Impact of an Introductory Drone Course on First-Year Engineering Students

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Abstract

This complete research paper explored the effects of an introductory drone course on first-year engineering students' self-efficacy, sense of belonging, and engineering identity, grounded in three distinct theoretical frameworks: social cognitive theory, theory of instructional departure, and social identity theory. We employed a convergent mixed method research design to address our research questions. A one-credit introductory drone course was offered to students at a western R1 public university, both in-person and HyFlex formats, over 16 weeks in Spring 2025. An online survey consisting of Likert-scale items, open-ended questions, and demographic questions was administered before and after the course to collect student data on how the introductory drone course shaped or altered their perceptions of self-efficacy in engineering, sense of belonging in engineering, and engineering identity. Among a total of 14 undergraduate engineering students who participated in either the pre-survey or the post-survey, only seven responded to both surveys, and three first-year engineering students were interviewed. Possibly, due to the small sample size of seven, student perceptions of self-efficacy, sense of belonging, and engineering identity did not show any statistically significant changes between pre- and post-surveys. However, the findings from open-ended responses on pre- and post-surveys and interviews highlighted that the introductory drone course had a positive impact on first-year engineering students' self-efficacy, sense of belonging, and engineering identity.

Introduction

Autonomous unmanned vehicles (AUVs), including unmanned aerial vehicles (UAVs; e.g., drones), unmanned ground vehicles (UGVs; e.g., ground robots), and unmanned surface vehicles (USV; e.g., drone boats) represent a rapidly emerging technology that is transforming a wide range of industries, including but not limited to medical delivery, military, precision agriculture, transportation, law enforcement, delivery system, and insurance businesses [1]-[6]. Due to AUVs' rapidly advancing technology and growing demand, the market holds tremendous future value. UAV's global market size was estimated to be $23.5 billion in 2019, and is now predicted to reach $230 billion by 2030 with a Compound Annual Growth Rate (CAGR) of 13.9% from 2020 to 2030 [7]-[10]. AUVs are a new driving force for economic development over the next few decades. Therefore, teaching an introductory drone course can offer significant benefits for engineering students.

With the rapidly growing technology and applications of UAVs, teaching an introductory drone course can help engineering students develop skills that strengthen the nation's STEM competitiveness in global markets. UAV education has emerged as a topic of increasing interest across multiple engineering majors, including aerospace, civil, computer, electrical and electronic, and mechanical engineering. While the impact of drone education for engineering students is undeniable, its role in engineering education has not been fully explored [11].

Purpose of the Study

Given the growing role of UAVs in industry and the increasing demand for drone education, this study examined the effects of a one-credit introductory drone course on first-year engineering students' self-efficacy, sense of belonging, and engineering identity, using upper-year engineering students as a comparison group. The following research questions guided the study: (a) How does an introductory drone course affect engineering students' self-efficacy, sense of belonging, and engineering identity; and (b) How do these effects differ for first-year engineering students compared to upper-year engineering students?

Literature Review

Characteristics of Drone Education in the Literature

Jiang et al. [11] scoped the domain of drone-based learning, drawing on 48 articles, and argued that trends in published articles on drone use in education were periodic from 2010 to 2024, yet the overall publication rate trended upward. Jiang et al. [11] also emphasized that 25% of publications were related to drone-specific technology and engineering, such as drone design, drone control, and drone fabrication materials, and 20.8% were related to other technology and engineering subdomains, such as computer science, artificial intelligence, and architecture. Drones are also used for teamwork, practical problem-solving, and hands-on practice in assembling and piloting drones.

One key finding from Jiang et al. [11] was the duration of learning activities. Although the largest portion of studies (25%) did not specify the duration of the activities, the highest rankings were 22.9% for single-session activities and 18.8% for short-term activities. Notably, semester-long courses related to drone study accounted for 8.3% of studies, while courses related to drone application accounted for only 4.2%. On one hand, drones were mostly used in short-term, infrequent, and collaborative learning activities in K-12 STEM education [12]-[16]. On the other hand, drone education was more common in higher education than in K-12 settings. One reason was that drones are positioned to offer engineering perspectives (e.g., aerial views and aerodynamic principles), making them suitable for specific engineering courses. Additionally, due to safety and legal considerations in drone use, applications in higher education are more applicable than in K-12. This study also noted that student aspects, including perceived self-efficacy, interaction effects, and engineering identity, have received less attention in the literature and have the potential to be more fully examined and understood.

Drone Education in Higher Education

In higher education, researchers and instructors employed different rationales to teach introductory drone concepts to students. For example, Molina et al. [17] used UAVs for an interdisciplinary engineering education project for undergraduate students from mechanical engineering, electrical engineering, and computer engineering, and explored the development of students' learning skills through the UAV project. With freshman to senior student participants, the study discovered that similar projects can encourage undeclared students to pursue science and engineering fields. They proposed that students would acquire specific skills such the ability to: (a) apply mathematical and physics concepts, (b) comply with realistic constraints such as economical, ethical, safety, and physical, (c) manage time, (d) work with CAD software, (e) learn programming languages, (f) understand professional and ethical responsibility, and (g) acquire knowledge of contemporary issues, technologies and techniques.

Abichandani et al. [18] published their findings from 14 drone workshops for 97 undergraduate and graduate students aiming to prepare them for three key drone industry requirements: (a) assembly, testing, and validation, (b) simulation of drone flight missions, and (c) manual and semi-autonomous piloting. They concluded that the majority of students reached the workshops' milestones by performing correct technical tasks for the following topics: (a) introduction to drone theory, (b) soldering, (c) 3D printing, (d) software in the loop (SITL) simulation, (e) flight controller setup, (f) hardware in the loop (HITL) simulation, (g) drone assembly, and (h) outdoor flight test. Findings indicated that students perceived drone education to be engaging and effective.

Norman et al. [19] proposed "Dronagogy" as an approach for drone-based learning in higher education following the pedagogy-space-technology framework. The pedagogy of Dronagogy was defined as a flexible learning theory and strategy based on the context. The space aspect for drone education could be one or a combination of structured physical, structured virtual, unstructured physical, and unstructured virtual learning spaces. Finally, the technology aspect was illustrated as active tracking-based, gesture-based, and controller-based video shooting and monitoring. Thus far, the research seems focused more on the technology and its effect on the pursuit of education generally. Previous studies tended to focus on designing new projects and workshops, as well as proposing frameworks to explain the potential effects of drone education on engineering students. However, there has been a lack of data-driven research evidence for the influence of drone courses on students' perceptions of engineering. Therefore, this study aimed to fill the gap in the research with a particular focus on first-year engineering students.

Theoretical Frameworks

This study is grounded in three distinct theoretical frameworks: Bandura's social cognitive theory, Tinto's theory of instructional departure, and social identity theory.

Social Cognitive Theory

Bandura's social cognitive theory is a model that represents how people's behavior can be regulated through personal factors and interactions with the environment [20]. Rooted in Bandura's social cognitive theory, self-efficacy is the personal belief about one's own capability to succeed in specific situations and/or accomplish a task [21]. In engineering, high self-efficacy can lead to greater persistence in the face of challenges, a willingness to take on difficult tasks, and a greater likelihood of success [22]. Self-efficacy can be developed through mastery experiences (successful tasks), vicarious experiences (seeing others succeed), verbal persuasion (receiving encouragement), and managing psychological responses (e.g., stress, anxiety) [23]. Thus, the impact of the introductory drone course on first-year engineering students is essential to assess.

Theory of Institutional Departure

Tinto’s theory of institutional departure defines three main reasons why students leave their program: academic difficulty, inability to resolve their academic or occupational goal, or inability to become connected or stay connected to the social and intellectual life of the institution [24]. Tied into Tinto's theory of institutional departure [24]-[25], or retention model, sense of belonging is an individual's perception of being accepted, valued, and included in a particular social or professional group. Factors, such as peer interactions, instructor behavior, course design, environmental identity, and personal psychological factors, can influence sense of belonging [26]. An engineering sense of belonging can lead to academic success, satisfaction, and the well-rounded formation of future engineers [26]. It is for this reason that identifying the effect of the introductory drone course on first-year engineering students’ sense of belonging is crucial.

Social Identity Theory

Social identity theory [27]-[30] is a unified conceptual framework that provides members of a group with a shared identity based on the group they are a part of [31]. Building on social identity theory, engineering identity can be defined as a student belief of being interested in and possessing relevant knowledge and skills like an engineer. Engineering identity can be formed through a combination of education, work experiences, professional interactions, and professional beliefs [32]. Additionally, factors such as making decisions regarding designs, working with others and sharing ideas, and accepting responsibility can also be identified as means for engineering identity development [33]. Developing a strong engineering identity can lead to greater motivation, persistence, and success in the field [34]. Therefore, the relationship between the introductory drone course and first-year engineering students’ engineering identity warrants attention.

Method

Setting and Course Description

In Spring 2025, a one-credit introductory drone course was offered to students at an R1 public university in the Midwestern United States. Classes were held once a week for 1 hour and 20 minutes over the period of 16 weeks The topics for each week are listed in Table 1. Although this course was offered mainly to first-year engineering students, students from upper-level undergraduate studies, graduate studies, and other disciplines also participated. Additionally, students selected between the in-person mode and the HyFlex mode. Students enrolled in the in-person mode should attend the class in person, except on a few occasions when the instructor delivered lectures online due to conference travels. While students enrolled in the Hyflex mode had access to both in-person and online attendance synchronously or asynchronously, they typically attended online.

Table 1. An overview of the introductory drone course syllabus

Time	Subject
Week 1	Meet and Greet + Course Overview and Foundations + pre-survey
Week 2	Team Building + Drone History + Understanding Drone Components

Week 3	Precision Agriculture + Guest Speaker
Week 4	Drone Testing and Coding
Week 5	Arduino IDE + Continue Drone Coding
Week 6	Compete with Code and Learn About Sensors
Week 7	Sensors + Engineering Design of Drones
Week 8	Team Projects + Brainstorming Ideation for the Poster
Week 9	Drone Rules, Regulations, and Applications + Guest Speaker
Week 10	Tinker CAD
Week 11	iDronebot and Coding
Week 12	Team building + Each team will discuss any challenges and limitations of their engineering prototype
Week 13	Self-paced learning among team members
Week 14	Elevate team pitching via separate zoom meetings
Week 15	Team activities to finalize team's project (UAV/UGV)
Week 16	Poster Presentation + post-survey

Participants

Among the 20 students who registered for the introductory drone course for the Spring 2025 semester, 16 students registered in the in-person mode, and the other four students registered to participate in the Hyflex mode. Of the 20 students, two in the Hyflex mode withdrew from the course, and one student did not consent to participate in the study. In addition, one was excluded for not completing the pre-survey or participating in the post-survey, and two students were excluded because they were graduate students. Therefore, 14 students, who responded to either the pre-survey, the post-survey, or both, became the participants of this study. Table 2 presents their demographic information.

Table 2. Demographic information of the Survey participants

Category	**Subcategory**		***n***	**%**
Major	Engineering	Civil Engineering	1	7.2
		Computer Science	1	7.2
		Electrical Engineering	1	7.2
		Mechanical Engineering	9	64.3
	Non-Engineering	Chemistry and Environmental Soil Science	1	7.2
		Sociology	1	7.2
*Race/ Ethnicity	Asian		1	7.2
	Multiracial		3	21.4
	White		10	71.4
Residence	Domestic (U.S. citizen or permanent resident)		14	100
	International		0	0
Sex	Female/ Woman		1	7.2
	Male/ Man		13	92.8
Student Level College/School	First year		7	50.0
	Second year		3	21.4

	Third year	2	14.3
	Fourth year	2	14.3
Total		14	100.0

While we invited all students to participate in an interview, three first-year engineering students were purposefully selected for an interview at the end of the semester: two in mechanical engineering and one in civil engineering. Two students were identified as White, and one as Multiracial.

Assessments

Two online surveys administered at the beginning and end of the course, respectively, were designed to collect student data on how the introductory drone course shaped or altered their perceptions of engineering. Both surveys included three instruments using a six-point Likert scale (1 = Strongly Disagree to 6 = Strongly Agree) to explore any changes in students' self-efficacy, sense of belonging, and engineering identity. Table 3 shows the definition of each construct, the number of items, and an example item from each instrument.

Table 3. Characteristics of the instruments

Construct	**Definitions**	**No. of Items**	**Example Item**	**Source**
Self-Efficacy in the Engineering Performance	A student's personal belief in the capability to be successful in an engineering course	4	I can learn the material for engineering.	[35]
Sense of Belonging in Engineering	"The feeling that one is similar in important ways to one's engineering peers" [38, p. 390]	3	I can relate to the people around me in engineering.	[36]-[38]
Engineering Identity	"a student's ability to feel like the kind of person who is interested in, possesses the relevant knowledge and skills in, and engages in engineering practices" [32, p. 3]	3	Being an engineer is an important part of my self-image.	Items were modified from [39]

Open-ended Questions

As described in Table 4, additional open-ended questions were included in pre- and post-surveys so that students could provide more in-depth insights into how the course affected their perceptions of course experiences.

Table 4. Open-ended questions in the pre- and post-surveys

Topics	**Pre-Survey**	**Post-Survey**
Self-efficacy (As a student)	*In what ways do you expect the Introduction to Drones course to impact your capability to perform successfully as a student? Please*	*In what ways did the Introduction to Drones course impact your capability to perform successfully as a student? Please provide as much detail as possible in your response.*

	provide as much detail as possible in your response.	
Self-efficacy (As an engineer)	*In what ways do you expect the Introduction to Drones course to impact your capability to perform successfully as an engineer? Please provide as much detail as possible in your response.*	*In what ways did the Introduction to Drones course impact your capability to perform successfully as an engineer? Please provide as much detail as possible in your response.*
Sense of Belonging	*In what ways do you expect that the Introduction to Drones course will affect your feeling of inclusion in engineering? Please provide as much detail as possible in your response.*	*In what ways did the Introduction to Drones course affect your feeling of inclusion in engineering? Please provide as much detail as possible in your response.*
Engineering Identity	*How do you expect this course to influence how you see yourself as an engineer? Please provide as much detail as possible in your response.*	*In what ways has this course influenced how you see yourself as an engineer? Please provide as much detail as possible in your response.*

Interview Protocol

The interview protocol consisted of four main sections: introduction, background information, core discussion, and closing. The core discussion of the interview was built on questions related to general aspects of the course mode (e.g., advantages of the class mode they chose), engagement, self-efficacy, sense of belonging, and engineering identity.

Procedure

Following an approval from the institutional IRB, an invitation to participate in the study was emailed to all students registered for the class one week before it began. During the first class, students received the link and QR code for the pre-survey, which took approximately 15 to 20 minutes to complete. Similarly, one week before the final class, students were invited to take the 15- to 20-minute post-survey. Participation in this study was entirely voluntary. In the last question of each survey, students were invited to participate in a one-hour one-on-one interview. We purposefully selected and interviewed three first-year students who expressed interest in participating in an interview at the end of the course. Students were invited to share their insights on how the course impacted their motivation, self-efficacy, sense of belonging, and engineering identity, followed by additional probing questions related to each of these topics. Each interview participant received a $25 gift card as thanks for participating in the interview.

Data Analysis

It was essential to analyze and integrate the quantitative and qualitative findings to provide robust answers to the research questions. Therefore, our rationale for employing a mixed methods research design is to increase the credibility of our findings [40]. Quantitative and qualitative data were collected concurrently in both pre- and post-surveys [41]. Consequently, a convergent mixed methods research design was used for this research [42].

It should be noted that although the quantitative component of this study is essential for drawing generalizable conclusions, the qualitative strand was prioritized in this research due to the small sample size of less than 30 [41]. First, we performed a descriptive analysis of students' responses to the six-point Likert scale instruments. Given the small sample size, non-parametric methods were selected as a conservative approach that does not rely on the normal distribution assumption. For example, the Wilcoxon Signed-Rank test was employed to compare pre- and post-survey responses for first-year and upper-level students separately, regarding self-efficacy, sense of belonging, and engineering identity. Additionally, the Wilcoxon rank-sum test was utilized to compare changes in perceptions between first-year and upper-level engineering students.

To mitigate potential biases in our qualitative analysis, we followed a grounded theory approach when analyzing students' open-ended responses. Thematic analysis helps researchers identify, analyze, and report patterns and themes found within data [43]. For this reason, thematic analysis was used to define themes and changes in students' self-efficacy, sense of belonging, and engineering identity. Two Ph.D. students studying engineering education with backgrounds in electrical and mechanical engineering, respectively, analyzed the interview data independently using NVivo 14 software. Their analyses and findings were compared in weekly meetings to reach consensus through discussion.

Results

Student Perceptions of Self-efficacy, Sense of Belonging, and Engineering Identity

Table 5 shows the descriptive statistics for all 14 students, including those who participated only in the pre-survey or only in the post-survey. On the pre-survey before taking the course, students rated on average between *Somewhat Agree* and *Agree* that the introductory drone course can have positive effects on their self-efficacy. The average rating was shifted to between *Agree* and *Strongly Agree* after the course was finished. Students' sense of belonging increased, too. However, their responses remained in the same range between *Somewhat Agree* and *Agree*. Similarly, the mean on the effect of the course on the engineering identity increased to some extent; yet, students' responses remained between *Somewhat Disagree* and Somewhat *Agree,* indicating a neutral view of students.

Table 5. Changes in all participants' perceptions of self-efficacy, sense of belonging, and engineering identity

Instrument	**Pre-survey**			**Post-survey**		
	N	***M***	***SD***	***N***	***M***	***SD***
Self-efficacy	13	4.67	0.23	8	5.19	0.18
Sense of belonging	13	4.03	0.43	8	4.58	0.48
Engineering identity	13	3.44	0.54	8	3.87	0.72

Table 6 presents the changes observed for seven students who participated in both surveys. While the means for self-efficacy, sense of belonging, and engineering identity show a slight increase, there were no statistically significant changes.

Table 6. Pre-post changes in student perceptions of self-efficacy, sense of belonging, and engineering identity (*n* = 7)

Perceptions	Pre-survey		Post-survey		Wilcoxon Signed-Rank Test	
	M	***SD***	***M***	***SD***	***V***	***p***
Self-efficacy	4.86	0.21	5.18	0.14	2	0.344
Sense of belonging	4.38	0.41	4.57	0.47	9	0.833
Engineering identity	3.48	0.75	3.81	0.66	8	0.675

Table 7 shows the descriptive statistics of the first-year and upper-year engineering students' perceptions of engineering, respectively. Both group students showed increases in self-efficacy and sense of belonging from before to after the introductory drone course. While first-year students' engineering identity scores increased, upper-year students' scores remained the same.

Table 7. Descriptive changes in first-year and upper-year engineering student perceptions

Perceptions	First-year (*n* = 4)				Upper-year (*n* = 3)			
	Pre-survey		Post-survey		Pre-survey		Post-survey	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Self-efficacy	5.00	0.00	5.25	0.00	4.67	0.48	5.08	0.55
Sense of belonging	4.67	0.33	4.83	0.29	4.00	0.00	4.22	0.55
Engineering identity	3.84	0.72	4.42	0.33	3.00	0.48	3.00	1.00

Table 8 presents the results of non-parametric statistical analyses examining the pre-post changes of perceptions between first-year and upper-year engineering students. Similar to Table 6, Table 8 shows that the means for self-efficacy, sense of belonging, and engineering identity increased in both first-year and upper-year responses. However, there were no statistically significant differences between the student groups.

Table 8. Statistical comparisons of perception changes between first-year and upper-year students

Perceptions	Pre-Post Changes				Wilcoxon rank-sum test	
	First-year (*n* = 4)		Upper-year (*n* = 3)			
	ΔM	***ΔSD***	***ΔM***	***ΔSD***	***W***	***p***
Self-efficacy	0.25	0.50	0.42	1.23	4.5	0.711
Sense of belonging	0.17	0.88	0.22	1.07	7	0.857
Engineering identity	0.58	1.20	0.00	1.34	7	0.857

Student Perceptions of Drone Education

Table 9 compares open-ended responses from first-year and upper-year students. The presented responses matched the pre- and post-survey data, capturing the same student's perception at each time point. Each pre-post paired responses correspond to a distinct individual to show how both group students' self-efficacy, sense of belonging, and engineering identity changed from the beginning to the end of the course.

Table 9. Comparisons of open-ended responses between first- and upper year engineering student perceptions

Perceptions	First-Year Engineering Students	Upper-Year Engineering Students
Self-Efficacy (Student)	Pre: *"It's another class that requires time to be blocked out each week but I think it's very doable."*	Pre: *"With this class I can get a better understanding of the hardware aspect that pairs with the software."*
	Post: *"Intro to Drones assisted my capability to perform successfully as a student."*	Post: *"Not sure there was much of an impact."*
Sense of Belonging	Pre: *"Classes that increase my knowledge of a certain technology or industry tend to make me feel more included in engineering."*	Pre*: "I'm not entirely sure."*
	Post: *"I feel more included as an engineer now."*	Post*: "Building the drones made me feel like the engineering part was possible rather than just the software as a CS major."*
Engineering Identity	Pre: *"I think it will increase my confidence as an engineer now and later."*	Pre: *"No individual course affects my feelings about whether I am an engineer."*
	Post: *"I see myself as more of an engineer now."*	Post: *"It hasn't I know I'm an engineer"*

Table 10 presents example responses from the three first-year engineering students who participated in interviews, organized by the extracted themes aligned with self-efficacy, sense of belonging, and engineering identity.

Table 10. Extracted themes and interview response examples from first-year engineering students

Perception (*Interview Question)	Extracted Theme	Example of Interview Response
Self-Efficacy (In what ways did you expect the drone course to impact your capability to perform successfully as an engineer?)	Hands-on Learning	*"Because it was kind of my first class where I actually built anything, so I was expecting it to help me in that area, where like giving me something that is hands-on to do rather than just theory."*
	Coding Skills	*"I definitely thought getting to apply code to the drones was interesting, and just watching what you put on the screen actually functions."*
	Technical Confidence	*"I think in that same area where after I built the drone, it felt like I could actually build things, and obviously I've done stuff before this one was a little bit more technical, and I think that it definitely gave me confidence in my ability to succeed."*
Sense of Belonging (In what ways did you expect that the drone course would affect your feeling of inclusion in engineering before you took the course?)	Professional Connection	*"A lot of times, you'll be out with other engineers and they'll start talking with you about something, and then, it's kind of sitting there like I don't really know what they're talking about. And then you either fake it and pretend like you know something, but sometimes, they pick up on that. But it's like somebody comes up and talks about drones, I'll be able to immediately key in and be like, I know about that, and now I can converse with you."*
		"To talk more clearly with people and understand them, being in an in-classroom environment and having those other engineers like my partner for that presentation we did, and just being able to like talk with him and then like hearing like his ideas."

Engineering Identity (How did you expect this course to influence how you see yourself as an engineer before taking this class?)	Experience Building	*“I was expecting to build things which would definitely help me understand my place as an engineer.”*
	Knowledge Application	*“I think it brought me more into the development side of things versus just the conceptual physics and math base that the [university] starts out with.”*
		“Because actually having the little drone and building it and doing the code, seeing all the applications is something I can do.”
	Advanced Topic Learning	*“The first year of engineering is kind of basic, just boring math stuff versus actual engineering. So I thought it would help me become more of an engineer.”*
	Future Application	*“One of the guest speakers who talked about how civil engineers actually use drone like these atomics to scan bridges like thermally to check to see if there's like cracks developing and stuff like that. So that kind of also showed that in civil engineering, you are going to use drones. It's just like all drone use is going to be a big part of the civil engineering going forward.”*
	No Change	*“I really didn't expect much of a change, just another class on the class on Docket.”*

Note. [*]*Only the questions regarding students’ expectations about the course's impact prior to enrollment are listed in the table.*

Discussion

Self-Efficacy in Engineering

As shown in Table 5, the average self-efficacy of all participants increased throughout the semester by number. As Table 7 shows, first-year students had higher average self-efficacy (M = 5.00) than upper-year students (M = 4.67) in the pre-survey and both groups increased their self-efficacy on the post-survey (M = 5.25, M = 5.08, respectively). However, the non-parametric analysis did not show a significant statistical impact. In particular, upper-year students demonstrated a greater increase in self-efficacy over the semester, which is consistent with the findings presented in Table 8. Nevertheless, these results did not reach statistical significance.

Conversely, responses from students to open-ended survey and interview questions indicate that the introductory drone course may exert a greater influence on the self-efficacy of first-year engineering students compared to their upper-year counterparts. The interviews further revealed that first-year engineering students reported that the course not only positively enhanced their confidence in gaining hands-on experience and applying coding techniques but also increased their confidence in the technical aspects of hands-on learning. Unfortunately, due to the limited sample size, we were unable to quantitatively compare the impact of the course between first-year and upper-year students at this time, but we concluded that the introductory drone course had a positive effect on first-year engineering students’ self-efficacy.

Engineering Students’ Sense of Belonging

First-year students showed a higher sense of belonging (M = 4.67) than upper-year students (M = 4.00) on the pre-survey, and both groups increased approximately at the same rate on the post-survey. The open-ended responses indicate that the introductory drone course may have a greater influence on the sense of belonging among first-year engineering students compared to their upper-year students, as no responses were obtained from upper-year students on their sense of belonging in engineering. The integrated findings from the open-ended and interview responses of first-year engineering students further revealed that they experienced some anxiety about communicating with a group of engineers and engaging in discussions on technical topics, likely due to concerns about their understanding. However, participation in this course facilitated comprehension of the technical aspects of drone and enhanced their ability to communicate effectively with other engineers, fostering a greater sense of inclusion within the engineering community. Thus, the increase in first-year students' sense of belonging observed in this study reflects the type of social and intellectual integration described in Tinto's Theory of institutional departure theory as critical to student persistence in higher education. Although the limited sample size precludes a quantitative comparison of the course's significance between first- and upper-year students at this time, qualitative data addressed that the introductory drone course had a positive effect on the sense of belonging among first-year engineering students.

Engineering Identity

As shown in Table 7, first-year students exhibited a higher initial engineering identity ($M = 3.84$) compared to upper-year students ($M = 3.00$). While the engineering identity of first-year students increased ($M = 4.42$) over time, no statistically significant changes were observed. On the other hand, upper-year students' engineering identity remained unchanged ($M = 3.00$) in the post-survey. Furthermore, non-parametric analysis revealed no significant differences between first-year and upper-year students in pre- and post-survey responses, potentially due to the limited sample size of the study.

The open-ended responses suggest that the introductory drone course may have a greater impact on the engineering identity of first-year students relative to their upper-year counterparts. Interview feedback from first-year students indicates that, through the drone course, they better understood their role as engineers and recognized the practical applications of drones across various fields, such as thermal scanning of bridges for crack detection. This demonstrated how such applications are directly connected to their majors (e.g., civil engineering). These findings align with social identity theory, which suggests that shared experiences and interactions within a professional community contribute to the development of a collective identity among its members. However, as reported in Table 9, upper-year students indicated that the course did not alter their perception of themselves as engineers. It is plausible that upper-year students already developed their engineering identity through prior coursework, and therefore, the introductory drone course did not provide additional influence. In summary, although the introductory drone course appears to positively influence engineering identity, the comparison of its effects between first- and upper-year students warrants further investigation with a larger sample size.

Limitations of the Study and Suggestions for Future Research

The small number of participants was a major limitation for the quantitative analysis, potentially reducing the statistical power and the reliability of the quantitative findings and further amplifying the already conservative nature of the non-parametric analysis presented in Tables 6 and 7. This limitation can be addressed by increasing student participation, particularly among first-year engineering students. A future study could expand the sample size by accumulating data across multiple course offerings, thereby increasing the statistical power and improving the generalizability of the findings.

Conclusion

This study sought to address a gap in the literature on the effect of an introductory drone course on engineering students' self-efficacy, sense of belonging, and engineering identity. Overall, this study concluded that the introductory drone course had a positive effect on first-year students' self-efficacy, sense of belonging, and engineering identity. Not only are these effects similar for first-year and upper-level engineering students, but in some cases, such as sense of belonging, effects are also more noticeable for first-year engineering students. The findings of this study indicate that offering an introductory drone course to first-year engineering students has the potential to strengthen their foundational understanding of drone technologies while also fostering positive outcomes in students' self-efficacy, sense of belonging, and engineering identity.

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