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Enhancing Drone Operator Competency within the Construction Industry: Assessing Training Needs and Roadmap for Skill Development

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Abstract: Industry 5.0 is expected to solve the issue of job insecurity and reluctance to adopt emerging technologies in Industry 4.0 through increased workforce participation. To achieve that, proactive training should be afforded to enable the workforce to co-work with new technologies. Drones are an emerging technology increasingly adopted in construction, which has enormous data collection and safety implications when operational skills are inadequate. Yet, current drone training programs appear to be generic, and their ability to equip operators for flying tasks is questioned. This study aims to answer this question by assessing the adequacy of existing drone training programs and proposing training needs and strategies for drone operators in the construction industry. Data collected using semi-structured interviews from 22 purposively selected respondents in Hong Kong and desk research of websites were subjected to inductive content and thematic analysis using MAXQDA Analytics Pro 2022 software and narrative review. It was deduced that drone training courses in Hong Kong were mostly generic (UAS Pilot Training—Level 1, FPV operation). Interviewees considered existing drone training/training courses as inadequate for four reasons, including "lack of context-fitting considerations", "incompetence of drone operators", and "lack of demand/interest". Regarding the need for specialized drone training courses, two barriers and two training ecosystem themes emerged, with the high cost of specialized courses being a potential barrier to adoption since they could hamper enrolment. The training ecosystem themes were consistent with the "the training is inadequate" theme. This study proposes two drone operation training strategies: "competence-based training" and a "train-the-trainer" model. Drone training courses or programs under each training strategy should include (i) training content such as "safety training" and off-GPS training and (ii) knowledge and skill maintenance measures such as mandatory continuous professional development and retraining techniques. The proposed training strategies will equip operators to work efficiently and safely with drones. The study offers valuable references for training organizations and government authorities.

Keywords: construction industry; AEC; workforce; skill development; drone; UAV; SUA; training

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1. Introduction

Industry 4.0 (I4) brought about new approaches for effective data management [1] through enhanced interconnectivity of networks that use Internet of Things (IoT) and Internet of Services (IoS) via cyber-physical systems [2]. The crux of the Fourth Industrial Revolution was transforming manufacturing processes from entirely physical systems to cyber-physical systems (CPS) to improve efficiency [3]. Although I4 reduced production costs by 10–30%, quality management costs by 10–20%, and logistic costs by 10–30% [3], it has been demonstrated that the IoT in industry tends to advance technological aspects at the expense of social or human aspects [1]. This is a shortcoming of I4 that can hamper taking full advantage of its potential. Other challenges to completely digitized manufacturing systems being obtainable in I4 include a lack of necessary expertise in smaller organizations to transform I4 [4] and little focus on improving environmental sustainability [3]. Also, resistance may spring from labor unions as employees fear losing control over existing systems [3,4].

To mitigate the shortcomings and challenges of I4 and ensure the robustness of value creation, it has been proposed that there has to be a human touch at the center of I4 activities [1,5], which moves the Industrial Revolution to Industry 5.0 (I5). Even within I5, attention has shifted from the digitalization of I5 to care for human physical and mental health [6]. The future of manufacturing relies on smart collaboration between humans and robots [6]. Unlike in the Fourth Revolution, where traditional robots cannot work side by side with humans, in the Fifth Industrial Revolution, collaborative robots known as “cobots” are designed to work with human employees [7]. In I5, humans will work safely with robots as their robotic co-workers who will understand and collaborate with them [3]. I5 adds a human-centric, sustainable, and resilient concept to the Fourth Industrial Revolution [1]. It implies that this arrangement will lead to a more efficient and productive process, trusted autonomy, and waste reduction [3]. To enhance the full potential of the human–machine interface, attention must be paid to challenges and possibilities that will inhibit it. With the enormous advantages held by I5, it will be impacted by transitioning, societal, technical, and ethical challenges [8].

The technological advancements in I5 comprise those in I4 with a human factor twist, as human–machine collaboration would require a better-trained workforce to foster efficient, viable, and safe production advancements [8]. Therefore, in I5, employee protection and control, workforce learning, and development would be at the center of human factors compared to I4. Technological modernizations in I5 include blockchain technology, unmanned aerial vehicles (drones), 5G and beyond wireless technology, exoskeleton technology, mixed reality, additive manufacturing, and digital twins. Among these technologies, drones have been mostly adopted in the construction industry because they help in effective data sharing and resolving production and epidemic challenges on construction sites [9]. They have become a standard tool for mapping and surveying, security surveillance, visual and safety inspection, asset management, 3D/4D environment modeling, and progress monitoring in the construction and engineering industry [10].

Alojaiman [8] noted that drones are continuously being developed as a guideline for the Fifth Industrial Revolution, as the I5 concept would better link the industry by utilizing a unified platform, such as the IoT and drone innovation. Innovations in drone technology include smart drones, promising new application opportunities in building and infrastructure [11]. I5 will require highly trained individuals and staff to learn new abilities to accomplish its goals effectively [8]. A well-suited training suit nicknamed Education 5.0, entailing training, unlearning, and relearning, would help the workforce to master skills to conform to and accommodate the needs of I5. Since the construction industry is one of the largest markets for drones [12,13], developing its own Education 5.0 roadmap for drones is imperative. As new technologies are introduced, the architecture, engineering, and construction (AEC) industry needs to increase overall workforce training and investment to prepare workers for the new skill demands of emerging technologies [12].

There have been numerous empirical studies on using drones within the I5 framework [13–15], but very few of those studies have been performed in the construction industry, most of which focused on drone applications. They include the study by Sharma and Arya [11], who used IoT and a cloud server to implement a drone network to track landfill site air quality in real time in hilly areas or distant locations. Liu et al. [16] considered the application of parallel drones in I5, particularly the cost and efficiency of using them for inspection in transmission line projects. Skill and workforce development are integral to preparing the human aspect of I5 for the new skill demands from collaboration and improved drone technologies. Yet, they have not been given much attention.

With technology altering jobs and how jobs are executed, there is an immense need for skilled people [17]. The construction industry requires a highly skilled workforce with technical and soft skills for effective operations [18,19], but there has been increased documentation of a shortage of skilled workers, resulting in a decline in the quality of jobs and an increase in safety-related incidents [18]. In the construction industry, drones are an emerging technology essential to its activities [9,20]. However, there has been a challenge in finding skilled and knowledgeable manpower to effectively utilize drones for construction operations [21]. For instance, the Korean construction industry faces difficulties using drones and laser scanners because of shortages in the skilled workforce. Drone applications within the construction industry are diverse. As drone technology has matured, human error is increasingly becoming a primary contributor to drone-related accidents [10,22]. The use of drones may create new safety challenges for surrounding people and assets. However, drone operator skill development seems to lag far behind technological advances. When I5 is adopted, proactive training should be afforded to trainees and trainers, making the construction workforce capable of co-working with new technologies. The existing training programs for drone operators are generic, excluding trade-specific training. Whether such generic training is sufficient to equip drone operators to conduct flying tasks is questioned.

In order to address this gap, the aim of this study is to propose training needs and strategies for drone operators on construction jobs by providing evidence from Hong Kong. To achieve this, the research objectives were (i) to assess the adequacy of existing drone training courses to meet the needs of the construction industry and essential training content for specialized drone training courses required to meet construction needs, (ii) to determine the availability of training grounds and their adequacy for practical drone flying skills in Hong Kong, and (iii) to determine drone operator proficiency assessment methods or criteria. This paper addresses drone operator skill development. It contributes to the existing body of knowledge on workforce development by identifying the key issues and needs for essential skills mastered by drone operators. Practically, the proposed training strategies will equip operators to work efficiently and safely with drones. The study provides valuable information for training bodies and government authorities to aid the implementation of the proposed training strategies. Drone operator training will meet emerging industry needs and avoid potential gaps between the demand and supply of the skilled workforce in the Industrial Revolution era.

2. Literature Review

2.1. Workforce Development

Detsimas et al. [23] stated that construction employees experience a lack of knowledge and skills when responding to the complexity associated with construction work. This echoes the literature suggesting that skill shortage is a concern in different nations, including Asia, Africa, and Europe, as it threatens the ability to deliver on target housing infrastructure [17]. There are no generalized definitions for workforce development. Jacobs and Hawley [21] defined workforce development as "the coordination of public and private sector policies and programs to provide individuals with the opportunity for a sustainable livelihood and help organizations achieve exemplary goals, consistent with the societal context".

According to Skills Australia (2010), cited in Harris and Short [24], workforce development is defined as "policies and practices which support people to participate effectively in the workforce and to develop and apply skills in a workplace context, where learning translates into positive outcomes for enterprises, the wider community and individuals throughout their working lives". In simple terms, per Jacobs and Hawley [21], workforce development involves job training and education for workers and a broader range of human performance interventions. Workforce development accomplishes three basic things: it helps employers obtain a skilled workforce, helps individuals succeed in the workplace, and helps the organization meet its goals [21]. With a focus on enabling drone operator skills, this study defines workforce skill development as a management tool used to reinforce individual training and improve the effectiveness of an organization's employees to enhance performance [17].

Giloth [25] opines that workforce development should focus on regions in addition to cities and neighborhoods. This emphasizes the significance of societal context in workforce development. In this study, we explore skilled workforce development for drone operators in Hong Kong to understand training and organizational peculiarities and needs within the Hong Kong construction industry. Irrespective of the definition of workforce development, training is at its core.

2.2. Drone Applications and Workforce Development

The tasks of successfully flying a drone require skills and experience in operating the equipment, image collection, and data editing to fit the objective of the intended operation [26]. Skills are required to deliver quality jobs to achieve productivity and economic value [27]. However, there has been a challenge in finding skilled and knowledgeable manpower to effectively utilize drones for construction operations [26]. The consequences of such skill shortages include low productivity, poor quality, and training and recruitment expenses [17]. Skill development would help to address the challenges of meeting the demands of changing economies and new technologies [17]. Hence, workforce development through training is paramount for effective drone operation.

2.3. The Research Problem

Empirical studies on drone applications within the AEC industry have primarily focused on drone application areas, safety and health management, data processing and management, training aid, and flight control within the I4 framework [28–37], with only a few conducted within the I5 framework [11,16]. Sharma and Arya [11] used the IoT (Internet of Things) and a cloud server to implement a drone network to track landfill site air quality in real time in hilly areas or distant locations. Liu, Sun, Cao, Chen, Pan, Dai and Pan [16] considered the application of parallel drones in Industry 5.0, especially the cost and the efficiency of using them for inspection in transmission line projects. The scope of Sharma and Arya [11] and Liu, Sun, Cao, Chen, Pan, Dai and Pan [16] did not cover workforce development. However, workforce development is integral to preparing the human aspect of I5 for the new skill demands from collaboration and improved drone technologies since it encompasses different areas of education and training.

Studies on drone education within the construction industry [26,37–43] have mainly focused on drone careers, curriculum development, and training at the tertiary education level, not specifically on the workforce needing upskilling. Al-Tahir [39] suggested that drones should be integrated into undergraduate programs using three levels to promote drone skills for geomatics purposes. The first level involves a capstone project, the second level includes a short session or module in a course, and the third level involves a complete course. Sanson [38] promoted drone knowledge and skills by adopting drones as teaching aids for undergraduate survey programs. Sanson encouraged the use of drones in surveying classes for construction mapping and road layouts. He, Lu, Song and Liu [40] cultivated a new way of surveying and mapping among tertiary institution students using a virtual simulation experiment of drones to help students learn and master how to obtain and process drone data into 3D models. Moon and Ock [26] conducted a preliminary study on the application of drones for data collection to determine the required curriculum for teaching drones to undergraduates studying construction and engineering in Korea. All of these studies were focused on preparing undergraduates to enter the workforce.

Nonetheless, technological advancement alters the skills needed, educational requirements, and job design in the workplace [21], which means some skilled workers may need upskilling since the adoption of drones for construction projects. With respect to workforce development among construction personnel who interface with drones, Cheng, Gheisari and Jeelani [43] investigated the effectiveness of using 360 virtual reality to educate construction workers on the safety challenges that drone presence poses within the construction site. The training aimed to improve construction workers' understanding of working safely with drones. Onososen et al. [44] examined the ability to use virtual reality to train drone operators and first-time users to safely fly drones for material handling and delivery on construction sites.

Contrary to previous studies, this study identifies the training needs of the skilled workforce in the construction industry by providing evidence from Hong Kong to develop a training roadmap for drone operators carrying out construction-related jobs. Hong Kong is a densely populated city with many high-rise buildings due to the scarcity of urban land [45]. Given the geographical peculiarities of Hong Kong and the skill shortage in using drones in a similar economy, particularly Korea, it is imperative to determine drone flying skills and needs in order to ensure the safe use of drones for construction tasks.

3. Methodology

A qualitative methodology involving the use of primary and secondary data was adopted for this study. A qualitative methodology was employed because quantitative methods will not adequately answer the research questions. Qualitative designs help to shed light on hidden patterns or the reasons behind observed patterns, especially the invisible ones [46]. As illustrated in Figure 1, data were collected using semi-structured interviews and desk research of websites. Desk research of websites in Hong Kong and three jurisdictions (the United Kingdom, the United States of America, and Australia) at the forefront of drone adoption in the construction industry was carried out using the Google database. According to Nwaogu, Yang, Chan and Chi [9], the US, China, the UK, and Australia are leading the research on drone applications in the construction industry with respect to collaboration and contribution. The desktop search was used to determine the training syllabus and training modes adopted by different jurisdictions.

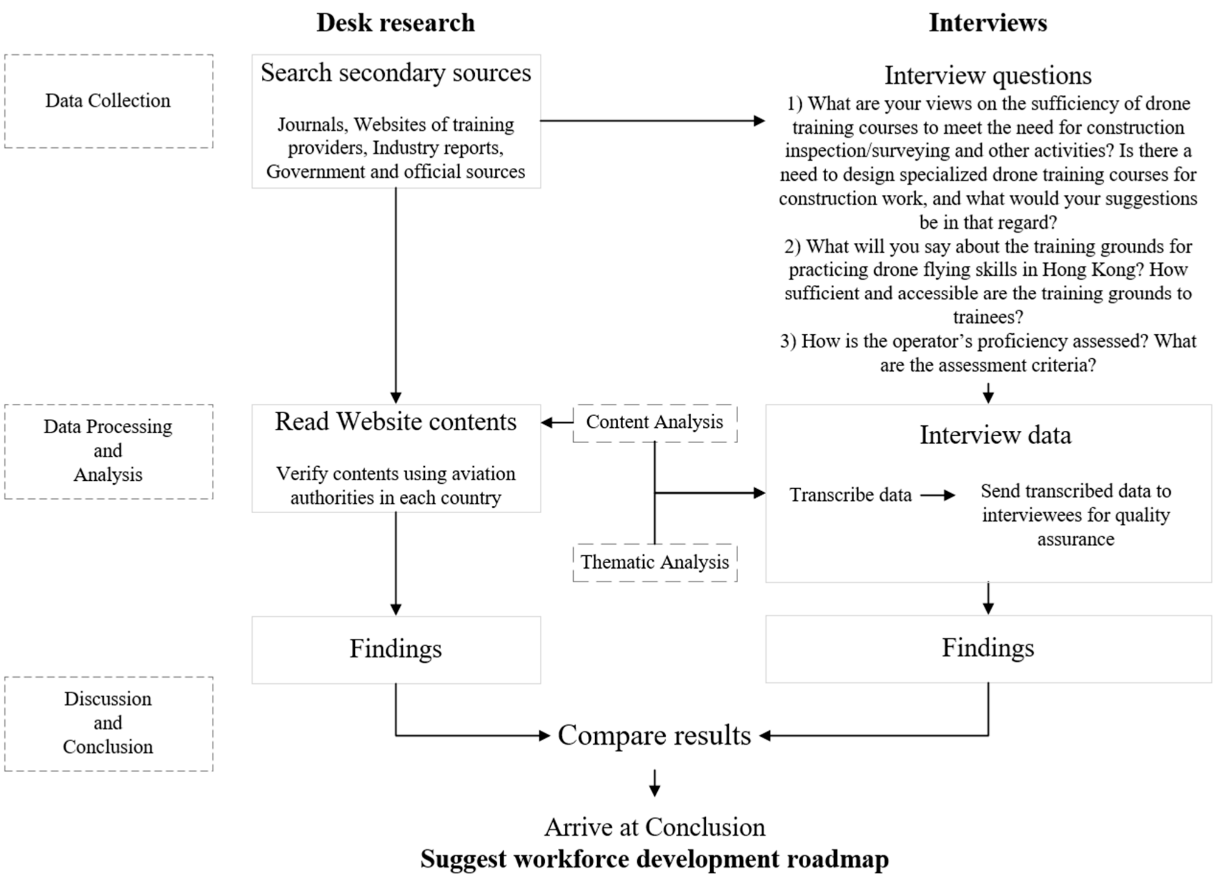

Figure 1. Methodology.

The interview surveys involved 22 purposively selected respondents to understand the status quo and industry needs for drone operator training. Purposive sampling was used to determine the study participants because it allows researchers to select participants or cases expected to be relevant based on previous experience or theory [46].

3.1. Data Collection

3.1.1. Desk Research of Drone Courses

An online search was undertaken via Google Chrome to determine training courses available for drone operators using the search terms: (drone OR UAV OR UAS) AND "training" AND "Hong Kong", "(drone OR UAV OR UAS)" AND "training" AND "(United Kingdom OR UK)", "(drone OR UAV OR UAS)" AND "training" AND "Australia", "(drone OR UAV OR UAS)" AND "training" AND "(United States of America OR US OR USA)", AND "(drone OR UAV OR UAS)" AND "training" AND "USA". Other search phrases were also utilized based on the results of the search strings. Training courses were collected from company websites, and to avoid repetitions, courses retrieved in one country were not repeated in another.

3.1.2. Interview Surveys

Interviews help researchers to gain insight into a person's experiences, opinions, and motivations [46]. Semi-structured interviews were used to collect data from 22 purposively selected interviewees because they are interactive and allow new topics to emerge, which can be queried by the researcher [46,47]. The interviewees included drone operators, drone trainers, and construction practitioners in Hong Kong. Each interview took around 30 min and was conducted via Zoom. The interview was recorded and transcribed immediately so that any unclear statements could be completed through memory of the spoken words from the interviewee or when sent out to the interviewee during the quality assurance process. In the quality assurance process, transcribed data were sent to participants so they could ascertain if their responses were transcribed correctly.

3.2. Data Analysis

The interview data were subjected to inductive content and thematic analysis via MAXQDA Analytics Pro 2022 version 22.2.0 software developed by VERBI GmbH. MAXQDA Analytics Pro 2022 is qualitative data analysis software that can index and automatically code extensive volumes of text [48]. MAXQDA Analytics was employed because it also supports quantitative analysis and has a variety of ways in which qualitative can be represented using visualization tools called MAXMaps. A saturation test was conducted by coding each interview transcript and noting if new aspects or nuances would emerge in subsequent interviews, as described in Hennink et al. [49]. Theoretical saturation was achieved when interviews displayed repetitive codes, and no additional codes were identified. Each transcript was labeled with the interviewee's first name and saved as a Microsoft Word document.

The transcripts were imported into the document section of MAXQDA to aid in a question-by-question comparison of the interviews for analysis. To guarantee the reliability of the data analysis, themes and categories were drawn in two stages to eliminate potential bias. This involved reading transcripts for each question to interpret the data and deduce a pattern or phenomenon, after which themes were developed. Each theme was then assigned to every interview with which it aligned. Those coded themes appeared in the lower left pane (i.e., code system) of the MAXQDA analysis window, and whenever a theme was clicked upon, all coded transcripts for that theme were displayed. Also, the number of responses (coded segment/documents) for each theme was displayed in front of the theme. The themes were checked by at least two authors, who agreed upon which themes needed refining. Some themes were refined based on representative terms in the literature. When themes were grouped, they became sub-codes of the parent category.

The themes were presented using the MAXQDA report tool "Summaries with Coded Segments" and MAXMaps (particularly "Code-Subcodes-Segments Model"). The "Code-Subcodes-Segments Model", was used to display the network on drone applications because it can display extensive information about a particular code, coded segments, and subcodes [48]. Likewise, the data collected from desk research were subjected to content analysis whereby the information from different websites was carefully read and compared, after which the importance of each one was defined. The results were reviewed again, and the final results were presented in narrative form using a table.

4. Results

4.1. Desk Research of Drone Courses

Data collected from websites using the search terms described in the methodology are displayed in Table 1. A total of 13 drone training courses were retrieved, including the A2 Certificate of Competency (A2 CofC) Course, General Visual Line of Sight (GVC or General VLOS) Course, Survey Course, Beyond Visual Line of Sight (BVLOS) Operational Safety Cases, First-Person View (FPV) Introduction Course, conversion courses (such as Remote Pilot Licence (RePL) to Civil Aviation Safety Authority (CASA) Pilot and PfCO to GVC Conversion Course), and Remote Pilot Licence (RePL) Course. The course duration ranged from a few hours to 10 days of training, and learning primarily involved theoretical and practical knowledge.

4.1.1. A2 Certificate of Competency (A2 CofC) Course

This course is unique to the UK and one of the first drone courses required to fly drones for recreational or commercial purposes. It is a highly theoretical course that gives the operator the knowledge needed by the UK Civil Aviation Authority (CAA) to operate a drone in the A2 category. The practical flight training can be self-guided. The A2 subcategory allows drones to be flown close to uninvolved people (as close as 5 m) with a drone weighing up to 2 kg. The A2 CofC course enables the flying of A1 and A2 drones in the A1 and A2 sub-categories of the open category classification in the UK [50]. Drones that can be flown in this category include hobby drones suitable for construction photography and videography, such as DJI Mavic Air, Mavic 2 Series, Mavic Pro, DJI Mavic 3 Series, and Phantom 4 Pro [9,50].

4.1.2. Visual Line of Sight (General VLOS) Course

Visual line of sight (VLOS) is a flight operation in which the operator can clearly see the drone in flight and its surrounding airspace in order to monitor and safely operate it without equipment and human assistance [51]. Equipment such as telescopes or binoculars are not permitted in VLOS operations, so the remote pilot's eyes must monitor the drone and its surrounding airspace. VLOS courses are available in several countries, including the UK, South Africa, and Australia. A Visual Line of Sight (VLOS) operator certificate is required for a drone operator or company to be able to fly a drone commercially [52]. The VLOS courses include the General Visual Line of Sight (General VLOS) course (GVC) in the UK and Certificate III in Aviation (Remote Pilot—Visual Line of Sight) in Australia.

4.1.3. General Visual Line of Sight (General VLOS) Course (GVC)

In the UK, this course is aimed at commercial drone pilots. The GVC remote pilot competency certificate provides the qualification suitable for Visual Line of Sight (VLOS) operations within the specific category [50]. The GVC qualification is needed if the operator operates their drone in the specific category, in which case, operational authorization is required [53]. The specific category of CAA covers drone operations that involve using drones outside the boundaries of the open category and operations that present a greater risk than those in the open category [53].

The operational authorization document outlines the operator's dos and don'ts, privileges, and limits [53]. Drones for operations in the specific category include commercial drones that are excellent for inspections and mapping, such as DJI M300 RTK and Matrice 200 Series [9,50].

4.1.4. PfCO (Permission for Commercial Operation) to GVC Conversion Course

This conversion course is unique to the UK. It is meant for those with a prior certification who want to fly their commercial drone in the new special category (for most commercial or enterprise drones). The operational authorization replaces the PfCO (Permission for Commercial Operation), and to obtain the operational authorization, a drone pilot must have a GVC [54].

4.1.5. Beyond Visual Line of Sight (BVLOS) Course

Unlike in VLOS, flight operation for BVLOS goes beyond the visual line of sight. This implies that drone flight is not in the operator's line of sight, and the aid of equipment (such as technology) and humans is required to monitor the flight and fly the drone safely [51]. The equipment and human assistance to control the drone securely in BVLOS include sensing tools and technology such as the ground control station (GCS) or remote pilot station (RPS) [55]. Those with BVLOS certification can fly a drone for long-range inspections, long-range aerial surveys of land or water, monitoring, and maintenance purposes.

At the moment, across several jurisdictions (e.g., Australia, the UK, Hong Kong, the US), approval has to be granted to fly a drone beyond the visual line of sight (BVLOS) [56,57]. The certification courses include Beyond Visual Line of Sight (BVLOS) Operational Safety Cases in the UK and BVLOS Outside Controlled Airspace (OCTA) in Australia.

4.1.6. First-Person View (FPV) Course

First-person view (FPV) provides an immersive experience like virtual reality for pilots as the feed from the flying drone is transmitted in real time [58]. Within an FPV system, drone flights can be visually monitored in real time via goggles, a mobile phone, or tablet screen, making it suitable for monitoring construction site operations [59]. The modules in a typical FPV course include practical and theoretical demonstrations, an overview of FPV equipment, FPV equipment for flight, including goggles, controller, and drone, basic maintenance, and practical exercises.

Flying FPV is legal in Australia, the UK, and the US, but restrictions and flight requirements abound because of limited situational awareness associated with FPV flight, which may jeopardize safety [60]. In the US, in addition to the Federal Aviation Administration (FAA) Part 107 drone license, a Level 1 Technician License is required to operate FPV drones unless the FPV system has an exception, e.g., the DJI FPV system. FPV courses are available in Australia, the UK, the US, and Hong Kong (HK). An example of FPV courses includes the First-Person View (FPV) Introduction Course in the UK.

Table 1. Drone Training Courses in the UK, HK, Australia, and the US.

Jurisdiction	Drone Course	Course Provider (Example)	Modules (Example per Course Provider)	Mode of Teaching and Assessment	Training Duration	Remarks
United Kingdom	A2 Certificate of Competency (A2 CofC) Course	Flyby Technology	• Basic videography and photography • Real estate from a distance • Real estate fly over	• Theoretical course • Practical flight training can be self-guided • Examination	1 day	This certificate is needed in the UK to fly a drone in the open fly category. Completion of an Operations Manual is required.
	CAA General Visual Line of Sight (GVC or General VLOS) Course	Flyby Technology	• Basic videography and photography • Real estate from a distance • Real estate fly over • Inspection work • Photogrammetry	• Theoretical course • Practical flight assessment • Examination	12 h to 2.5 days	This is required to fly a drone that weighs between 0 and 25 kg, i.e., drones that would require operational authorization. Completion of an Operations Manual is required.
	PfCO (Permission for Commercial Operation) to GVC Conversion Course			• Theoretical refresher course • Examination	1 day	A CAA Operational Authorisation (formerly PfCO) or NQE Recommendation Certificate is a prerequisite to start this course.
United Kingdom	Survey Course	Drone Pilot Academy	• Planning a mission for multiple flights and overlaps • Data capturing • Data processing • Setting out, ground control points	• Theoretical course • Practical	1 day	
United Kingdom	Beyond Visual Line of Sight (BVLOS) Operational Safety Cases	Drone Pilot Academy	• Beyond visual line of sight • Heavy lifting • Carrying sensitive data • Humanitarian aid logistics	• Theoretical course • Practical		This is an Operational Safety Cases.
	First-Person View (FPV) Introduction Course	Drone Pilot Academy	• Practical and theoretical demonstrations • Overview of all FPV equipment, and maintenance	• Theoretical course • Practical	1 day	

Table 1. *Cont.*

Jurisdiction	Drone Course	Course Provider (Example)	Modules (Example per Course Provider)	Mode of Teaching and Assessment	Training Duration	Remarks
Hong Kong	Ground School	UAS Solutions (IAMUAS)	• Air law and responsibilities, airspace operating principles, aircraft knowledge • Meteorology, human factors, airmanship, and aviation safety • Planning and operating procedures	• Theory Course • Theory • Examination	2 days	
Hong Kong	UAS Pilot Training—Level 1	DJI Academy	• Live demonstration • Flight operations (designated maneuvers, FPV flight, Inspection mission)	• On-Site Training • Theoretical course • Practical flight • Examination (theory and practical)		Practical training takes place at 50,000 square feet facility at Yuen Long (see Figure 2).
Hong Kong	UAS Pilot Training—Level 1	DJI Academy	• Overview of DJI commercial drone ecosystem and latest drone technology • General flight safety knowledge • Maintenance operations	• Theoretical course (via online learning) • Examination		
	Inspection Training	DJI Academy	• Flight safety • Panoramic videography and photography, capturing from multiple angles • Automated flight mission • Beyond visual range (BVR)/BVLOS inspection • Analysis and processing of data	• Theoretical Course • Practical • Examination (theory and practical)	8 days	The learner would learn basic drone flying skills and inspection skills.

Table 1. *Cont.*

Jurisdiction	Drone Course	Course Provider (Example)	Modules (Example per Course Provider)	Mode of Teaching and Assessment	Training Duration	Remarks
	Small Unmanned Aircraft (SUA) Advanced Rating	Hong Kong Productivity Council (HKPC)	• Airspace classification and restrictions for aircraft • Aircraft general knowledge • Meteorology, airmanship, and human performance • Operations manual, flight planning and procedures	• Theoretical course • Practical • Examination (theory and practical)	5 days	The learner should hold a "Remote Pilot Certificate" issued by the Civil Aviation Department (CAD) throughout the course and log at least two hours of flight as a remote pilot within the preceding 12 months before being recommended to CAD [61].
	Practical Workshop on Small Unmanned Aircraft (SUA)	Vocational Training Council (VTC)	• Drone knowledge (2 h) • Principles of flight, major systems and components, operational limitations, system maintenance, and battery management • Normal operations, basic maneuvers, flying a designated pattern, location/altitude, and hover hold	• Theoretical course • Practical • Examination (theory and practical)	6 h	The learner should hold a "Remote Pilot Certificate" issued by the Civil Aviation Department (CAD) throughout the course and log at least two hours of flight as a remote pilot within the preceding 12 months before being recommended to CAD [61].
Hong Kong	FlightPro Small Unmanned Aircraft (SUA) Advanced Rating Course	FlightPro Drone Solutions	• Air legislation and publication, airspace in Hong Kong • Flight planning and procedures • Weather, pre-flight actions and post-flight action, normal operations and basic maneuvers	• Theoretical course • Practical • Examination (theory and practical)	5 days	The learner must hold a "Remote Pilot Certificate" issued by the Civil Aviation Department (CAD) and log at least two hours of flight within the preceding 12 months before being recommended to CAD [61].
Australia	Remote Pilot Licence (RePL)	UAV Training Australia	• Remotely piloted aircraft (RPA) law and systems, meteorology • Human factors • Operational flight planning		5 days	Anyone who wants to use drones for work purposes requires the RePL and must adhere to the Standard Operating Conditions laid out by CASA.

Table 1. *Cont.*

Jurisdiction	Drone Course	Course Provider (Example)	Modules (Example per Course Provider)	Mode of Teaching and Assessment	Training Duration	Remarks
	Remote Pilot Licence (RePL) CASA Pilot Conversion	UAV Training Australia	• Instructor-led classroom theory • Online theoretical modules	• Five hours of practical flight time plus CASA flight assessment	2 days	The course offers individuals with aviation experience, holding a Private Pilot Licence (PPL), Commercial Pilot Licence (CPL), or an Airline Transport Pilot Licence (ATPL), an entry into the drone industry.
Australia	Aerial Photography course	UAV Training Australia	• Autonomous mission setup • Photography styles, angles, lighting, filters, and software • High-resolution 3D surface models		2 days	This is an advanced course, participants move beyond the basic training. Course content includes data processing and image editing.
USA	Professional Drone Pilot	Carolina Drone Academy	• FAA 14 CFR (Code of Federal Regulations) Part 107 • Airspace classification, requirements, flight restrictions • Meteorology, human factors affecting pilot performance • Radio communications procedures • Maintenance and pre-flight inspection procedures		3 days	
	Advanced Drone Photography & Videography	Carolina Drone Academy	• Hardware & controller settings • Software configurations • Dialing in camera options • Key flight maneuvers		2 days	This course covers camera options, various settings, accessories, and best practices for maximizing the use of a Drone for taking aerial photos and videos.

Figure 2. OTG [62] An outdoor drone training ground in Hong Kong.

4.2. Interview Survey

The demographic information of the interviewees is detailed in Table 2. The interviewees included construction professionals (architects, building inspectors, civil engineers, land surveyors), drone system developers, and drone trainers. The interviewees had an average of 11 years of experience working in the industry, with the majority, 10 (45.5%), reporting that they had 6 to 10 years of experience. The interviewees' profession and years of experience indicated they had the expertise to provide reliable information for the study.

Table 2. Demographic characteristics of the interviewees.

Variable	Attribute	Frequency (*n*)/Percentage (%)
Work experience	1–5 years	5 (22.7)
	6–10 years	10 (45.5)
	11–15 years	3 (13.6)
	16–20 years	2 (9.1)
	25–30 years	2 (9.1)
	Total	22 (100)
Profession	Drone systems developer	3 (13.6)
	Drone service provider	4 (18.2)
	Drone trainer	2 (9.1)
	Researcher	2 (9.1)
	Pilot	2 (9.1)
	Architect	2 (9.1)
	Building inspector	3 (13.6)
	Civil engineer	2 (9.1)
	Land surveyor	2 (9.1)
	Total	22 (100)

All of the 22 (100%) respondents indicated the activities for which they use drones. As shown in Figure 3, the content analysis revealed four primary application areas of drones among the interviewees, with the majority (76.5%) being inspection, followed by mapping and surveying (64.7%), light detection and ranging (LiDAR) and aerial photography (23.5%), and search and rescue (5.9%).

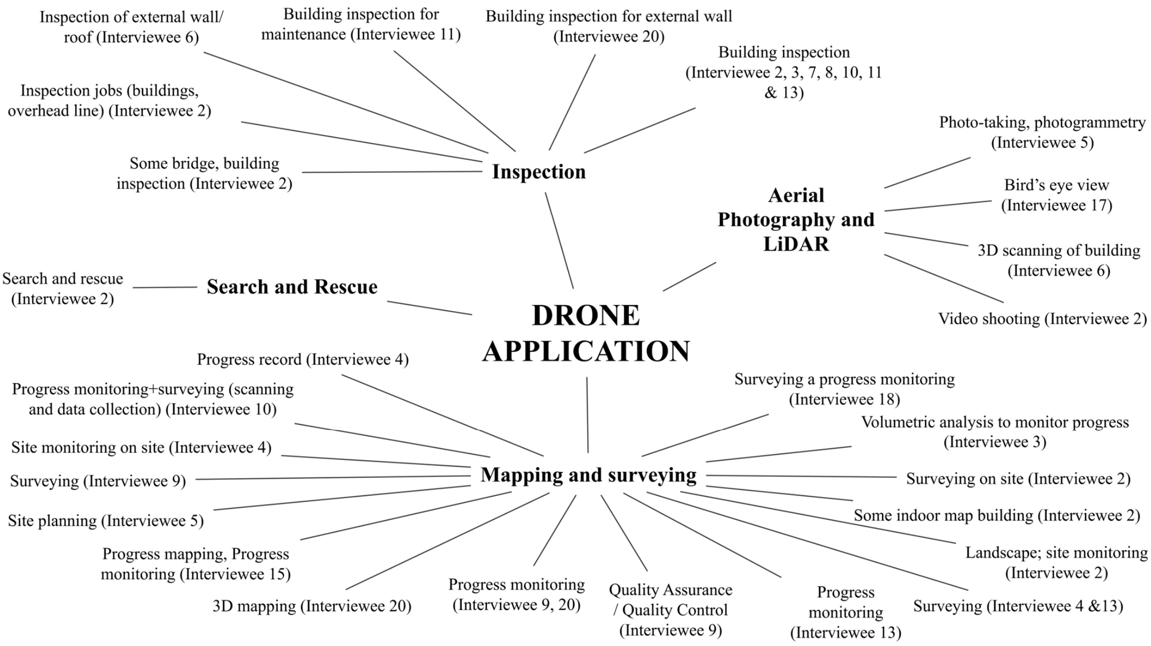

Figure 3. Areas of drone application among interviewees.

4.2.1. Drone Training

The respondents provided information on drone qualifications, courses, licenses, and training provider. The training courses undertaken by the respondents included FPV and SUA Advanced Rating. Comments on their drone licenses include "I hold a UK pilot license", "drone training was provided to my team by a UK professional team", and "Civil Aviation Department issued my drone pilot license upon completing drone training from an approved training institute in Hong Kong".

Sufficiency of Drone Training Courses

The respondents commented on whether drone training courses are sufficient to meet the needs of construction inspection/surveying and other activities. The majority (85.7%) noted that the training courses were inadequate, while 14.3% believed that the training courses were adequate. The responses are listed in Table 3. Four themes emerged, which were about the reasons why the training courses may be inadequate.

Table 3. Sufficiency of drone training courses for construction activities.

Category	Themes	Specific Response
Training courses are inadequate	Lack of context-fitting considerations	Generic training courses. Most training refers to other countries, but overseas situations differ greatly from those in Hong Kong. In Hong Kong, buildings and roads are quite congested, so the existing generic training is questioned.
	Incompetence of drone operators	It is difficult to find competent/skilled operators.
		It is difficult to find experts capable of carrying out various drone operations.
	Demand/interest	Whether the training courses are sufficient depends on the market demand.
		The in-house drone operators did not receive special training. They only have experience/interest in drone operation.
	Shortage in specialized drone courses	No specialized training; existing training focuses on photography.
Training courses are adequate		Existing training courses can fulfill the requirements of building. inspection/surveying because they are easy tasks.

The Need for Specialized Drone Training Courses

The interviewees lamented a lack of training courses for advanced drone operations in Hong Kong, noting a need to design specialized training courses to fit applications within the construction industry. Table 4 outlines some challenges in the drone training ecosystem that necessitate the development of specialized training courses for construction as well as barriers that could hinder their creation. High cost and demand/interest emerged as barriers that can impede the development of specialized drone training courses. One interviewee noted that specialized courses would be more expensive than regular courses, which could hamper subscriptions. One interviewee responded along the lines of supply and demand; he mentioned that there appears to be a shortage of specialized courses, but when the interest in or demand to use drones for specific construction tasks increases, training courses must be designed to accommodate such needs. Two themes (i.e., scarcity of skilled drone operators and the inability of existing training to fit context needs) were about the challenges in the present training ecosystem that call for the need to design specialized drone training courses for construction.

Table 4. The need to craft specialized drone training courses.

Category	Themes	Specific Response
Training Ecosystem	Scarcity of skilled drone operators for some operations	It is difficult to find experts capable of carrying out various drone operations. Therefore, there is a need for specialized training.
		It is difficult to find competent/skilled drone operators.
	Inability of existing training to fit context need	No specialized training. Most of the training refers to other countries. The situation overseas is quite different from that in Hong Kong. Buildings/roads are quite congested, so the existing generic training is questionable.
Barriers	Demand/interest	Specialized training is driven by the client/market. Maybe the market demand is not strong.
	High Cost	Specialized training is needed, but the cost will increase because of the creation of special scenarios (e.g., building inspection). Cost can deter subscription to specialized courses. If the government subsidizes and encourages construction companies to participate in specialized training, construction employees will be willing to do so.

First, the interviewees described the challenge of getting drone operators to carry out drone operations that are not photography-related as a reason why specialized drone training is necessary. Second, the interviewees revealed that drone training is structured to follow the requirements of other countries, resulting in a curriculum that lacks content tailored to address the peculiarities, challenges, and needs of Hong Kong. Two suggestions were offered to be considered when designing drone training courses, including (i) the peculiarities of Hong Kong should be considered when developing a drone training curriculum and teaching a drone course, and (ii) safety training should be expanded to fit safety assessments and the needs of the construction workplace.

Recommendations for Training Design

Nine themes emerged, later grouped into five broader categories: training structure and procedure, program content and skill development, awareness, evaluation, and resource management. Two themes were about training program content: safety training and off-GPS training. The remaining seven themes were the training redesign procedure, training duration, continuous skill development, sensitization, assessment, and increasing training facilities. They were about measures that would improve and sustain the quality of drone training. Table 5 details the suggestions for drone training design in the construction industry.

Table 5. Training design recommendations for the construction industry.

Theme Category	Themes	Comments
Training structure and procedure	Training redesign procedure	A stepwise process should be conducted. First, the training body should fulfill the basic requirements of the approved training organization (ATO). The basic requirements do not specify any special operations used for specific sectors. The second step should focus on the course design for special operations, e.g., for building inspection, the distance between a building and the drone should be stipulated and taught to ensure the captured data are clear. Such a course will help drone operators use their permits more easily.
	Training duration	Break the training into different classes/ratings for different jobs/different flying distances (e.g., photography, long-distance). Two hours of flying experience is the requirement for an advanced training course, which is questioned. Is that enough? I do not think it is enough.
	Continuous development	Trainers have to be trained first.
		Continuous professional development may be needed. Continuous practice of flying skills and receiving updates on drone technologies is necessary.
Program content and skill development	Safety training	Safety training is essential to pilots so that they can understand the characteristics of the product they are driving and the uniqueness of the construction space in Hong Kong. Our buildings are primarily multi-storey, and we perform construction activities in a limited space.
		Include new safety measures and new regulations.
	Off-GPS training	Off-GPS training is important. However, the new generation of drones does not have an off-GPS function. Landing protection allows for soft landings, but this function is difficult to control when landing on a floating vessel. Therefore, having this essential skill would help when there is GPS interference.
	Simulation	Engage in simulations as a means of flight training.
		Virtual reality (VR) drone games may help to improve flying skills.
Awareness	Sensitization	Training of drone operator mentality is essential.
Evaluation and monitoring	Assessment	Additional assessments of operator skill should be conducted if they are to carry out specialized jobs; for instance, the operators should tell the assessors how they would fly the drone in a specific job scenario.
Resource management	Increase training facilities	It is important to develop effective training that can support a sufficient supply of remote pilots. It is recommended that universities or construction companies arrange such training grounds for practical training. The training grounds can simulate practical scenarios such as loss of GPS, compass interference, and complex operation environments.
		More training facilities are required than open space.

4.2.2. Availability of Drone Training Grounds

The interviewees commented on the availability of training grounds for practicing drone flying skills in Hong Kong. Their responses, as outlined in Table 6, include the availability of training grounds, shortcomings of available drone training grounds, and recommendations. Two availability themes were deduced: the lack of training facilities and examples of existing drone training grounds. The interviewees indicated a few training grounds (namely, the Tseung Kwan O training ground and two pilot training grounds at country parks) are available but are insufficient. The concerns about the training grounds were related to the suitability of the training grounds to adequately train drone pilots within the geographical and construction peculiarities of Hong Kong. All recommendations on training grounds revolved around the need for higher institutions to offer practical drone training as they have the essential facilities and manpower.

Table 6. Availability of training grounds for practicing drone flying.

Availability Theme	Response		
	Availability of Training Grounds	**Shortcomings of the Training Ground**	**Recommendation**
Lack of training facilities	There are very few training grounds.		
	There is a lack of land for pilot training.		It is recommended that universities or construction companies arrange such training grounds for practical training. The training grounds can be used to simulate practical scenarios such as loss of GPS, compass interference, and complex operation environments.
	Training facilities for practicing flying skills are not sufficient.		It is recommended that educational institutes provide such facilities.
	Training grounds and facilities are not sufficient. Lack of training facilities, e.g., building inspection.		Training facilities by higher institutions will be good for pilot training for specialized jobs (e.g., inspection).
Examples of existing training grounds	Tseung Kwan O (TKO) training grounds to train flying skills and safety awareness.		
	Few training grounds, e.g., country parks. VTC intends to explore training grounds.	Flying at country parks may induce safety risks.	For outdoor training grounds, a special design of obstacles is required.
	The existing pilot training grounds are located at country parks, which are quite different from the city environment.	So, novice pilots have flying experience but may not have sufficient practical experience.	For outdoor training grounds, a special design of obstacles is required. More training facilities are required than open space.

4.2.3. Drone Proficiency Assessment

Interviewees commented on how an operator's proficiency is assessed by drone training institutions and the assessment criteria before engaging a drone operator for construction activities (see Table 7). One theme emerged for assessing an operator's proficiency by training institutions: a test. Three themes emerged regarding the assessment criteria for engaging a drone operator: FPV or remote helicopter operator skills, certificates, and understanding of drone situations. All four themes were related to proof of competence. The interviewees also provided suggestions on assessing drone proficiency, which centered around checking the log of flight hours and operator's ability to demonstrate competence in using drones for construction activities.

Table 7. Drone proficiency assessment and suggestions.

Code	Themes	Coded Segments
How drone operator's proficiency is assessed	Test	Some exams are required. Alternatively, the Civil Aviation Authority has some certificates for drone operators, and CAA has also authorized some institutions to train and issue these certificates.
Assessment criteria before engagement	FPV or remote helicopter operation skills	It is difficult to recruit remote pilots because we do not know their proficiency levels. For instance, the driver holds a flying license, but we do not know whether he can fly the drone car safely when the site is congested. We do not rely only on CAD-issued certificates. Instead, we recruit people who operate remote helicopters or members of First-Person-View (UK) because they are trained with higher levels of skills. FPV (no GPS) is very useful for congested areas, but skilled persons are lacking.

Table 7. *Cont.*

Code	Themes	Coded Segments
	Certificate	Authorized training organization's theory and practice.
	Understanding of drone situations	We check for understanding of flight philosophy. Flight philosophy is essential, e.g., rotation, flying height, sensor, drone cannot 100% differentiate the distance of objects if glass is present. Off-GPS flying skills, such as landing on a designated location. Experienced operators can handle off-GPS emergency procedures.
		We check for some knowledge of construction.
Suggestions on assessment criteria	Evidence of flight hours	Keep a logbook of flight hours. Hours of experience should be tracked.
	Demonstrate competence	Additional assessment of operator skill should be conducted if they will carry out specialized jobs; for instance, the operators should tell the assessors how they would fly the drone in a specific job scenario.

5. Discussion

Overall, by comparing the desktop research and interview results, the UK and Australia's drone training courses seem to be adapted in Hong Kong by finetuning the modules to meet the Hong Kong context with respect to densely populated environments and regulations. This is not farfetched, as the UK and Australia are among the top five countries leading drone research in the AEC industry [9]. Moreover, the UK and Australia are advanced industrialized countries that share expatriates and migrants with Hong Kong [63]. Therefore, having a drone license that can be utilized in three jurisdictions or would need little upskilling is appealing. For instance, Australia's CASA "RePL" standard course is provided in Hong Kong.

5.1. Drone Training Courses

It was deduced that the drone training courses undertaken by the respondents included FPV operation and SUA Advanced Rating. This is consistent with desk research, which showed that, in Hong Kong, conducting building surveys or inspections using drones at high flying altitudes (i.e., above 300 ft above ground level) or flying over uninvolved people/structures is categorized as "advanced operations" and would require the remote pilot to hold an SUA Advanced Rating [64]. Also, the altitude of the operation must be considered, in which the drone operator (remote pilot) must ensure that flight is performed with a visual line of sight (VLOS) maintained at all times with a visual observer deployed to assist the operator in keeping the SUA in VLOS or by unaided visual observation using FPV operation to conduct the flight safely [64]. The mode of instruction for the drone courses included face-to-face (in class and outdoor) and online learning with theoretical and practical knowledge.

This study found that despite the availability of drone training institutions and some international courses modified to fit the context of Hong Kong, most respondents lamented that the training courses were inadequate. Their reasons for that response centered on the lack of context-fitting considerations in the training courses, incompetence of drone operators, lack of interest in or demand for some drone courses, and lack of specialized courses for construction activities. As with any industry, interest in or demand for a commodity will drive supply [65,66]. Thus, the respondents noted that specialized courses could be provided but would depend on demand or interest for them, as at the moment, it appears that the interest of the workforce is on regular drone operations such as photography. Since the workforce is more interested in photography, this signals why there is a question about the quality or competence of drone operators in performing other drone-aided construction activities with the aid of drones. Generally, the competency of drone operators has been a significant concern affecting public acceptance of drone operations within urban areas [65].

It was deduced that although there is a need for non-generic (i.e., industry-specific) drone training courses that would equip the construction-skilled workforce with the requisite skills to employ drones on projects for advanced tasks (such as inspection tasks, mapping, and surveying), barriers to adoption and facilitators to designing specialized drone training courses exist. The scarcity of skilled drone operators for some operations, the inability of existing training to fit context needs, and the demand or interest for specialized courses appeared as facilitators to designing specialized drone training courses. This is consistent with the reasons why the respondents judged the present drone training courses as inadequate. This implies that the respondents' concerns must be addressed in order to make training courses adequate.

The cost of specialized courses was identified as a barrier to adopting specialized drone training courses, even though industry-specific courses are necessary. Industry-specific courses (i.e., specialized courses) allow operators to tap into the full potential of employing drones in their professional duties. Thus, it is not surprising that specialized training would be more expensive than courses that offer some basic remote pilot certification or license as they equip drone operators with skills to undertake more industry-specific applications in a safe and regulatory-compliant manner.

Recommendations for Drone Training

Nine themes emanated from the interview discussion as content suggestions or training directions for non-generic (industry-specific) drone training courses. Interviewees' recommendations on the need for "safety training" and "simulation" reinforced the findings of prior studies, e.g., [22], and add to existing knowledge by highlighting off-GPS training, especially where soft landing is impossible. Despite the advantages of using drones on construction sites, their incorporation raises safety concerns and challenges (such as noise distractions, crashing, and collisions due to technical or human error) associated with flying them on job sites, as well as legal liability from unsafe circumstances created [22]. To ensure safety, in several jurisdictions, including Hong Kong, regulations from aviation agencies (e.g., FAA, CAD, CAA) require that drones should be flown in a clear line of sight between the operator and the drone [10] or with the assistance of an additional observer or aid of advanced sensing technology. The workforce should be trained to understand and abide by the operator and equipment requirements outlined in the regulations in their country (i.e., jurisdiction) of practice. This would develop their mindset on safety culture.

In addition to in-person drone flying training, the workforce would benefit from simulation training, i.e., training conducted via virtual reality, augmented reality (AR), and mixed reality training. Delivering practical flying training in simulating scenarios similar to an actual construction site would help workers to develop drone flying competence and improve safe flying skills. At the same time, the training would be delivered safely without putting workers at actual risk [22]. Simulations of drone flight can also be used to train the workforce on proper data capturing, processing data collected into 3D models [40], and how to respond to technical failures or emergencies. Although the newer generation of drones have GPS and do not have an off-GPS function, drone operators could benefit from simulated training to learn how to maneuver several cases of GPS loss, including where soft landing is impossible.

Aside from human error, technical failures such as the loss of GPS signal are another source of safety issues (accidents) arising from drone use. Teaching skilled construction workers (learning drone operation skills) to respond to emergencies such as signal interference (loss of GPS signal, loss of command-and-control link, loss of navigation lighting) would eliminate or mitigate such safety concerns. In Hong Kong, a drone pilot should be able to respond to drone emergencies or technical failures (such as loss of GPS signal), regain active control, and land using attitude (ATTI) mode, with simulations of such emergencies being recommended during training to help learners develop the required skills and know-how [62,64].

There is a call for continuous development in drone training. This is well suited as the aim of continuous professional development (CPD) is to sustain competence among professionals (skilled workers) and introduce new skills to them as required for contemporary practice needs [67]. Mandatory continuous development is required in the construction profession; having programs on drones and technological improvements delivered using a variety of teaching methods and situated learning could help keep workers updated. All of the recommendations discussed, and others such as assessment, can be adequately addressed if drone training is delivered using student-centered and exploratory learning approaches, like competency-based training, instead of traditional training methods. In traditional training methods, skill development is judged from a one-shot assessment task at the end of each module, but in competency-based training (CBT), skill development or expertise is demonstrated by consistent performance and judged by feedback using multiple assessments simultaneously by an assessor over a period of time [68]. With CBT, assessment issues and their recommendation will be adequately addressed as evaluation is geared toward clearly specified criteria or standards in the industry, and the training outcome is measured against competency or not yet competent [68].

5.2. Availability of Drone Training Grounds

This study deduced that there are at least three training grounds in Hong Kong, including the Tseung Kwan O training ground and two other pilot training grounds at country parks. The interviewees revealed that the training grounds are open and insufficient for mastering drone flying, as they lack the basic facilities to properly learn inspection or survey skills. The interviewees believed that, by practicing flying in an open training ground with no obstacles, novice pilots will have flying experience but may not have sufficient practical experience to carry out surveying, inspections, and other technical tasks. They also added that, aside from the poor quality of jobs that such an operator might deliver, basing flying training in an open space might induce safety risks as operators have not learned to fly around obstacles.

Hong Kong is a densely populated city with many high-rise buildings due to the scarcity of urban land [45]. Given the geographical and construction peculiarities of Hong Kong, it is imperative to conduct drone flying training in a facility with obstacles to equip operators with the requisite knowledge, experience, and competence to fly on an actual construction site or as-built building. To overcome the open training ground challenge, interviewees recommended that higher institutions join in providing practical drone training as they have the essential facilities and manpower for adequate training.

5.3. Drone Proficiency Assessment

It was gathered that drone training institutions assess drone operator proficiency using a summative assessment, particularly a test that may be a theory examination and/or practical test, and the drone training institutions issue a certificate or license after passing the test. The Civil Aviation Department (CAD) may also issue a certificate or license based on the evidence of completion of training offered by an authorized training organization (ATO) and passing the requisite test. While some middle-level construction professionals engage drone operators based on certificates or licenses issued by ATO or CAD, others do not rely on those certificates or licenses. Instead, they assess the operator's proficiency and engage them using either of the following criteria: FPV or remote helicopter operator skills and operator's understanding of drone situations. It is imperative to prove and ascertain competence before assigning such professional tasks in order to ensure that specialized operations are carried out safely and legally.

Ideally, in Hong Kong, one of the duties and responsibilities of a drone operator for building survey/inspection works is keeping all logs and records of the operations, which must be properly completed and signed [64]. Also, a minimum of 20 h of flight experience is required before enrolling in the "Advanced Rating" training course, which affords drone operators the license to perform construction surveys and inspection tasks with advanced operation status. This implies that keeping flight logs should be a norm for drone operators, which might help them reinforce their competence to perform drone-related tasks rather than merely presenting a certificate or license.

6. Roadmap for Training Drone Operators

Maintaining a realistic balance between technical and generic skill development activities in the workplace is vital to developing employee competence to a desirable level [23]. As illustrated in Figure 4, the categories and themes derived from interviewees' recommendations for specialized drone training courses aligned with competency-based training (CBT) and the train-the-trainer (TTT) model as they emphasize identifying, developing, and continuously assessing competencies for drone operators and trainers.

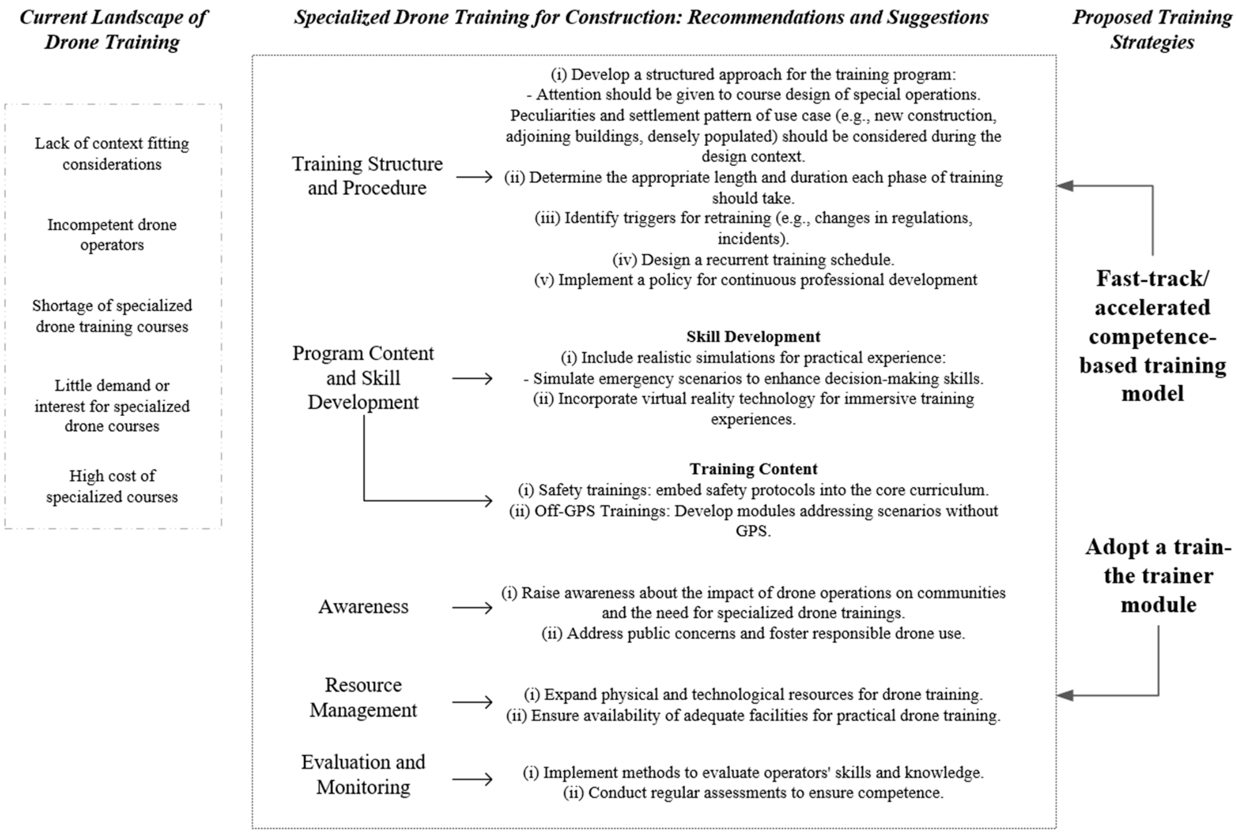

Figure 4. Roadmap for workforce development for drone operations.

Training Structure and Design: Redesigning the present drone training program with a structured approach ensures that it aligns with identified competencies, allowing trainees to master specific skills and knowledge. Also, the need to determine an appropriate length for each training phase is consistent with CBT, as it emphasizes the achievement of competencies rather than adherence to fixed timelines [68]. At the core of CBT is continuous development. It entails establishing a recurrent training schedule and triggers for retraining [69]. CBT and TTT acknowledge the need for continuous skill development and adaptation to changes in technology or regulations.

Content and Skill Development: Safety and simulation are critical competencies in CBT [70]. They can be incorporated into the TTT model since disseminating knowledge and enhancing skills among the workforce are the core of TTT [71]. Developing modules addressing scenarios without GPS aligns with the competency-based approach, focusing on specific skills related to manual control and navigation of drones [68].

Evaluation and Monitoring: Regular formative and summative assessments are fundamental to CBT and the train-the-trainer model to ensure trainees and trainers acquire the required competencies [68,71].

Therefore, the following training strategies are proposed to enhance drone operator skills for construction-related jobs: (i) fast-track or accelerated drone competency-based training and (ii) train-the-trainer model. Both strategies can be developed so that construction organizations become training institutes. Some companies train their construction operatives in some trades (e.g., bricklaying, plastering), but in this case, there would be a formal structure, which would differ for each strategy as there would be a need for assessors and/or internal verifiers.

6.1. Competency-Based Training

Competency-based training is a training approach that is more concerned about what a person can do as a result of training rather than the process involved in training [72]. A competency-based training framework focuses on developing the skills, knowledge, and abilities (competencies) necessary for effective performance in a given field. It would meet drone workforce training needs immediately (in the Construction 4.0 era) and long term (Construction 5.0). Competency-based training (CBT) would help to reform how the skilled workforce in the construction industry acquires technical skills to meet technological changes. Unlike the traditional training model presently used for drone training that relies on tests and a minimum pass mark to judge competence, in a competency-based training framework, competence is ascertained using a combination of at least three assessment methods to evaluate learning against a set of learning outcomes and assessment criteria. CBT is concerned with on-the-job needs and training to industry-specific standards so that the skills delivered by the training match the skills needed by the industry immediately and in the long term [68].

Assessment is critical in CBT courses and involves the use of constructive feedback to provide information about the gap between the learner's current performance and the desired learning goals [68]. Each unit in a CBT course includes learning outcomes and assessment criteria against which an assessor must use a combination of assessment methods to judge mastery. Drone training and training content should be delivered using CBT, as it will help to find a lasting solution to safety and legal issues associated with drone use. Therefore, there is a need to develop national occupational standards for drone operation and flying skills in the construction industry, against which an assessor will judge a learner's work and skills. Assessment techniques used in CBT include recognition of prior learning, expert witness/witness testimony, knowledge questions (question and answer), learner's statement (reflective account), observation, product evidence (e.g., risk assessment), professional discussion, scenario or case study, and simulation (except for workplace evidence of skills).

6.2. Adopting a Train-the-Trainer Model

Train-the-trainer programs have been employed in various fields for workforce development to address skill gaps via on-the-job training to enhance skills [71]. This training model is excellent for retraining staff, developing new skills, and enhancing collaboration to sustain training [71]. In the meantime, before a competency-based training model is developed for drone operation and flying skills, human resources in construction organizations can adopt a train-the-trainer model to meet the skilled workforce development needs and minimize the substantial financial commitment associated with drone training, which would increase with specialized courses. Interviewees suggested that the government should provide subsidies to encourage the adoption of specialized drone training courses. However, this might not be feasible in the long run for some reasons: (i) skill development is for an organization's performance, and the skills can be taken to another jurisdiction in the case of staff transfer; (ii) for how many personnel would the government provide subsidies. Hence, it is not cost effective for the government.

The train-the-trainer model will involve at least one staff member trained as a master drone trainer in specialized drone flying who will use on-the-job training methods in the workplace to teach other workers, especially subordinates, how to fly drones based on the exact needs of the workplace. The advantages of the train-the-trainer model include retraining of skilled workforce, savings on increased training costs, improved collaboration, and social support in the workplace. The training should involve AR/VR simulations to tap the safety performance benefits of simulations. The train-the-train model can be developed to include assessments like in traditional teaching, which grants in-house trained staff the ability to acquire a license from appropriate monitoring and awarding bodies.

7. Theoretical and Practical Implications of Findings

Previous studies have mainly focused on using VR to enable the safe use of drones in construction settings. This study adds to the body of knowledge by conducting a needs assessment of the present situation of drone flying and training within the construction industry of Hong Kong. The findings inform the training needs and strategies required to improve the quality of drone operation for construction tasks. The study revealed a variety of drone training programs in Hong Kong, including the SUA Advanced Rating course essential for building inspection. Irrespective of this, the study identified several problems with drone flying and training in Hong Kong, such as incompetence of drone operators, lack of context-specific considerations, a shortage of specialized courses, lack of demand for/interest in specialized drone training courses, and high cost of specialized courses. A robust curriculum and proper training would greatly improve drone flying skills, safety, quality of data collection, and productivity. Therefore, this study proposes a shift toward a competency-based training model that extends beyond traditional grading systems to assess proficiency, emphasizing practical skills and continuous professional development. Specifically, training courses should incorporate safety protocols, simulations, and off-GPS training to ensure proficiency in real-world construction scenarios.

The study highlights that collaboration between higher education institutions and industry stakeholders would increase practical training opportunities among the construction workforce. It advocates for comprehensive drone teaching units aligned with national occupational standards and a train-the-trainer model that would equip master drone trainers with skills to facilitate on-the-job skill development among their subordinates. This study calls for further research to take an inventory of drone licenses held and training courses undertaken by drone operators in the construction industry.

8. Limitations of the Study

This study utilized a qualitative methodology, which, like every methodology, has limitations. In this study, only two drone training courses (FPV and SUA Advanced Rating) were deduced during the interview. A more detailed list of drone training courses could not be identified from the interviews. This might be because drone use within the construction industry is gaining popularity and training programs are still maturing. Further research should build on this study by using the courses identified through the market survey and interview to determine drone training courses undertaken and drone pilot licenses held by drone operators in the construction industry. Such studies should adopt a quantitative or mixed methodology to identify a list of drone courses undertaken and licenses held by members of the construction industry. The studies should include open-ended options so respondents can state courses not included in the survey list. This would provide information on drone pilot competencies and licenses held within the construction industry and those that should be acquired before carrying out certain construction jobs.

9. Conclusions

Unlike Industry 4.0, Industry 5.0 will promote more skilled jobs and there is a need for professional skills in co-working with machines. Training strategies that will assure competency are required to help meet the needs of Construction 4.0 and Construction 5.0. This study used a qualitative method through semi-structured interviews and desk research of websites to collect data necessary to propose training needs and strategies for drone operators in construction-related jobs. Three objectives were set out for the study:

(i) identify existing drone training courses and assess their adequacy to meet the needs of the construction industry, (ii) determine essential training content for specialized drone training courses to meet construction needs, and (iii) determine drone operator proficiency assessment methods or criteria. The interview data were subjected to inductive content and thematic analysis via MAXQDA Analytics Pro 2022 version 22.2.0 software.

The drone training held by the interviewees included FPV and SUA Advanced Rating. The SUA Advanced Rating training course is unique to Hong Kong and is required for building inspections/surveys under Advanced Operations. The mode of instruction for the drone courses included face-to-face (in class and outdoor) and online learning with theoretical and/or practical knowledge. Drone training courses in Hong Kong include several generic courses (UAS Pilot Training—Level 1, FPV operation) and non-generic courses, i.e., specialized courses (inspection training and SUA Advanced Rating). It was deduced that training courses in Hong Kong are presently inadequate to meet the drone usage needs of the Hong Kong construction industry with "lack of context-fitting considerations", "incompetence of drone operators", "lack of demand/interest", and "shortage of specialized drone courses" emerging as four main reasons.

In terms of the need to develop specialized drone training courses, two challenges within the present training ecosystem and two barriers were identified. This study concludes that the high cost of specialized drone training courses is a potential barrier to adoption, as it could hamper enrollment/subscriptions given that such courses are more expensive than regular ones. "Scarcity of skilled drone operators" and "inability of current training courses to fit context needs" were the training ecosystem themes. These themes were consistent with the "training is inadequate" theme. This implies that these concerns must be addressed to make training courses adequate.

Although nine proposed drone training design themes emerged, only two were about training content: safety training and off-GPS training. The remaining seven themes drew attention to measures that would improve and sustain the quality of drone training. This study emphasizes the need for drone training courses for construction purposes to include "safety training", "simulations", and off-GPS training. It also highlights the need to include knowledge and skill maintenance measures, such as mandatory continuous professional development and retraining techniques, in drone operator programs.

"Test" emerged as the only proficiency assessment theme, while three assessment criteria themes, "FPV or remote helicopter operator skills", "certificate", and "understanding of drone situations" emerged. The assessment criteria indicated that most construction managers or project managers do not rely on drone training certificates to assign drone operations; instead, they use other things to ascertain competence. This study suggests two additional assessment criteria: check the log of flight hours, and the operator should demonstrate competence in using drones for construction activities by explaining a drone operation procedure.

This study concludes that existing drone training follows a traditional training model in which competence is judged by formative and summative assessments, which are graded. This study points out the shortcomings of following a traditional training model for a technology such as drones, which requires competence due to its tremendous potential for the building and civil engineering industry and the safety concerns and legal liability surrounding its integration. Therefore, a competency-based training strategy is proposed. This study proposes two training strategies for skilled workforce development for drone operation: "competency-based training" and a "train-the-trainer" model. Drone training courses or programs under each training strategy should include (i) training content such as "safety training" and off-GPS training, and (ii) knowledge and skill maintenance measures such as mandatory continuous professional development and retraining techniques.

The study revealed that the training grounds in Hong Kong are insufficient for mastering drone flying. Therefore, this study recommends that higher institutions support drone training in Hong Kong by providing practical training since they have adequate training facilities. This study calls for research on comprehensive teaching units for national occupational standards for drone operation and flying skills for construction activities. The research should consider the use of drones for vertical buildings/structures. There is also a need to develop training assessment procedures under the train-the-trainer model for a drone master trainer engaged in on-the-job training for his/her subordinates.

This paper contributes to the existing body of knowledge on workforce development by identifying the key issues and need for essential skills mastered by drone operators. Practically, the proposed training strategies will equip operators to work efficiently and safely with drones. The study provides valuable references for training bodies and government authorities to implement the proposed training strategies.

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References

1. Ordieres-Meré, J.; Gutierrez, M.; Villalba-Díez, J. Toward the industry 5.0 paradigm: Increasing value creation through the robust integration of humans and machines. *Comput. Ind.* **2023**, *150*, 103947. [CrossRef]
2. Barraza de la Paz, J.V.; Rodríguez-Picón, L.A.; Morales-Rocha, V.; Torres-Argüelles, S.V. A Systematic Review of Risk Management Methodologies for Complex Organizations in Industry 4.0 and 5.0. *Systems* **2023**, *11*, 218. [CrossRef]
3. Nahavandi, S. Industry 5.0—A Human-Centric Solution. *Sustainability* **2019**, *11*, 4371. [CrossRef]
4. Bednar, P.M.; Welch, C. Socio-Technical Perspectives on Smart Working: Creating Meaningful and Sustainable Systems. *Inf. Syst. Front.* **2020**, *22*, 281–298. [CrossRef]
5. Hussain, S.; Singh, A.M.; Mohanty, P.; Gavinolla, M.R. Next generation employability and career sustainability in the hospitality industry 5.0. *Worldw. Hosp. Tour. Themes* **2023**, *15*, 308–321. [CrossRef]
6. Liao, S.; Lin, L.; Chen, Q. Research on the acceptance of collaborative robots for the industry 5.0 era—The mediating effect of perceived competence and the moderating effect of robot use self-efficacy. *Int. J. Ind. Ergon.* **2023**, *95*, 103455. [CrossRef]
7. Doyle-Kent, M.; Kopacek, P. Industry 5.0: Is the Manufacturing Industry on the Cusp of a New Revolution? In *Proceedings of the International Symposium for Production Research 2019*; Lecture Notes in Mechanical Engineering; Springer: Cham, Swizerland; pp. 432–441.
8. Alojaiman, B. Technological Modernizations in the Industry 5.0 Era: A Descriptive Analysis and Future Research Directions. *Processes* **2023**, *11*, 1318. [CrossRef]
9. Nwaogu, J.M.; Yang, Y.; Chan, A.P.C.; Chi, H.-L. Application of drones in the architecture, engineering, and construction (AEC) industry. *Autom. Constr.* **2023**, *150*, 104827. [CrossRef]
10. Sakib, M.N.; Chaspari, T.; Behzadan, A.H. A feedforward neural network for drone accident prediction from physiological signals. *Smart Sustain. Built Environ.* **2021**, *11*, 1017–1041. [CrossRef]
11. Sharma, R.; Arya, R. UAV based long range environment monitoring system with Industry 5.0 perspectives for smart city infrastructure. *Comput. Ind. Eng.* **2022**, *168*, 108066. [CrossRef]
12. Wang, X. Chapter Ten—Preparing the public transportation workforce for the new mobility world. In *Empowering the New Mobility Workforce*; Reeb, T., Ed.; Elsevier: Amsterdam, The Netherlands, 2019; pp. 221–243. [CrossRef]
13. Nauman, A.; Obayya, M.; Asiri, M.M.; Yadav, K.; Maashi, M.; Assiri, M.; Ehsan, M.K.; Kim, S.W. Minimizing energy consumption for NOMA multi-drone communications in automotive-industry 5.0. *J. King Saud Univ.-Comput. Inf. Sci.* **2023**, *35*, 101547. [CrossRef]

14. Mahmood, K.; Tariq, T.; Sangaiah, A.K.; Ghaffar, Z.; Saleem, M.A.; Shamshad, S. A Neural Computing-based Access Control Protocol for AI-driven Intelligent Flying Vehicles in Industry 5.0-assisted Consumer Electronics. *IEEE Trans. Consum. Electron.* **2023**. [CrossRef]
15. Jain, D.K.; Li, Y.; Er, M.J.; Xin, Q.; Gupta, D.; Shankar, K. Enabling Unmanned Aerial Vehicle Borne Secure Communication With Classification Framework for Industry 5.0. *IEEE Trans. Ind. Inform.* **2022**, *18*, 5477–5484. [CrossRef]
16. Liu, H.; Sun, Y.; Cao, J.; Chen, S.; Pan, N.; Dai, Y.; Pan, D. Study on UAV parallel planning system for transmission line project acceptance under the background of industry 5.0. *IEEE Trans. Ind. Inform.* **2022**, *18*, 5537–5546. [CrossRef]
17. Musonda, I.; Okoro, C. Assessment of current and future critical skills in the South African construction industry. *High. Educ. Ski. Work-Based Learn.* **2021**, *11*, 1055–1067. [CrossRef]
18. Albalawi, R.K.; Goodrum, P.M.; Taylor, T.R.B. Applying the Tier II Construction Management Strategy to Measure the Competency Level among Single and Multiskilled Craft Professionals. *Buildings* **2023**, *13*, 1175. [CrossRef]
19. van Heerden, A.; Jelodar, M.B.; Chawynski, G.; Ellison, S. A Study of the Soft Skills Possessed and Required in the Construction Sector. *Buildings* **2023**, *13*, 522. [CrossRef]
20. Elghaish, F.; Matarneh, S.; Talebi, S.; Kagioglou, M.; Hosseini, M.R.; Abrishami, S. Toward digitalization in the construction industry with immersive and drones technologies: A critical literature review. *Smart Sustain. Built Environ.* **2021**, *10*, 345–363. [CrossRef]
21. Jacobs, R.L.; Hawley, J.D. The Emergence of 'Workforce Development': Definition, Conceptual Boundaries and Implications. In *International Handbook of Education for the Changing World of Work: Bridging Academic and Vocational Learning*; Maclean, R., Wilson, D., Eds.; Springer: Dordrecht, The Netherlands, 2009; pp. 2537–2552. [CrossRef]
22. Jeelani, I.; Gheisari, M. Safety challenges of UAV integration in construction: Conceptual analysis and future research roadmap. *Saf. Sci.* **2021**, *144*, 105473. [CrossRef]
23. Detsimas, N.; Coffey, V.; Sadiqi, Z.; Li, M. Workplace training and generic and technical skill development in the Australian construction industry. *J. Manag. Dev.* **2016**, *35*, 486–504. [CrossRef]
24. Harris, R.; Short, T. Exploring the Notion of Workforce Development. In *Workforce Development: Perspectives and Issues*; Harris, R., Short, T., Eds.; Springer: Singapore, 2014; pp. 1–16. [CrossRef]
25. Giloth, R.P. Learning from the field: Economic growth and workforce development in the 1990s. *Econ. Dev. Q.* **2000**, *14*, 340–359. [CrossRef]
26. Moon, S.; Ock, J. Developing the Framework of Drone Curriculum to Educate the Drone Beginners in the Korean Construction Industry. *Drones* **2023**, *7*, 356. [CrossRef]
27. Siddique, S.; Ahsan, A.; Azizi, N.; Haass, O. Students’ Workplace Readiness: Assessment and Skill-Building for Graduate Employability. *Sustainability* **2022**, *14*, 1749. [CrossRef]
28. Ashour, R.; Taha, T.; Mohamed, F.; Hableel, E.; Kheil, Y.A.; Elsalamouny, M.; Kadadha, M.; Rangan, K.; Dias, J.; Seneviratne, L.; et al. Site inspection drone: A solution for inspecting and regulating construction sites. In Proceedings of the 2016 IEEE 59th International Midwest Symposium on Circuits and Systems (MWSCAS), Abu Dhabi, United Arab Emirates, 16–19 October 2016; pp. 1–4.
29. Gheisari, M.; Esmaeili, B. Applications and requirements of unmanned aerial systems (UASs) for construction safety. *Saf. Sci.* **2019**, *118*, 230–240. [CrossRef]
30. Umar, T. Applications of drones for safety inspection in the Gulf Cooperation Council construction. *Eng. Constr. Archit. Manag.* **2021**, *28*, 2337–2360. [CrossRef]
31. de Melo, R.R.S.; Costa, D.B. Integrating resilience engineering and UAS technology into construction safety planning and control. *Eng. Constr. Archit. Manag.* **2019**, *26*, 2705–2722. [CrossRef]
32. De Melo, R.R.S.; Costa, D.B.; Álvares, J.S.; Irizarry, J. Applicability of unmanned aerial system (UAS) for safety inspection on construction sites. *Saf. Sci.* **2017**, *98*, 174–185. [CrossRef]
33. Daffara, C.; Muradore, R.; Piccinelli, N.; Gaburro, N.; de Rubeis, T.; Ambrosini, D. A Cost-Effective System for Aerial 3D Thermography of Buildings. *J. Imaging* **2020**, *6*, 76. [CrossRef] [PubMed]
34. Jalinoos, F.; Amjadian, M.; Agrawal Anil, K.; Brooks, C.; Banach, D. Experimental Evaluation of Unmanned Aerial System for Measuring Bridge Movement. *J. Bridge Eng.* **2020**, *25*, 04019132. [CrossRef]
35. Liu, D.; Chen, J.; Hu, D.; Zhang, Z. Dynamic BIM-augmented UAV safety inspection for water diversion project. *Comput. Ind.* **2019**, *108*, 163–177. [CrossRef]
36. Moon, D.; Chung, S.; Kwon, S.; Seo, J.; Shin, J. Comparison and utilization of point cloud generated from photogrammetry and laser scanning: 3D world model for smart heavy equipment planning. *Autom Constr* **2019**, *98*, 322–331. [CrossRef]
37. Lobo, D.; Patel, D.; Morainvile, J.; Shekhar, P.; Abichandani, P. Preparing Students for Drone Careers Using Active Learning Instruction. *IEEE Access* **2021**, *9*, 126216–126230. [CrossRef]
38. Sanson, J. Drone use in the construction industry leads to integration into the current civil and construction engineering technology curriculum. In Proceedings of the 2019 CIEC, New Orleans, LA, USA, 30 January–1 February 2019.
39. Al-Tahir, R. Integrating UAV into geomatics curriculum. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2015**, *40*, 387–390. [CrossRef]

40. He, Y.; Lu, H.; Song, Y.; Liu, L. Design and Implementation of Virtual Simulation Experiment System for Acquisition and Production of UAV Real-scene 3D Data. In Proceedings of the 2021 IEEE 4th International Conference on Automation, Electronics and Electrical Engineering (AUTEEE), Shenyang, China, 19–21 November 2021; pp. 249–254.
41. Pereira, E.R.; Zhou, S.; Gheisari, M. Integrating the use of UAVs and photogrammetry into a construction management course: Lessons learned. In Proceedings of the ISARC—International Symposium on Automation and Robotics in Construction, Berlin, Germany, 20–25 July 2018; pp. 1–8.
42. Sharma, J.B.; Hulsey, D. Integrating the UAS in Undergraduate Teaching and Research – Opportunities and Challenges at University of North Georgia. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2014**, *XL-1*, 377–380. [CrossRef]
43. Cheng, J.-Y.; Gheisari, M.; Jeelani, I. Using 360-Degree Virtual Reality Technology for Training Construction Workers about Safety Challenges of Drones. *J. Comput. Civ. Eng.* **2023**, *37*, 04023018. [CrossRef]
44. Onososen, A.; Musonda, I.; Ramabodu, M.; Dzuwa, C. Task Performance to Understand the Effectiveness of Visualisation Technology-Based Training for Human-Drone Interaction Learning. In *Advances in Information Technology in Civil and Building Engineering*; Lecture Notes in Civil Engineering; Springer: Cham, Swizerland; pp. 297–310.
45. Lau, S.S.Y. Physical Environment of Tall Residential Buildings: The Case of Hong Kong. In *High-Rise Living Asian Cities*; Springer: Dordrecht, The Netherlands, 2010; pp. 25–47.
46. Busetto, L.; Wick, W.; Gumbinger, C. How to use and assess qualitative research methods. *Neurol. Res. Pract.* **2020**, *2*, 14. [CrossRef] [PubMed]
47. Yang, Y.; Chan, A.P.C.; Darko, A.; Gao, R.; Zahoor, H. Factors affecting structural steelwork adoption from a project lifecycle perspective: The case of Hong Kong. *J. Clean. Prod.* **2019**, *230*, 634–646. [CrossRef]
48. Kuckartz, U.; Rädiker, S. MAXMaps: Creating Infographics and Concept Maps. In *Analyzing Qualitative Data with MAXQDA: Text, Audio, and Video*; Springer International Publishing: Cham, Swizerland, 2019; pp. 231–252. [CrossRef]
49. Hennink, M.M.; Kaiser, B.N.; Marconi, V.C. Code Saturation Versus Meaning Saturation: How Many Interviews Are Enough? *Qual. Health Res.* **2017**, *27*, 591–608. [CrossRef] [PubMed]
50. Heliguy. A2 CofC v GVC: Which UK Drone Training Course Is Best? Available online: https://www.heliguy.com/blogs/posts/uk-drone-laws-a2-cofc-vs-gvc#:~:text=In%20general,%20the%20A2%20CofC,used%20to%20conduct%20commercial%20operations (accessed on 4 September 2023).
51. Beté, T.d.S.; Storópoli, J.E.; Rodriguez Ramos, H.; Conti, D.d.M.; Capellani Quaresma, C.; Querido Oliveira, E.A.d.A. Comparative Analysis of Unmanned Aircraft Regulations for The Development Of Startups. *J. Technol. Manag. Innov.* **2021**, *16*, 41–55. [CrossRef]
52. Stopforth, R. VLOS and BVLOS RPAS Operators Certificate: Case Study for Inspection Requirements. In Proceedings of the 2021 Rapid Product Development Association of South Africa—Robotics and Mechatronics—Pattern Recognition Association of South Africa (RAPDASA-RobMech-PRASA), Pretoria, South Africa, 3–5 November 2021; pp. 1–5.
53. Civil Aviation Authority. Flying in the Specific Category. Available online: https://www.caa.co.uk/drones/rules-and-categories-of-drone-flying/flying-in-the-open-category/ (accessed on 23 October 2023).
54. Heliguy. Convert Your PfCO to A GVC. Available online: https://www.heliguy.com/products/pfco-to-gvc-conversion-course (accessed on 24 October 2023).
55. Coastal Drone. The Difference Between BVLOS, VLOS, and EVLOS. Available online: https://coastaldrone.co/the-difference-between-bvlos-vlos-and-evlos/ (accessed on 24 October 2023).
56. Civil Aviation Safety Authority. Apply for Beyond Visual Line-of-Sight Approvals. Available online: https://www.casa.gov.au/drones/registration-and-flight-authorisations/apply-flight-authorisations/apply-beyond-visual-line-sight-approvals#Therequirements (accessed on 22 October 2023).
57. Civil Aviation Authority. Drone Trial of Routine BVLOS Operations Concept Authorised. Available online: https://www.caa.co.uk/newsroom/news/drone-trial-of-routine-bvlos-operations-concept-authorised/ (accessed on 24 October 2023).
58. Tezza, D.; Caprio, D.; Laesker, D.; Andujar, M. Let's Fly! An Analysis of Flying FPV Drones Through an Online Survey. In Proceedings of the Interdisciplinary Workshop on Human-Drone Interaction (iHDI) @ CHI, Honolulu, HI, USA, 26 April 2020.
59. Kim, S.; Kim, S. Opportunities for construction site monitoring by adopting first personal view (FPV) of a drone. *Smart Struct. Syst.* **2018**, *21*, 139–149.
60. Civil Aviation Safety Authority. Flying First Person View. Available online: https://www.casa.gov.au/drones/drone-rules/flying-first-person-view#Thedosanddon%E2%80%99tsofflyingFPV (accessed on 22 October 2023).
61. HKSAR Government. *Small Unmanned Aircraft Approved Training Organisation—Requirements Document*; Unmanned Aircraft Office: Hong Kong, China, 2023.
62. OTG. Training Facilities. Available online: https://www.otg.com.hk/education/ (accessed on 25 October 2023).
63. McKercher, B.; Yankholmes, A. Travel as learned behaviour: Western migrants in Hong Kong and Macau. *Tour. Manag.* **2018**, *67*, 191–200. [CrossRef]
64. HKSAR Government. *Small Unmanned Aircraft Advisory Circular No. AC-005*; The Government of the Hong Kong Special Administrative Region: Hong Kong, China, 2022; pp. 1–14.
65. Çetin, E.; Cano, A.; Deransy, R.; Tres, S.; Barrado, C. Implementing mitigations for improving societal acceptance of urban air mobility. *Drones* **2022**, *6*, 28. [CrossRef]
66. Cohn, P.; Green, A.; Langstaff, M.; Roller, M. Commercial drones are here: The future of unmanned aerial systems. In *Capital Projects & Infrastructure*; McKinsey & Company: Chicago, IL, USA, 2017.

67. Ross, K.; Barr, J.; Stevens, J. Mandatory continuing professional development requirements: What does this mean for Australian nurses. *BMC Nurs.* **2013**, *12*, 9. [CrossRef] [PubMed]
68. Boahin, P.; Hofman, W.A. Perceived effects of competency-based training on the acquisition of professional skills. *Int. J. Educ. Dev.* **2014**, *36*, 81–89. [CrossRef]
69. Campbell, C.; Silver, I.; Sherbino, J.; Cate, O.T.; Holmboe, E.S.; Collaborators, I.C. Competency-based continuing professional development. *Med. Teach.* **2010**, *32*, 657–662. [CrossRef] [PubMed]
70. City & Guilds. Marine Construction, Systems Engineering and Maintenance (2463). Available online: https://www.cityandguilds.com/-/media/productdocuments/transport_maintenance/marine/2463/2463_level_3/centre_documents/2463_03_l3_diploma_qualification_handbook_v4-2-pdf.ashx (accessed on 2 April 2024).
71. Yarber, L.; Brownson, C.A.; Jacob, R.R.; Baker, E.A.; Jones, E.; Baumann, C.; Deshpande, A.D.; Gillespie, K.N.; Scharff, D.P.; Brownson, R.C. Evaluating a train-the-trainer approach for improving capacity for evidence-based decision making in public health. *BMC Health Serv. Res.* **2015**, *15*, 547. [CrossRef]
72. Smith, E. A Study of the Penetration of Competency-based Training in Australia. *Res. Post-Compuls. Educ.* **1996**, *1*, 169–185. [CrossRef]

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