Examining Professional Identity Practices in Autonomous Robots: Toward Professional Identity Development of Construction Engineering and Management Students

Mariam Tomori and Omobolanle Ogunseiju(✉)

Georgia Institute of Technology, Atlanta, GA 30332, USA
{mtomori3,omobolanle}@gatech.edu

Abstract. The construction industry is rapidly advancing technologically, with robotics playing a vital role in enhancing project efficiency, safety, and productivity. However, the industry faces a shortage of skilled technical workforce to advance the implementation of construction robotics. This can be due to the shortage of construction professionals who identify with implementing robotics in the industry. Hence, to prepare the future workforce in this field, it's crucial to develop students' professional identities, as their identities (self-perception) often correlate with career persistence, career success, and retention in the field. Likewise, high career identities among students also correlate with successful performance in future construction roles. As a first step to addressing this, it is imperative to investigate the practices of professionals who identify with the implementation of robotics in the industry. This study investigates the professional identity practices of industry experts utilizing autonomous robots, particularly unmanned aerial vehicles (UAVs), in the industry. Guided by social practice theory, semi-structured interviews were conducted with industry professionals who identify with construction robotics to elucidate the professional practical applications, actions, and steps taken in the deployment of UAVs on construction sites. This study provides the professional practices needed for students to identify as professionals who utilize UAVs in the construction industry. The findings reveal key technical skills in regulatory knowledge, operational flight skills, and data processing expertise. By bridging the gap between academic preparation and industry expectations, this study contributes to workforce development by elucidating the professional identity practices needed to advance robotics in construction.

Keywords: Autonomous robots · Professional identity practices · Construction education

1 Introduction

The construction industry continues to significantly contribute to the global economy with over \$ 10 trillion spent annually. With a projected increase of 50% in annual spending, the construction industry will grow exponentially and involve more complex

A. GhaffarianHoseini et al. (Eds.): SASBE 2024, LNCE 591, pp. 773–782, 2025.
https://doi.org/10.1007/978-981-96-4051-5_75

activities and resources. To effectively manage construction projects, autonomous robots such as unmanned aerial vehicles are revolutionizing the construction industry, bringing a wave of safety, accuracy, and efficiency [1, 2]. These high-tech robots excel in precision surveying, effortlessly enhancing safety by reaching dangerous areas and providing real-time data that drives efficiency and informed decision-making [2]. According to Watson [1], the majority of large construction projects already involve unmanned aerial vehicles (UAVs) at some stage in construction. As we enter the era of robotics, there is a need to cultivate a workforce adept at deploying autonomous robots in the construction industry. However, the professional identity practices that are crucial for nurturing students' alignment with construction autonomous robots remain unknown.

Few studies have focused on understanding professional identity practices (PIP) for developing student identity. Khosronejad et al. [3] applied the implied identity framework to empirical data from students' collaborative work, comparing different aspects of practiced engineering identity. Khosronejad [4] emphasized the role of web search in mediating students' participation and decision-making processes in collaborative activities, highlighting how technology influences professional practices and identities. Their study argues that implied identity, perceived through interactions and reflections, helps in understanding professional identity practices, thereby enhancing learners' identities. However, no study has examined PIP in the context of autonomous robots. This gap underscores the need for a deeper exploration of the necessary technical skills required to develop the professional identity of students within construction engineering education.

Hence, this study adopts a qualitative approach to understand and articulate the professional identity practices that enable practitioners to engage with and adopt autonomous robots effectively. By understanding these practices, students can be equipped with the requisite technical skills needed for implementing UAVs in the field of automation and robotics. Understanding the practices emerging from this research could assist educators in shaping a new generation of construction engineers with the requisite competencies to implement autonomous robots for advancing the construction industry.

2 Background

2.1 Review of Professional Practice in Construction Engineering Education

In higher education, professional practice, as defined by Curtin [5] is the required knowledge and skills needed for a student to succeed in a practical environment. This practice is often required to be undertaken as a part of higher education programs charged with the responsibility of preparing students for their future professional endeavors [6, 7]. However, while several studies have focused on professional engineering practices and workplace transitioning, professional practices in robotics are underexplored. For example, Riadh [8] broadly explored several factors contributing to professional practices in engineering. These include technical skills, communication skills, reflective practice, ethics and legal aspects, leadership and innovation, entrepreneurship, safety, and sustainability in design. These combined elements define best practices in engineering professionalism. Shepard [9] developed a comprehensive description of engineering practice through interviews with engineering faculty, aiming to understand the relationship between how engineering is taught and practiced. Based on the review of the literature, there is still a significant gap in understanding the practices of construction industry experts utilizing autonomous robots. This study aims to bridge this gap by identifying professional practices that need to be incorporated into construction engineering education.

2.2 Review of Unmanned Aerial Vehicles (UAVs) in Construction

Several studies have addressed the competencies required for operating UAVs, but none have thoroughly investigated UAV professional practices in real-world contexts. For example, Hildebrand and Hildebrand [10] explore drone use, emphasizing how hobbyists prioritize safety and regulations. Schmidt, Schadow [11, 12] evaluate key competencies for drone pilots, including knowledge, flight skills, cognitive abilities, interpersonal skills, and personality in drone pilot through an online questionnaire. Several studies discuss integrating drones into construction engineering curricula. For instance, Phang, Pusppanathan [13] integrates drones through a service-learning program for engineering students, enhancing their learning, sense of responsibility, and international exposure. Similarly, Nwaogu, Yang [14] assess the competencies required for construction education, recommending specialized drone training courses focused on safety and continuous professional development. Our study builds on these recommendations, emphasizing the knowledge and skills needed to effectively operate UAVs in construction, by interviewing experienced professionals.

2.3 Theoretical Framework: Social Practice Theory

This study employs Social Practice Theory (SPT) to understand how professional practices are enacted in the field of autonomous robots and how they contribute to identity development. SPT posits that identities are formed through action, over time, emerging from social experiences within cultural and historical influences. This aligns with Erikson's [15] view of identity, suggesting that identity may be influenced by interactions with others. According to Schatzki [16], practice is defined as a "temporally unfolding and spatially dispersed nexus of doings and sayings", which includes practical understanding, general understanding, rules, and teleo-affective structures. These elements are critical in shaping how construction engineering practices are performed and understood. Practical understanding involves knowing how to carry out desired actions through basic doings and sayings, thereby becoming a competent member of a practice [17]. In the context of construction engineering, this could refer to understanding how to use autonomous robots effectively in construction tasks, from planning to analysis and then to the presentation of results. General understanding corresponds to more abstract senses of the "worth, value, nature, or place of things" [17], such as valuing the integration of autonomous robots for their potential to improve efficiency, safety, and innovation in construction projects. Rules include "explicit formulations that prescribe, require or instruct actions to be undertaken" [17, 18]. This could refer to safety protocols, regulations, or operational guidelines for autonomous robots. Lastly, teleo-affective structures refer to a "range of acceptable beliefs to carry out project or tasks" [17, 18] and focus on "how practices should be carried out and how novices are socialized into these practices". This is crucial for students as they transition from academic settings to professional environments where they apply their knowledge and skills in real-world contexts. Therefore, this study seeks to provide answers to the **research question:** ***what are the essential knowledge and skills required for effective UAV implementation in construction?***

3 Methodology

This study employs purposive and snowball sampling methods to recruit fifteen (N = 15) construction industry practitioners who regularly utilize UAVs. Through semi-structured interviews, the objective is to delve into the experiences and perspectives of virtual design and construction professionals actively engaged with UAVs.

Data Collection. Firstly, participants completed a brief pre-interview survey online through Qualtrics (Fig. 1). This survey was designed to assess participants' suitability for the study, obtain consent and demographics, and evaluate their passion, knowledge, and experience with UAVs. After the survey, participants scheduled their interviews via a Doodle Poll link. The interviews were conducted at the School of Building Construction at the Georgia Institute of Technology, providing a conducive environment for participants to share their experiences. Data collection involved audio recordings and note-taking during semi-structured interviews. The semi-structured interviews included open-ended questions focused on the skills and practices needed to effectively implement UAVs with each lasting approximately one hour.

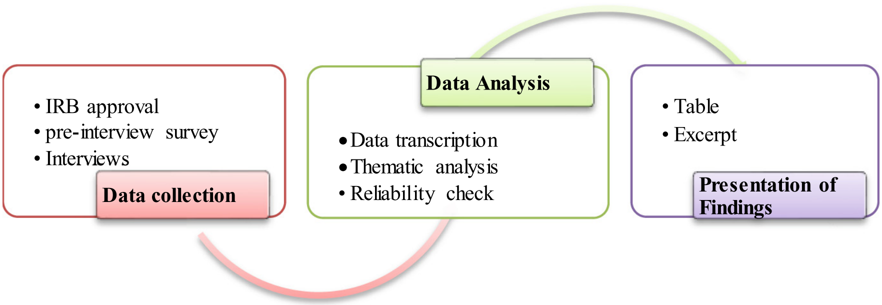

Fig. 1. Methodology flow chart

Data Analysis. After the completion of the tasks, the data were analyzed using a deductive phenomenological approach with NVivo software to identify technical identity practices demonstrated during the interviews. The audio recordings were transcribed verbatim using Microsoft Word, and the transcripts underwent deductive thematic analysis using a phenomenological approach facilitated by NVivo 14 software. This process involved familiarizing with the data, cleaning the transcripts, organizing and interpreting the data, and identifying meaningful themes. To ensure the reliability of the findings, intercoder reliability (ICR) assessments were conducted. Ten percent (10%) of the transcripts were reviewed by an independent coder, achieving an agreement level of 0.9.

Codes that did not achieve a rating of one were reviewed and recorded by the researchers to further solidify the study's credibility. Figure 1 shows the methodology overview.

4 Results

4.1 Overview of Participant Profiles

All the participants had either a Bachelor's or Technical degree and were currently employed in the Virtual Design & Construction sector. 90% and 55% of the participants were male and 35–44 years, respectively. Regarding industry experience, 20%, 60%, and 20% of participants have 1–5 years, 5–10 years and 16–20 years of experience, respectively. The company sizes represented are diverse, with 75% of participants working in large-sized companies and 25% in medium-sized companies. Notably, all participants demonstrated a strong interest and passion for UAVs, reflecting their enthusiasm for fostering innovation within the industry and indicating strong reliability of the study's findings.

4.2 Research Question: What Are the Essential Knowledge and Skills Required for Effective UAV Implementation in Construction?

The findings reveal a detailed understanding of the essential knowledge and skills required to implement UAVs effectively in construction projects. This section (Table 1) categorizes and elaborates on key areas such as regulatory knowledge, operational knowledge (flight skills), and data processing expertise.

Category 1: Regulatory Knowledge. Regulatory Knowledge for UAVs includes FAA regulations, No-fly zones, and drone pilot certifications (Table 1). These are further explained below.

Theme 1: FAA Regulations. A fundamental aspect of UAV operations in construction is understanding the Federal Aviation Administration (FAA) rules and regulations. This includes knowledge of airspace restrictions, such as the different classes of airspace and the restrictions associated with each. For instance, UAVs can generally fly up to 400 feet in unrestricted airspace, but this limit decreases near airports. Understanding registration requirements is also crucial, as drones above certain weight thresholds (e.g., over 55 lb) must be registered with the FAA as aircraft. Interestingly, 100% of the professionals point out the rules and regulations as important. A professional explained that *"They need to understand the FAA laws. That's going to be the biggest thing, rules and regulations, … I can't fly over 400 feet, you know? There are a ton of rules. And this UAV weighs this much and if it's over that I need to register it with the government. The biggest thing that students need to understand is rules.."*

Theme 2: No-Fly Zones. Professionals emphasized the importance of being aware of prohibited areas for drone flights, such as National Parks, highways, airports, and certain public spaces, without prior approval from Air Traffic Control (ATC). They highlighted the process of obtaining waivers for these restrictions to ensure legal compliance and operational safety.

Theme 3: Drone Pilot Certification. Recognizing the requirement for obtaining a Part 107 certification is critical. This certification validates a pilot's ability to operate UAVs commercially within the regulatory framework, ensuring both safety and legality in various environments.

Table 1. Essential Knowledge and Skills Required for Effective UAV Implementation

Categories	Themes	Codes
Regulatory Knowledge	FAA Regulations	FAA rules, including airspace restrictions, registration, and maximum allowed altitude
	No Fly Zone Awareness	Knowledge of areas where drone flight is prohibited without ATC approval
	Drone Registration	Register drones above a certain weight with the FAA
	Drone Pilot Certification	Pilots should be Part 107 certified
Operational Knowledge (Flight Skills)	Pre-flight planning & checks	Automated mapping, pre-flight checks, flight planning
	Purpose of Capture	Understanding job scope and areas of interest
	UAVs' applications	Site Inspections; Progress Documentation, Surveying, Marketing and Reporting, Volumetric measurement
	Safety protocols	Maintaining situational awareness during drone operations. Keeping the drone within sight during operation
	Manual vs Automated Flights	Understanding the difference between manual control and automated missions Maintaining smooth, steady movement for professional use
	UAV Hardware	Drones such RTK drones, controllers, propellers, SD cards, batteries, helipads, and communication tools like walkie-talkies or phones
	Soft skills	Soft skills such as communication and planning
	Personnel	Crew Requirements: Trained Pilot, trained visual observer
Data analysis &reporting Knowledge	Post-flight data processing	3D models, Ortho mosaic images, Point clouds, Topography, Drone mapping, Georeferenced TIF, and Volumetric Calculations
	Software & Tool	Photogrammetry, Panorama, Drone Deploy, and Pix4D

Category 2: Operational Knowledge (Flight Skills). Operational knowledge involved in the implementation of UAVs includes pre-flight planning and checks, purpose of capture, personnel, safety protocols, soft skills, and UAV applications, UAV hardware, manual & automated flight navigation. Findings emerging from each theme are discussed below.

Theme 1: Pre-flight Planning and Checks. Effective UAV implementation begins with meticulous pre-flight planning and checks. This includes automated mapping, pre-flight checks, and detailed flight planning to ensure mission success and safety. Utilizing software for pre-flight mapping helps in planning the flight path and ensuring coverage of the desired area. Also, thorough equipment checks, such as ensuring batteries are charged, firmware is updated, and the drone's physical condition is optimal, are crucial for preventing in-flight issues. Furthermore, drone setup and test flights are essential to verify operational functionality and control responsiveness, with professionals communicating with on-site teams to understand data capture requirements. It is also important that camera settings are adjusted for high-quality captures, managing filters, lighting, white balance, and resolution based on task needs. Additionally, site inspection is critical for understanding the terrain, identifying obstacles, and requesting necessary clearances.

Theme 2: Purpose of Capture. Understanding the scope of the project and the specific area of interest is essential for focused and efficient UAV operations. Clearly defining the objectives of the flight, such as capturing specific images or videos for volumetric calculations, Orthomosaic images, or progress tracking, guides the flight plan and data collection process.

Theme 3: Safety protocols. During drone flights, maintaining situational awareness and executing smooth, steady maneuvers are essential. This includes continuously monitoring the surroundings to avoid obstacles and ensure the drone remains within the visual line of sight. Understanding how weather impacts UAV performance and planning flights during optimal conditions is also important. Keeping the drone within sight at all times prevents loss of control and ensures safety. Also, maintaining visual contact with the UAV allows operators to monitor its position and respond to any issues. It is also important to continuously scan the environment to anticipate and avoid potential hazards.

Theme 4: UAV applications. Professionals in construction utilize UAVs for site inspections, ensuring safety and compliance from an aerial perspective. They employ UAVs for progress documentation and surveying, providing accurate data and visual records of construction phases. Additionally, UAVs are instrumental in marketing and reporting, as well as conducting precise volumetric measurements for inventory and logistics. This is similar to the findings of Yildizel and Calis [19].

Theme 5: *Manual vs. Automated Flights.* Balancing between manual control for precise situational adjustments and automated flights for systematic coverage of larger areas is crucial. Mastering manual flight skills is essential for situations where automated systems may fail or require human intervention while utilizing automated flight plans often ensures consistent and repeatable data collection, particularly in complex projects. Professional UAV operation requires smooth and steady movements to capture high-quality data and imagery. Practising controlled, steady movements to avoid jerky footage or data inaccuracies while using appropriate flight modes and gimbal settings helps maintain stability. Automated flight plans are programmed using applications like Drone Deploy, ensuring efficient site coverage and data accuracy.

Theme 6: UAV Hardware. Ensuring the proper selection and maintenance of UAV hardware, such as RTK drones, controllers, propellers, SD cards, batteries, helipads, and communication tools like walkie-talkies or phones, is critical for the efficient and safe operation of drones. High-quality and reliable hardware minimizes the risk of technical failures and enhances the precision of data collection. Similarly, knowing the right resources required for a specific task is crucial for capturing high-quality images. Most professionals stated that they change UAV lenses depending on the type of project.

Theme 7: Soft Skills. Soft skills such as effective communication and meticulous planning are essential for coordinating drone operations, ensuring that all team members are aligned and that operations are executed smoothly. Good communication prevents misunderstandings and enhances safety, while thorough planning helps anticipate potential challenges and devise effective strategies. Similar study [20], also identified soft skills as one of the key skills for effective implementation of UAVs.

Theme 8: Personnel. Having a trained crew, including a qualified pilot and a trained visual observer, is crucial for complying with safety regulations and ensuring successful mission execution. The expertise of trained personnel ensures that the UAV operations are conducted safely and effectively, minimizing risks and enhancing the quality of the outcomes.

Category 3: Data Analysis and Reporting Knowledge. Data processing expertise includes themes on post-flight data processing and software tools [20]. These are further discussed below.

Theme 1. Post-flight data processing. Findings revealed that visual inspections are conducted by comparing captured data with 3D models. The captured data are processed to generate outputs such as 3D models, Ortho mosaic images, point clouds, topography maps, and georeferenced TIF files. Precise measurement and analysis of site conditions and materials were identified as vital by the professionals. Professionals use UAV data to perform volumetric calculations of stockpiles, excavated materials, and other site elements to manage resources effectively. Integrating UAV data with other construction management tools and software provides comprehensive project insights and facilitates informed decision-making.

Theme 2. Software tools. Software tools like Photogrammetry, Panorama, Drone Deploy, and Pix4D are employed to stitch images together and analyze data. Other softares identify by Mohsan et. al. [21] are Skyworks Aerial System, SkyWards, RedBird, MapBox, Dedrone, and Airware. As revealed by a professional: *"Another thing is understanding the software for processing all those photos and videos."*

5 Discussion and Conclusion

This study investigates the professional identity practices of industry experts utilizing autonomous robots, particularly UAVs, in the industry. The findings revealed that the cultivation of expertise in UAV usage among construction professionals involves the understanding of regulatory knowledge, operational flight skills, and data processing expertise. Understanding FAA regulations and the necessity of certifications such as Part 107 instills a sense of responsibility and professionalism. Students equipped with this knowledge are better prepared to operate within legal boundaries, ensuring safety and compliance. This regulatory awareness also underscores the importance of adherence to industry standards, fostering a professional identity grounded in ethical and legal practices. Studies by Ljungblad, Man [22] conclude that being a professional pilots requires knowledge of regulations, training, and networks to ensure safer drone practices in society. Similarly, studies by Yildizel and Calis [19] also confirm the important of regulatory knowledge. Mastering pre-flight planning, understanding the purpose of data capture, maintaining situational awareness, and balancing manual and automated flight operations are critical skills for construction professionals. These operational competencies not only enhance technical proficiency but also contribute to the development of a meticulous, safety-conscious mindset [20]. Such skills are essential for students as they transition from academic learning to professional practice, reinforcing their identity as capable and reliable construction engineers. It is also important to equip students with the data analytical skills needed to transform raw data into actionable insights for informed decision-making and effective project management. By integrating UAV data with other construction management tools, students can also develop a holistic understanding of project dynamics, enhancing their ability to manage complex construction projects efficiently. These practices could serve as a guideline for other professionals and educators to gain a better understanding and expertise in UAV. Hence, the study's findings suggest the necessary skills and knowledge needed to be incorporated into the construction engineering and management curriculum in order to advance autonomous robots in the industry.

Acknowledgments. This material is based upon work supported by the National Science Foundation (Award #: 2306226). Any opinions, findings, or conclusions expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Watson, S.: How drones became crucial kit for construction sites (2022)
2. Liang, H., et al.: Towards UAVs in construction: advancements, challenges, and future directions for monitoring and inspection. Drones **7**(3), 202 (2023)
3. Khosronejad, M., Reimann, P., Markauskaite, L.: Implied identity: a conceptual framework for exploring engineering professional identity practices in higher education. In: 2015 IEEE Frontiers in Education Conference (FIE). IEEE (2015)
4. Khosronejad, M., Reimann, P., Markauskaite, L.: Engineering professional identity practices: investigating the use of web search in collaborative decision making. In: ASCILITE Publications, pp. 329–327 (2016)
5. University of Cambridge: What is Professional Practice? (2023)
6. Khosronejadtoroghi, M.: Implied identity: conceptualising professional identity development in higher education (2018)
7. Hager, P.: Professional practice in education: research and issues. Aust. J. Educ. **40**(3), 235–247 (1996)
8. Habash, R.: Professional Practice in Engineering and Computing: Preparing for Future Careers. CRC Press (2019)
9. Sheppard, S., Colby, A., Macatangay, K., Sullivan, W.: What is engineering practice? Int. J. Eng. Educ. **22**(3), 429 (2007)
10. Hildebrand, J.M., Hildebrand, J.M.: Situating hobby drone practices. aerial play: drone medium, mobility, communication, and culture, pp. 45–71 (2021)
11. Schmidt, R., Schadow, J., Eißfeldt, H., Pecena, Y.: Key competences and training of civil drone pilots. In: 27th ITS World Congress, Hamburg, Germany (2021)

12. Schmidt, R., Schadow, J., Eißfeldt, H., Pecena, Y.: Insights on remote pilot competences and training needs of civil drone pilots. Transp. Res. Procedia **66**, 1–7 (2022)
13. Phang, F.A., et al.: Integrating drone technology in service learning for engineering students. Int. J. Emerg. Technol. Learn. **16**(15) (2021)
14. Nwaogu, J.M., Yang, Y., Chan, A.P., Wang, X.: Enhancing drone operator competency within the construction industry: assessing training needs and roadmap for skill development. Buildings **14**(4), 1153 (2024)
15. Erikson, E.H.: Identity and the Life Cycle. WW Norton & Company (1994)
16. Schatzki, T.R.: Social Practices: A Wittgensteinian Approach to Human Activity and the Social. Cambridge University Press, Cambridge (1996)
17. Lisewski, B.: An examination of how tutor-practitioners conceptualise and enact practice-based-knowing in a small Higher Education Fashion School: a social practice theory approach. Lancaster University (United Kingdom) (2018)
18. Schatzki, T.R.: Peripheral vision: the sites of organizations. Organ. Stud. **26**(3), 465–484 (2005)
19. Yıldızel, S.A., Çalış, G.: Unmanned aerial vehicles for civil engineering: current practises and regulations. Avrupa Bilim ve Teknoloji Dergisi **16**, 925–932 (2019)
20. Av8prep, Key Skills and Competencies for Successful UAV Operators
21. Mohsan, S., Othman, N., Li, Y.: Unmanned aerial vehicles (UAVs): practical aspects, applications, open challenges, security issues, and future trends. Intell. Serv. Robot. **16**, 109–137 (2023)
22. Ljungblad, S., et al.: What matters in professional drone pilots' practice? An interview study to understand the complexity of their work and inform human-drone interaction research. In: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (2021)