

Table 1
USAFA Majors Classified as STEM or non-STEM

Non-STEM Majors	STEM Majors
Bachelor of Science	Basic Science
Behavioral Sciences (General, Human Factors, Leadership)	Biochemistry
Economics	Biology
Economics	Chemistry (General, Materials)
Foreign Area Studies (General, Geography, History, Military & Strategic Studies, Political Science)	Computer and Network Security
General Studies (Humanities, Social Sciences)	Computer Science (Cyber Warfare Option, General)
Geospatial Science	Cyber Science
History (American, General, International, Military)	Data Science
Humanities	Engineering (Aeronautical, Astronautical, Chemical, Civil, Computer, Electrical, Environmental, General, Mechanical, Systems, Systems Management)
Legal Studies	General Studies (Basic Sciences, Engineering)
Military & Strategic Studies	Mathematics (Applied, General)
Philosophy	Meteorology
Political Science	Operations Research
Social Sciences	Physics
	Space Operations

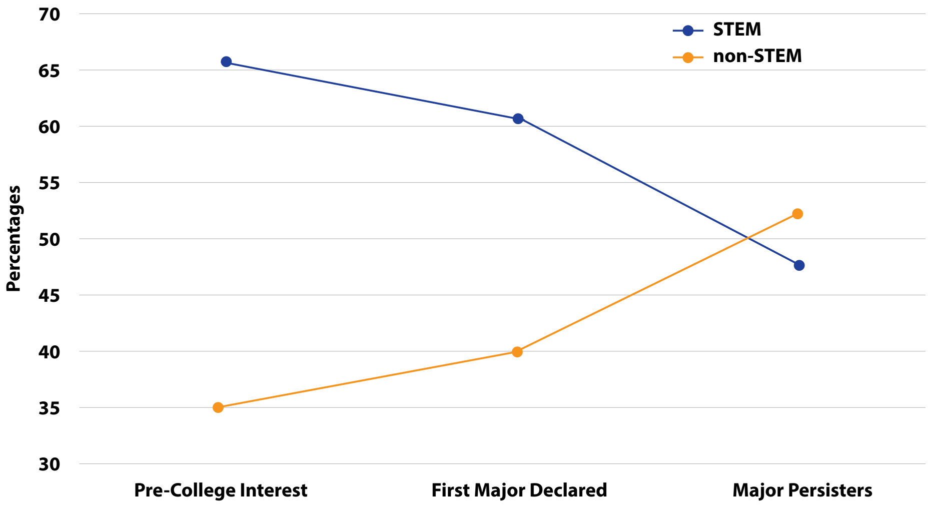
From "Course of Instruction 2021–2022," by United States Air Force Academy, 2021.

from a STEM major to a non-STEM major), STEM *Persisters* (those cadets who kept the same STEM major), non-STEM *Persisters* (those cadets who kept the same non-STEM major), cadets who changed from a STEM major to a different STEM major (classified together with STEM *Persisters*), cadets who changed from a non-STEM major to a different non-STEM major (classified together with non-STEM *Persisters*), undecided cadets who declared a STEM major, and undecided cadets who declared a non-STEM major. Because many cadets showed up in the data set for both AYs, duplicates were removed.

The data analyses consisted of descriptive statistics for each of the variables and inferential statistics comparing independent and dependent variables one at a time. In addition, a binary logistic regression model was used when appropriate (Hosmer et al., 2013; Legg et al., 2001; Osborne, 2015) to obtain the best model of which factors were most closely associated with the dependent variable. Because of the exploratory nature of this test, minimum statistical significance was

Figure

Percentage of Cadets and Their Interest in STEM and non-STEM Majors at Three Points During Their Time at USAFA



assigned a probability (*p*) value of less than 0.05 to balance the risks of Types I and II errors.

The qualitative portion of the study relied on a short survey. The sample consisted of 44 USAFA cadets who voluntarily answered the prompt: "In the near future, the Air Force may consider possible alternatives to increase the number of cadets who graduate with undergraduate degrees in Basic Sciences/Engineering. What three recommendations should the Academy implement to attract undecided cadets to declare a major in Basic Sciences/Engineering?" A survey methodology was selected because it provides flexibility in conducting the study, uses narrative material in a research design, and integrates tools to contextualize the views of a particular group rather than generalize across a whole population (Check & Schutt, 2012; Creswell, 2012; Swayne & Dodds, 2011).

Utilizing Quirkos, a qualitative data visualization software, responses were analyzed using the phases of Thematic Analysis (Boyatzis, 1998; Braun & Clarke, 2006; Creswell & Tashakkori, 2007; King, 2004; Nowell et al., 2017; Saldaña, 2021). The four phases included (a) *familiarization* with the data, completed through repeated reading of the data and actively searching for meaning and patterns among emerging noticeable traits on words and phrases collected; (b) *initial code generation*, to begin identifying core recommendations; (c) *sorting and collating relevant data and searching for themes*, which capture and unify the nature or basis of the experience into a meaningful whole (Desantis & Ugarriza, 2000); and (d) *review of themes*, where the major themes were clarified, reorganized, consolidated, and named to immediately give the reader a sense of what the themes were about.

Results

Descriptive Statistics for the Independent Variables

The data set comprised of 5,070 cadets split between 3,627 (71.5%) male cadets and 1,443 (28.5%) female cadets. The sample included 3,280 (64.7%) Caucasian cadets and 1,634 (32.2%) cadets from underrepresented minorities. Race data were not available for 156 (3.1%) of the cadets. A total of 973 cadets (19.2%) attended a preparatory school and 332 cadets (6.5%) were classified as *Scholars*.

Cadets were classified as freshmen who declared a major (614, 12.1%), sophomores (1,321, 26.1%), juniors (1,088, 21.5%), seniors (1,060, 20.9%), and seniors who graduated in May 2020 (986, 19.4%). Of the freshmen cadets, 464 cadets did not declare a major at the time of this study. Most cadets, 3,544 (97.0%), declared a single major, with 108 cadets (3.0%) declaring a secondary major. For academic minors, 2,827 cadets (77.4%) did not have one, 763 cadets (20.9%) declared one minor, and 62 cadets (1.7%) declared two minors.

The average GPA in the sample was 3.07, with a standard deviation of 0.57 points. The skewness and kurtosis values did not exceed ± 1.0, which means that GPA can be approximated as a normally distributed variable. The SAT-RW scores for cadets averaged 670 points and had a standard deviation of 62.3 points. SAT-M scores were higher, with an average of 683 points and a standard deviation of 70.2 points. Like GPA, the SAT skewness and kurtosis values did not exceed ± 1.0.

Descriptive Statistics for the Dependent Variables

Of the cadet sample, 3,297 cadets kept the same major in both AYs, with totals similarly split among STEM and non-STEM disciplines; 1,553 cadets (47.1%) declared a STEM major, and 1,744 cadets (52.9%) declared a non-STEM major. 215 cadets changed from one major to another within the same discipline; 119 cadets (55.3%) switched within STEM majors and 96 cadets (44.7%) switched within non-STEM majors. For the 1,420 undecided cadets who declared a major, 857 (60.4%) of them chose a STEM major, and the rest, 563 (39.6%), chose a non-STEM major.

A total of 137 cadets were STEM *Arrivers* or *Departers*. While 121 cadets (88.3%) switched from STEM to non-STEM, only 16 cadets (11.7%) switched in the other

Table 2
Number of Cadets as a Function of the Categorical Variables of Interest

Variable	Descriptor	Major Code* and Number of Cadets								Total
		1	2	3	4	5	6	7	8	
Gender	Male	10	88	76	63	1,166	1,238	608	377	3,626
	Female	6	33	43	33	387	506	249	186	1,443
Race	Causasian	10	75	71	55	1,051	1,088	560	369	3,279
	Minority	5	42	46	39	455	579	280	188	1,634
Attended Prep School	No	13	87	96	67	1,372	1,310	742	409	4,096
	Yes	3	34	23	29	181	434	115	154	973
***Scholars* Status**	No	12	118	111	88	1,378	1,691	797	542	4,737
	Yes	4	3	8	8	175	53	60	21	332
Class Rank/ Year	Freshman	1	2	0	0	0	0	431	180	614
	Sophomores	6	68	52	23	253	120	423	376	1,321
	Juniors	9	41	54	56	445	474	3	6	1,088
	Seniors	0	10	9	17	449	573	0	0	1,058
	2020 Grads	0	0	4	0	406	573	0	0	986
Secondary Major	No	16	120	117	92	1,469	1,705	827	558	4,904
	Yes	0	1	2	4	84	39	30	5	165
Number of Minors	None	14	93	97	60	1,137	1,198	761	497	3,857
	One	2	25	22	34	401	497	89	56	1,127
	Two	0	3	0	2	15	49	7	10	86

Note. Major codes are 1 for STEM *Arrivers*, 2 for STEM *Departers*, 3 for cadets who changed from a STEM major to a different STEM major, 4 for cadets who changed from a non-STEM major to a different non-STEM major, 5 for STEM *Persisters*, 6 for non-STEM *Persisters*, 7 for undecided cadets who declared a STEM major, and 8 for undecided cadets who declared a non-STEM major.

direction, an eight-to one ratio. The Figure compares the percentage of cadets' choice for STEM and non-STEM majors before starting their first semester, when a major was declared, and as upperclassmen.

Table 2 summarizes the number of cadets within each categorical independent variable, classified by STEM and non-STEM major switching, if any. Table 3 summarizes the average GPA and SAT scores, along with their standard deviation, classified by STEM and non-STEM major switching, if any.

Table 3
Descriptive Statistics for the Quantitative Variables of Interest

Variable	Major Code* and Number of Cadets							
	1	2	3	4	5	6	7	8
GPA	3.23	2.74	3.08	2.85	3.25	2.93	3.25	2.79
	0.52	0.49	0.48	0.51	0.44	0.47	0.52	0.54
SAT-RW	665.6	657.2	662.8	656.7	678.6	653.9	681.0	653.8
	68.3	54.1	66.2	71.4	58.2	60.0	59.1	63.6
SAT-M	683.1	668.7	693.0	648.2	702.1	652.0	704.5	650.1
	68.5	63.8	77.6	72.4	62.4	62.4	63.7	66.9

Note. Major codes are 1 for STEM *Arrivers*, 2 for STEM *Departers*, 3 for cadets who changed from a STEM major to a different STEM major, 4 for cadets who changed from a non-STEM major to a different non-STEM major, 5 for STEM *Persisters*, 6 for non-STEM *Persisters*, 7 for undecided cadets who declared a STEM major, and 8 for undecided cadets who declared a non-STEM major.

Inferential Analysis of STEM Departers and Persisters

Categorical Data. The sample size consisted of 1,672 STEM *Persisters* and 121 STEM *Departers*. Due to the categorical nature of the data, a Chi-square analysis was conducted (using raw data, not percentages) and reported in Table 4. Subcategories with five or fewer individuals were noted so that any significant relationships are interpreted carefully.

It was found that gender, race, and whether a cadet has a minor were not statistically associated with STEM attrition. Cadets who graduated from a prep school were significantly more likely to become STEM *Departers*. Cadets classified as *Scholars* were significantly less likely to become STEM *Departers*. Having a secondary major seems to be associated with persisting as a STEM major; however, there were not enough cadets for a definitive test.

Quantitative Data. Due to the level of measurement of GPA and SAT scores, t-test statistics comparing their averages were calculated and reported in Table 5. Levene tests showed statistically similar variances, so the reported t-statistics assume homoscedasticity. The statistical analysis demonstrated that STEM *Departers* were more likely to have lower GPA and SAT scores compared with STEM *Persisters*. A Pearson correlation test showed significant correlations between GPA and SAT-RW ($r = 0.438$, $p < 0.001$), GPA and SAT-M ($r = 0.500$, $p < 0.001$), and SAT-M and SAT-RW ($r = 0.612$, $p < 0.001$).

Table 4
Statistical Comparison of Categorical Variables for STEM Persisters *and* Departers

Variable	Descriptor	STEM *Departers*	STEM *Persisters*	Total	X^2	*df*	*p*
Gender	Male	88 6.6%	1,242 93.4%	1,330	0.142	1	0.706
	Female	33 7.1%	430 92.9%	463			
Race	Causasian	75 6.3%	1,122 93.7%	1,197	1.285	1	0.257
	Minority	42 7.7%	501 92.3%	543			
Attended Prep School	No	87 5.6%	1,468 94.4%	1,555	24.774	1	< 0.001
	Yes	34 14.3%	204 85.7%	238			
Scholars Status	No	118 7.3%	1,489 92.7%	1,607	8.697	1	0.003
	Yes	3 1.6%	183 98.4%	186			
Secondary Major	No	120 7.0%	1,586 93.0%	1,706	4.555	1	0.033
	Yes	1 1.1%	86 98.9%	87			
Number of Minors	None	93 7.0%	1,234 93.0%	1,327	0.547	1	0.459
	One or two	28 6.0%	438 94.0%	466			

Binary Logistic Regression (BLR) Model. The model included attendance to prep school, *Scholars* status, GPA, and SAT-M scores. The reason why SAT-RW was not included in the model is because BLR is susceptible to multicollinearity (Evans, 1996). The best BLR model, which explained 17.1% of the variance in the data (per the Nagelkerke pseudo R^2 coefficient), revealed that the only predictor of cadets becoming STEM *Departers* was GPA, which is consistent with a previous significant *t*-test.

The other variables were loaded into the BLR model in the order shown in Table 6; however, these additional variables did not significantly increase the explained variance.

Table 5

Statistical Comparison of Quantitative Variables for STEM Persisters *and* Departers

Variable	Average ± Standard Deviation Sample Size		t	df	p
	STEM *Departers*	STEM *Persisters*			
GPA	2.74 ± 0.49 121	3.23 ± 0.45 1,671	-11.58	1,790	< 0.001
SAT-RW	657.2 ± 54.1 121	677.5 ± 58.9 1,658	-3.67	1,777	< 0.001
SAT-M	668.7 ± 63.8 121	701.5 ± 63.6 1,658	-5.46	1,777	< 0.001

Table 6

BLR Results for STEM Departers *and* Persisters

Best Model	Wald	e^B	p	*Nagelkerke Pseudo* R^2
GPA	104.9	9.87	< 0.001	0.171
Prep School	0.512	-	0.474	
Scholars Status	0.044	-	0.833	
SAT-M	0.528	-	0.467	

STEM Arrivers. The sample consisted of 1,840 non-STEM *Persisters* (who either remained in their original non-STEM major or switched between non-STEM majors) and 16 STEM *Arrivers*. The only categorical variables that appeared to be associated with cadets leaving non-STEM majors for STEM majors was *Scholars* status. For quantitative data, t-test statistics demonstrated that STEM *Arrivers* are more likely to have higher GPA (t = 2.54, df = 1,854, p = 0.011) and SAT-RW scores (t = 2.32, df = 15.22, p = 0.034) compared with non-STEM *Persisters*. However, the small sample size of STEM *Arrivers* limited the conclusiveness of these findings.

Inferential Analyses of Undecided Cadets Who Declared a Major Categorical Data. The sample size consisted of 857 (60.4%) undecided cadets who declared a STEM major and 563 (39.6%) undecided cadets who declared a non-STEM major. Using raw data (not percentages), Chi-square analyses were calculated and reported in Table 7. None of the analyses included five or fewer individuals.

Cadets who were in the *Scholars Program* and who declared a secondary major were statistically more likely to declare a STEM major. Cadets who attended a preparatory school were statistically more likely to declare a non-STEM major.

Table 7
Statistical Comparison of Categorical Variables for Undecided Cadets Selecting a Major

Variable	Descriptor	Declared STEM Majors	Declared non-STEM Majors	Total	X^2	*df*	*p*
Gender	Male	608 61.7%	377 38.3%	985	2.536	1	0.111
	Female	249 57.2%	186 42.8%	435			
Race	Causasian	560 60.3%	369 39.7%	929	0.026	1	0.871
	Minority	280 59.8%	188 40.2%	468			
Attended Prep School	No	742 64.5%	409 35.5%	1,151	42.967	1	< 0.001
	Yes	115 42.7%	154 57.2%	269			
Scholars Status	No	797 59.5%	409 35.5%	1,339	6.759	1	0.009
	Yes	60 74.1%	21 25.9%	81			
Secondary Major	No	827 59.7%	558 40.3%	1,385	9.646	1	0.002
	Yes	30 85.7%	5 14.3%	35			
Number of Minors	None	761 60.5%	497 39.5%	1,258	2.687	2	0.261
	One or two	89 61.4%	56 38.6%	145			

Quantitative Data. *T*-test statistics comparing the average GPA and SAT scores of undecided cadets who declared STEM and non-STEM majors were calculated and reported in Table 8. Undecided cadets who declared a STEM major had significantly higher GPA and SAT scores, as shown in Table 9.

BLR Model. This model included prep school attendance, *Scholars* status, secondary major, GPA, and SAT-M scores. Given that SAT-RW and SAT-M scores are highly correlated (r = 0.612, p < 0.001), only SAT-M was used to avoid multicollinearity. The best BLR model, which explained 25.0% of the variance in the data, revealed that the strongest predictor of cadets declaring a STEM major was GPA, followed by SAT-M scores, and *Scholars* status.

Table 8

Statistical Comparison of Quantitative Variables for Undecided Cadets Selecting a Major

Variable	Average ± Standard Deviation Sample Size		*t*	*df*	*p*
	Declared STEM Majors	Declared non-STEM Majors			
GPA	3.25 ± 0.52 857	2.79 ± 0.54 563	15.70	1,418	< 0.001
SAT-RW	681.0 ± 59.1 857	653.8 ± 63.6 563	8.24	1,418	< 0.001
SAT-M	704.5 ± 63.7 857	650.1 ± 66.9 563	15.44	1,418	< 0.001

Table 9

BLR Results for Undecided Cadets who Declared a Major

Best Model	Wald	e^B	*p*	*Nagelkerke Pseudo* R^2
GPA	71.62	0.326	< 0.001	0.196
SAT-M	61.329	0.992	< 0.001	0.247
Scholars Status	5.024	1.893	0.025	0.250
Prep School	-	-	0.749	
Secondary Major	-	-	0.087	

Inferential Analyses of GPA and SAT Scores by Major

Since SAT scores and cadet interest in STEM disciplines are known to USAFA before cadets start their first semester, statistically comparing these scores by major status while keeping track of GPA could provide an early predictor of potential STEM *Departers*. A Levene statistic revealed that the between-group variances by major status were not similar, likely caused by the wide variation in sample size between groups, so a Kruskal-Wallis (nonparametric) comparison was more appropriate.

The Kruskal-Wallis tests showed that the GPA of STEM *Departers* is the lowest of the group, a GPA like that of non-STEM cadets, those who were undecided, and those who switched within non-STEM majors. In contrast, the SAT scores of STEM *Departers* are located near the midpoint of the distribution. Most SAT-RW scores are statistically similar, except for the significantly higher scores of STEM *Persisters* and undecided cadets who declared STEM majors. For SAT-M scores, only the

Table 10
Theme and Code Summary for Qualitative Cadet Responses

Themes	Description	Total Codes
Occupation and Job Markets	Refers to occupational value expectancy and future job opportunities once USAF/ USSF commitments are fulfilled. Also contains coded information regarding internships and civilian opportunities and job markets.	19
Coursework Difficulty	Perceived notions of challenging or difficult course content that requires effort or scaffolding not accounted for before beginning the course.	16
Coursework Quantity	Refers to the content amount and pacing required to complete the course.	15
Instructors	Refers to recommendations regarding instructor dynamics, perceptions of teaching styles, instructor support during learning, and perceived depth of knowledge.	11
Other STEM Informal Learning Opportunities	Informal learning opportunities include field trips, museums, guest speakers, and other activities where knowledge transfer occurs outside USAFA.	3
Quality of Life	Narrative referring to perceived levels of stress or limited time to balance academics with non-academic, including the required USAFA physical and military leadership training.	2
Textbook Fees	High cost of textbooks required for STEM courses.	1
Diversity and Inclusion	Recommendation regarding broad communications of activities within USAFA where women and minorities are represented.	1
Total number of codes		68

scores of STEM *Arrivers* are statistically like that of STEM *Departers*. These results suggest that the mathematical and oral/written communication proficiency of STEM *Departers* before starting their freshmen year are adequate for cadets to thrive, at least in some STEM majors.

Qualitative Analysis of Survey Responses

Four major themes were identified from the qualitative responses shared by 44 cadets: (a) *occupation and job market*; how cadets perceived their future professional opportunities and how the general job prospects outside USAFA linked with the current majors offered; (b) *coursework difficulty*, recommendations and comments that pertained to the sense of efficacy and difficulty of the STEM major courses; (c) *coursework quantity*, recommendations about reducing the number of topics, tasks, and activities that need to be completed in each course; and (d) *instructors*, comments and recommendations to USAFA regarding faculty interaction and quality.

Table 10 listed the top 10 themes that emerged from the data and how many cadets provided them. A single cadet's response could code under multiple themes.

Occupation and Job Market. Nineteen of the surveyed cadets indicated that occupation and job market considerations, if discussed broadly during the undeclared period at the academy, could attract undecided cadets to declare a major in basic sciences and engineering. These statements reflect limitations either on access to such information or a lack of active search for the information on behalf of the cadets. Regarding declaring and retaining STEM majors at the academy, a cadet commented: "Show how they are applicable outside USAFA," while another stated that it was important to "tell people the job outcomes of those majors." Other recommendations pointed to a keen interest among cadets to have full disclosures on the necessary work, time, and effort required for STEM courses, arguing that "before [cadets] come [to USAFA], that's the time to tell them that it's a STEM school." This notion aligns with the manifested need for information on what majors "do" outside USAFA and what the occupational outlooks are for each major. This same recommendation is repeated under the coursework quantity theme, as they align in intention and scope.

Coursework Difficulty. Sixteen cadets reported on the perceived high level of difficulty throughout STEM major coursework. One participant expressed it in direct terms by requesting an "easier workload for engineering classes" and to make "engineering more approachable for those without experience." These statements denote cadets without previous engineering experience find the coursework at the academy challenging. This is an indication of gaps in knowledge or skills or that cadets lack the necessary scaffolding for engineering coursework before entering USAFA. Another interpretation for cadet comments on coursework difficulty might be related to what Bar et al. (2009) reported on the scholarly traits of students who move to courses with less "difficulty" at traditional universities; they explain that students gravitate toward leniently graded courses to maintain stronger GPAs. This trend may be further incentivized at USAFA, since GPA is heavily weighted in selection of cadets' future occupational careers (i.e., cadets with higher GPAs are more likely to get their career fields of choice, especially if they are interested in becoming pilots).

Coursework Quantity. Fifteen cadets manifested feeling "[burnt] out," "exhausted," and had a "decrease in quality of life." For instance, two cadets suggested "decrease the workload on students who choose STEM majors" and for instructors to "go at a slower pace covering course content." It is here the concept of course quantity links with the idea of a large amount of content versus the pace at which the course is covered. Identification of such notions is significant as burnout fully mediates the relationship between effort-reward imbalance and withdrawal intentions for both first year and subsequent-year students (Williams et al., 2018).

Instructors. Eleven cadets reported low satisfaction with their interactions with course instructors, stating that "STEM major teachers need to act like they care more about cadets" and that USAFA should "allow better teachers to teach core classes instead of the worst ones in the department." Cadet recommendations included revising the hiring requirements for faculty, "[getting] better teachers in STEM courses," encouraging facilitators to become more engaged with students in the courses, and improving the quality of instructors, in terms of content delivery and providing student support.

Discussion

The quantitative data indicated that STEM *Departers* were more likely to have relatively low GPA and SAT-M scores, more likely to come from a preparatory school, and less likely to be in the *Scholars Program*, compared with STEM *Persisters*. Undecided cadets who later declared a STEM major were more likely to be in the *Scholars* program, to declare a secondary major, and to have higher GPA and SAT scores while less likely to have attended a preparatory school. When comparing the distribution of SAT scores, STEM *Departers* seemed to be at a critical midpoint in the score distribution and may go either way in terms of career selection depending on their freshmen coursework. The GPA data suggested that, as underclassmen, cadets probably struggled with the high school to college transition, attitudinal factors like motivation and self-efficacy (Aulck et al., 2017; Chen, 2013; Cohen & Kelly, 2020; Park et al., 2019). Cadets also struggled with introductory science classes such as physics and chemistry. Along with calculus, these courses were previously identified as gateway classes at USAFA (Dwyer et al., 2020). As their GPAs decreased, many undecided cadets who were interested in STEM declared non-STEM majors, while others who had declared STEM majors quickly switched out of them as they encountered academic difficulties.

The fact that the demographics and academics BLR model could explain no more than 20-25% of the data variance implies that nonacademic and attitudinal factors impact STEM attrition. Cadet recommendations for additional information about employment options for different majors may indicate a low awareness of occupational value expectancy (Appianing & Van Eck, 2018) regarding careers within and outside military ecosystems. The limitations of the BLR model could also be due to low levels of academic self-regulation (Park et al., 2019).

Within the teaching community, the term "course difficulty" is generally accepted to communicate the learning content complexity of a course. This complexity is often attributed to the levels of necessary scaffolding to support students as they learn ever more complex topics, helping them achieve the expected learning outcomes, and employing the appropriate pedagogies to teach the course (Andres, 2017). Since GPA comprises nearly two-thirds of the model used to determine which Air Force jobs cadets will have upon graduation (e.g., entrance selection for pilot training programs), some cadets may depart STEM majors simply to choose an easier major and improve their grades. Additionally, cadets might likely be reacting to factors like teaching style, strategies, and tactics, as well as each course's learning content complexity (Bailey et al., 2016).

Recommendations

Based on the mixed-methods analyses, several suggestions for improvement can be put forth. One recommendation to identify opportunities to prevent STEM departures and incentivize STEM arrivals is the development of a data-driven algorithm that uses monthly data pulls from the registrar's office to monitor freshmen cadets and immediately identify those at risk of becoming STEM *Departers* and those who could be recruited into STEM majors. Cadets who identify themselves as STEM-interested in the basic sciences survey offered before first semester classes start and who have SAT scores above a certain threshold can go into a database. As the first semester progresses, any cadet on the list whose GPA drops below a certain threshold could be flagged for an interview with a STEM academic success specialist. The goal of this specialist would be to accurately isolate the root causes of the cadet's academic struggles and help him or her address these causes. A potential obstacle for implementing this recommendation might be resourcing of the academy-wide office or academic departments to lead and manage this effort.

Prep school attendance consistently arose as a factor associated with STEM attrition. It is recommended that USAFA critically examine the preparatory school's science, mathematics, and engineering curriculum and enhance it as needed. A good starting point may be to consider implementing authentic science experiences, model development, and data-driven modeling, praised by many in the field for their connection with best practices in STEM education (Hallström & Schönborn, 2019).

Cadets' academic performance in STEM courses could improve if USAFA hires or provides faculty with pedagogical preparation to instruct introductory STEM courses. The literature documents that introductory courses should be taught by experienced instructors who are better equipped to avoid the teaching methodology pitfalls that many less experienced instructors have (Burroughs et al., 2019; Podolsky et al., 2019). Military faculty typically teach for three to four years, so they may not have enough time to develop experience and pedagogical content knowledge.

Possible options may be to hire experienced civilian faculty members with a background in STEM pedagogies for introductory STEM courses or to provide additional institutional support to military faculty through quality professional development. One option could be sending military faculty to complete a one-year graduate certificate or master's degree in STEM Curriculum and Instruction through a collaboration with the University of Colorado at Colorado Springs. This university already provides a master's degree in Counseling and Leadership for the Air Officer Commanding Leadership Development Program at USAFA. Another option could be arranging pedagogical training through military organizations like the Center for Educational Innovation (Air Force) and the Faculty Development and Recognition Program (Army). They can provide STEM-specific faculty development opportunities, build STEM-centered communities of practice (Gehrke & Kezar, 2019; Ma et al., 2019; Stark & Smith, 2016), and assist in building a pipeline that can return high-performing instructors to training and education assignments more than once in a career.

A final recommendation, which would increase cadet knowledge about both STEM and non-STEM coursework difficulty, quantity, and time and effort commitments, is to create additional recruitment information sessions. In these carefully planned sessions, new cadets meet with senior cadets to discuss experiences and challenges, with a focus on the opportunities open to them because of their chosen major.

Conclusion

The U.S. Department of Defense considers a well-qualified STEM workforce as essential for a robust military, and USAFA is uniquely positioned to increase the quality of graduates in STEM careers. The purpose of this study was to use a mixed-methods approach to examine academic, demographic, and attitudinal factors associated with USAFA cadets becoming STEM *Departers*. The first research question asked to what extent there was a significant difference in the demographic and academic factors for STEM *Departers* and STEM *Persisters*. It was found that cadets who attended prep school, who were not classified as *Scholars*, who had low GPAs, and who had low SAT-M or low SAT-RW scores were more likely to switch out of STEM majors.

The second research question asked which data-based models could best identify cadets at risk of becoming STEM *Departers*. From the binary logistic regression model of STEM *Departers*, GPA emerged as the strongest factor associated with cadets leaving or arriving at STEM majors.

The third research question asked cadets to identify practices USAFA can implement to prevent attrition from STEM majors. Thematic analysis provided valuable insight into cadet attitudinal perceptions, uncovering recommendations within four main areas: occupation and job market, coursework difficulty, coursework quantity, and instructors. The identification of these four themes was consistent with the literature regarding STEM attrition and retention and could lead USAFA to consider attitudinal factors to fine-tune predictive or early warning systems for retaining STEM-interested cadets.

In terms of future research, classifying majors dichotomously into broad categories of STEM and non-STEM may not be capturing the nuances of each major and their role in STEM attrition. A possible alternative could be to examine attrition for individual STEM majors to account for their academic rigor and quantitative load. A likely hypothesis is that attrition is more prevalent in quantitative STEM majors (e.g., chemistry, engineering, mathematics, and physics), compared to majors in the life sciences. Future studies could also examine the role of course design in STEM classes, particularly those at the introductory level. Instructors with good instructional skills may not be able to maximize their cadets' academic performance if the course's design is inconsistent with the latest research-based practices in STEM teaching and learning.

According to the National Academies of Sciences, Engineering, and Medicine (2015), the Air Force requires the products of basic STEM research, which are critical to future success, and the Air Force's capabilities in these disciplines must expand at an accelerating rate to keep pace with increased mission complexities and the access of relevant technologies to potential adversaries. It is critical to recognize the problem of STEM attrition at military higher education institutions, and as a national security imperative, the Air Force should invest resources to prioritize its reduction among cadets.

References

Andres, H. P. (2017). Active teaching to manage course difficulty and learning motivation. *Journal of Further and Higher Education*, *43*(2), 220–235. https://doi.org/10.1080/0309877X.2017.1357073

Appianing, J., & Van Eck, R. N. (2018). Development and validation of the value-expectancy STEM assessment scale for students in higher education. *International Journal of STEM Education*, *5*(1), 1–16. https://doi.org/10.1186/s40594-018-0121-8

Apriceno, M., Levy, S. R., & London, B. (2020). Mentorship during college transition predicts academic self-efficacy and sense of belonging among STEM students. *Journal of College Student Development*, *61*(5), 643–648. https://doi.org/10.1353/csd.2020.0061

Aulck, L., Aras, R., Li, L., L'Heureux, C., Lu, P., & West, J. (2017). *STEM-ming the tide: Predicting STEM attrition using student transcript data*. https://arxiv.org/pdf/1708.09344.pdf

Bailey, M. A., Rosenthal, J. S., & Yoon, A. H. (2016). Grades and incentives: Assessing competing grade point average measures and postgraduate outcomes. *Studies in Higher Education*, *41*(9), 1548–1562. https://doi.org/10.1080/03075079.2014.982528

Bar, T., Kadiyali, V., & Zussman, A. (2009). Grade information and grade inflation: The Cornell experiment. *Journal of Economic Perspectives*, *23*(3), 93–108. https://doi.org/10.1257/JEP.23.3.93

Belser, C. T., Shillingford, M., Daire, A. P., Prescod, D. J., & Dagley, M. A. (2018). Factors influencing undergraduate student retention in STEM majors: Career development, math ability, and demographics. *Professional Counselor*, *8*(3), 262–276 (EJ1198867). ERIC. http://files.eric.ed.gov/fulltext/EJ1198867.pdf

Bowen, B. D., Wilkins, J. L. M., & Ernst, J. V. (2019). How calculus eligibility and at-risk status relate to graduation rate in engineering degree programs. *Journal of STEM Education*, *19*(5), 26–31.

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. SAGE Publications.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bressoud, D. (2015). Insights from the MAA national study of college calculus. *The Mathematics Teacher*, *109*(3), 178–185.

Brewer, H. E., Gonzalez-Espada, W. J., & Boram, R. D. (2019, April 11). *Why do students leave quantitative STEM majors? Perspectives from Eastern Kentucky* [Oral presentation]. Annual National Conference on Undergraduate Research, Kennesaw State University, Kennesaw, GA, United States.

Burroughs, N., Gardner, J., Lee, Y., Guo, S., Touitou, I., Jansen, K., & Schmidt, W. (Eds.). (2019). Teaching for excellence and equity: Analyzing teacher characteristics, behaviors and student outcomes. In *Teaching for excellence and equity* (Vol. 6, pp. 7–17). Springer. https://doi.org/10.1007/978-3-030-16151-4_2

Cabell, A. L. (2021). Career search self-efficacy and STEM major persistence. *The Career Development Quarterly*, *69*(2), 158–164. https://doi.org/10.1002/cdq.12256

Camilli, G., & Hira, R. (2019). Introduction to a special issue—STEM workforce: STEM education and the post-scientific society. *Journal of Science Education and Technology*, *28*(1-8). https://doi.org/10.1007/s10956-018-9759-8

Carnevale, A. P., Jayasundera, T., & Repnikov, D. (2014). *Understanding online job ads data*. Georgetown University, Center on Education and the Workforce. https://cew.georgetown.edu/wp-content/uploads/2014/11/OCLM.Tech_.Web_.pdf

Check, J., & Schutt, R. K. (2012). Survey research. In J. Check & R. K. Schutt (Eds.), *Research methods in education* (pp. 159–185). SAGE Publications.

Chen, X. (2013). *STEM attrition: College students' paths into and out of STEM fields* (NCES 2014-001). National Center for Education Statistics.

Chen, X. (2015). STEM attrition among high-performing college students in the United States: Scope and potential causes. *Journal of Technology and Science Education*, *5*(1), 41–59. http://dx.doi.org/10.3926/jotse.136

Cohen, R., & Kelly, A. M. (2020). Mathematics as a factor in community college STEM performance, persistence, and degree attainment. *Journal of Research in Science Teaching*, *57*(2), 279–307. https://doi.org/10.1002/tea.21594

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluation quantitative and qualitative research* (4th ed.). Pearson Education.

Creswell, J. W., & Tashakkori, A. (2007). Differing perspectives on mixed methods research. *Journal of Mixed Methods Research*, *1*(4), 303–308. https://doi.org/10.1177%2F1558689807306132

DeSantis, L., & Ugarriza, D. N. (2000). The concept of theme as used in qualitative nursing research. *Western Journal of Nursing Research*, *22*(3), 351–372. https://doi.org/10.1177%2F019394590002200308

DeVilbiss, S. (2014). *The transition experience: Understanding the transition from high school to college for conditionally-admitted students using the lens of Schlossberg's Transition Theory* [Unpublished doctoral dissertation]. University of Nebraska at Lincoln.

Duncheon, J. C. (2018). "You have to be able to adjust your own self": Latinx students' transitions into college from a low-performing urban high school. *Journal of Latinos and Education*, *17*(4), 358–372. https://doi.org/10.1080/15348431.2017.1355248

Dwyer, J. H., González-Espada, W. J., de la Harpe, K., & Meier, D. C. (2020). Factors associated with students graduating with STEM degrees at a military academy: Improving success by identifying early obstacles. *Journal of College Science Teaching*, *50*(1), 20–27.

Evans, J. D. (1996). *Straightforward statistics for the behavioral sciences*. Brooks/Cole.

Fayer, S., Lacey, A., & Watson, A. (2017). *STEM occupations: Past, present and future*. U.S. Bureau of Labor Statistics.

Foley, D., Milan, L., & Hamrick, K. (2020). *The increasing role of community colleges among bachelors' degree recipients: Findings from the 2019 National Survey of College Graduates*. National Center for Science and Engineering Statistics.

Gehrke, S. & Kezar, A. (2019). Perceived outcomes associated with engagement in and design of faculty communities of practice focused on STEM reform. *Research in Higher Education*, *60*(6), 844–869.

González-Espada, W. J., Belcher, L. T., & Meier, D. (2020a, November 7). *Understanding STEM attrition at USAFA: Identifying factors associated with selecting and switching majors* [Oral presentation]. Annual Meeting of the Kentucky Academy of Science [virtual].

González-Espada, W. J., Belcher, L. T., & Meier, D. (2020b, October 29). *Understanding STEM attrition at USAFA: Identifying factors associated with major switching majors* [Poster presentation]. 12th Annual Scholarship of Teaching and Learning (SoTL) Forum, US Air Force Academy, Colorado Springs, CO, United States.

González-Espada, W. J., Belcher, L. T., & Meier, D. (2021, January 11). *Selecting and switching STEM majors at USAF: Associated retention factors* [Poster presentation]. National Winter American Association of Physics Teachers Virtual Meeting.

Gottfried, M. A. (2015). The influence of applied STEM coursetaking on advanced mathematics and science coursetaking. *The Journal of Educational Research*, *108*(5), 382–399. https://doi.org/10.1080/00220671.2014.899959

Green, A., & Sanderson, D. (2017). The roots of STEM achievement: An analysis of persistence and attainment in STEM majors. *The American Economist*, *63*(1), 79–93. https://doi.org/10.1177%2F0569434517721770

Hallström, J., & Schönborn, K. J. (2019). Models and modelling for authentic STEM education: Reinforcing the argument. *International Journal of STEM Education*, *6*(1), 1–10. https://doi.org/10.1186/s40594-019-0178-z

Hilgoe, E., Brinkley, J., Hattingh, J., & Bernhardt, R. (2016). The effectiveness of the North Carolina early mathematics placement test in preparing high school students for college-level introductory mathematics courses. *College Student Journal*, *50*(3), 369–377.

Hira, R., & Hira, A. (2008). *Outsourcing America: The true cost of shipping jobs overseas and what can be done about it*. AMACOM Division of American Management Association.

Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied logistic regression* (3rd ed.). Wiley.

Hrabowski, F. A., III, & Henderson, P., (2017). Toward a more diverse research community: Models of success. *Issues in Science and Technology*, *33*(3) 33–40.

Jacobs, M., & Pretorius, E. (2016). First-year seminar intervention: Enhancing first-year mathematics performance at the University of Johannesburg. *Journal of Student Affairs in Africa*, *4*(1), 75–84. https://doi.org/10.14426/jsaa.v4i1.146

Jelks, S. M. R., & Crain, A. M. (2020) Sticking with STEM: Understanding STEM career persistence among STEM bachelor's degree holders. *The Journal of Higher Education*, *91*(5), 805–831. https://doi.org/10.1080/00221546.2019.1700477

Kennedy, D. (2017). *The development of professional military education at the United States Air Force Academy* [Doctoral dissertation, Kansas State University]. K-State Research Exchange.

King, N. (2004). Using templates in the thematic analysis. In C. Cassell & G. Symon (Eds.), *Essential guide to qualitative methods in organizational research* (pp. 256–268). SAGE Publications.

Legg, M. J., Legg, J. C., & Greenbowe, T. J. (2001). Analysis of success in general chemistry based on diagnostic testing using logistic regression. *Journal of Chemical Education*, *78*(8), 1117–1121. https://doi.org/10.1021/ed078p1117

Ma, S., Herman, G. L., West, M., Tomkin, J., & Mestre, J. (2019). Studying STEM faculty communities of practice through social network analysis. *Journal of Higher Education*, *90*(5), 773–799. https://doi.org/10.1080/00221546.2018.1557100

Morgan, S. L., Leenman, T. S., Todd, J. J., & Weeden, K. A. (2013). Occupational plans, beliefs about educational requirements, and patterns of college entry. *Sociology of Education*, *86*(3), 197–217. https://doi.org/10.1177%2F0038040712456559

National Academies of Sciences, Engineering, and Medicine. (2015). *Improving the Air Force scientific discovery mission: Leveraging best practices in basic research management*. The National Academies Press. https://doi.org/10.17226/21804

National Research Council. (2010). *Examination of the U.S. Air Force's science, technology, engineering, and mathematics (STEM) workforce needs in the future and its strategy to meet those needs*. The National Academies Press. https://doi.org/10.17226/12718

National Research Council. (2012a). *Assuring the U.S. Department of Defense a strong science, technology, engineering, and mathematics (STEM) workforce*. The National Academies Press. https://doi.org/10.17226/13467

National Research Council. (2012b). *Report of a workshop on science, technology, engineering, and mathematics (STEM) workforce needs for the U.S. Department of Defense and the U.S. defense industrial base*. The National Academies Press. https://doi.org/10.17226/13318

National Research Council. (2014). *Review of specialized degree-granting graduate programs of the Department of Defense in STEM and management*. The National Academies Press. https://doi.org/10.17226/18752

National Science Board. (2018). *Science and engineering indicators 2018: National center for education statistics 2011–12 beginning postsecondary students longitudinal study first follow-up* (NSB-2018-1). National Science Foundation.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, *16*(1), 1–13. https://doi.org/10.1177%2F1609406917733847

O'Keefe, D. S., Valentine-Rodríguez, J., González-Espada, W., Meier, D., & Belcher, L. T. (2021, November 5). *A mixed-methods analysis of STEM attrition at USAFA from fall 2019 to spring 2021* [Poster presentation]. 13th Annual Scholarship of Teaching and Learning (SoTL) Forum, US Air Force Academy, Colorado Springs, CO, United States.

Osborne, J. W. (2015). *Best practices in logistic regression*. SAGE Publications.

Park, C. L., Williams, M. K., Hernandez, P. R., Agocha, V. B., Carney, L. M., DePetris, A. E., & Lee, S. Y. (2019). Self-regulation and STEM persistence in minority and non-minority students across the first year of college. *Social Psychology of Education*, *22*(1), 91–112. https://dx.doi.org/10.1007%2Fs11218-018-9465-7

Petrovic, J., & Pale, P. (2015). Students' perception of live lectures' inherent disadvantages. *Teaching in Higher Education*, *20*(2), 143–157. https://doi.org/10.1080/13562517.2014.962505

Piatkowski, M. J. (2020). Expectations and challenges in the labour market in the context of industrial revolution 4.0. The agglomeration method-based analysis for Poland and other EU member states. *Sustainability*, *12*(13), 5437. https://doi.org/10.3390/su12135437

Podolsky, A., Kini, T., & Darling-Hammond, L. (2019). Does teaching experience increase teacher effectiveness? A review of US research. *Journal of Professional Capital and Community*, *4*(4), 286–308. https://doi.org/10.1108/JPCC-12-2018-0032

Saldaña, J. (2021). *The coding manual for qualitative researchers*. SAGE Publications.

Seymour, E., & Hunter, A. B. (2019). *Talking about leaving revisited: Persistence, relocation, and loss in undergraduate STEM education*. Springer Nature.

Shedlosky-Shoemaker, R., & Fautch, J. M. (2015). Who leaves, who stays? Psychological predictors of undergraduate chemistry students' persistence. *Journal of Chemical Education*, 92(3), 408–414. https://doi.org/10.1021/ed500571j

Singh, N., & Phoon, C. K. L. (2021). Not yet a dinosaur: The chalk talk. *Advances in Physiology Education*, *45*(1), 61–66. https://doi.org/10.1152/advan.00126.2020

Sithole, A., Chiyaka, E. T., McCarthy, P., Mupinga, D. M., Bucklein, B. K., & Kibirige, J. (2017). Student attraction, persistence and retention in STEM programs: Successes and continuing challenges. *Higher Education Studies*, *7*(1), 46–59. http://dx.doi.org/10.5539/hes.v7n1p46

Stark, A. M., & Smith, G. (2016). Communities of practice as agents of future faculty development. *Journal of Faculty Development*, *30*(2), 59–67.

Swayne, L. E., & Dodds, M. (Eds.). (2011). *Encyclopedia of sports management and marketing*. SAGE Publications.

Williams, C. J., Dziurawiec, S., & Heritage, B. (2018). More pain than gain: Effort–reward imbalance, burnout, and withdrawal intentions within a university student population. *Journal of Educational Psychology*, *110*(3), 378–394. https://doi.org/10.1037/edu0000212

Wolff, M., Wagner, M. J., Poznanski, S., Schiller, J., & Santen, S. (2015). Not another boring lecture: Engaging learners with active learning techniques. *Journal of Emergency Medicine*, *48*(1), 85–93. https://doi.org/10.1016/j.jemermed.2014.09.010

Xu, Y. J. (2018). The experience and persistence of college students in STEM majors. *Journal of College Student Retention: Research, Theory & Practice*, *19*(4), 413–432. https://doi.org/10.1177%2F1521025116638344

Zhao, B., & Potter, D. D. (2016). Comparison of lecture-based learning vs discussion-based learning in undergraduate medical students. *Journal of Surgical Education*, *73*(2), 250–257. https://doi.org/10.1016/j.jsurg.2015.09.016

Note

1. The Scholars Program at USAFA helps academically talented cadets reach their full potential by offering special core course sections that deepen and broaden Scholars' intellectual development and opportunities for completing a senior thesis or capstone project in the cadet's chosen major.