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A FIVE-YEAR ANALYSIS OF INDUSTRY AND ACADEMIA EXPECTATIONS IN VIRTUAL DESIGN AND CONSTRUCTION EDUCATION

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ABSTRACT: The construction industry is rapidly evolving due to technological advancements, shifting workforce demands, and increasing project complexities. Emerging tools like Virtual Design and Construction (VDC), Building Information Modeling (BIM), and robotics are reshaping the field, making it essential for academic curricula to align with industry needs. This study examines the changing skill requirements for construction graduates specializing in VDC over five years. Using the Delphi method, a panel of 24 experts - 12 industry professionals and 12 educators - assessed the competencies graduates should acquire. Key areas of focus included BIM, Geographic Information Systems (GIS), model management, VDC skills, and collaboration. Over time, academia emphasized foundational knowledge and soft skills, while industry professionals increasingly prioritized technical proficiency and hands-on experience. Notably, skills in emerging technologies like generative design, artificial intelligence (AI), and augmented/virtual reality (AR/VR) gained industry attention but remained underrepresented in academic programs. The study highlights a gap between academia's theoretical focus and the industry's demand for practical expertise in advanced VDC tools and collaboration platforms. While both sectors agree on the importance of BIM and communication skills, academic programs must better integrate AI-driven tools, generative design, and immersive technologies. The paper concludes with curriculum recommendations that emphasize emerging technologies and real-world applications. By closing this gap, educational institutions can better prepare graduates for the evolving construction industry, providing valuable insights for educators and industry leaders in shaping a future-ready workforce.

1. INTRODUCTION

The construction industry is undergoing a rapid transformation due to advancements in technology, shifting workforce demands, and increasing project complexities. VDC has emerged as a critical field, integrating digital tools and processes to enhance efficiency, collaboration, and decision-making in construction projects. As industry reliance on VDC grows, the skills required for professionals entering this field continue to evolve. However, a disconnect persists between academic preparation and industry expectations, leaving many graduates underprepared for the realities of VDC roles.

Academic institutions traditionally emphasize foundational knowledge, theoretical concepts, and soft skills, such as communication and teamwork. While these are essential, industry professionals increasingly prioritize technical proficiency and hands-on experience with advanced tools and methodologies. Employers now seek graduates who are well-versed in BIM, GIS, model coordination, and emerging technologies such as generative design, AI, AR, and VR. These skills enable professionals to navigate complex projects, automate workflows, and enhance decision-making processes. Despite industry demand, many of these competencies remain underrepresented in current curricula.

This study aims to identify the key skills required for a fresh graduate pursuing a VDC position and assess the extent to which academia is preparing students for these roles. Using a five-year Delphi study, a panel of 24 experts - 2 industry professionals and 12 educators - evaluated the competencies essential for entry-level VDC professionals. The study examines trends in skill requirements, gaps between academic training and industry needs, and the increasing emphasis on advanced digital tools.

By bridging this gap, academic programs can better align with industry expectations and equip graduates with the technical expertise, problem-solving abilities, and collaborative skills necessary for success in VDC roles. This paper provides insights into the evolving landscape of VDC education and offers curriculum recommendations to ensure that fresh graduates enter the workforce with the knowledge and experience required to thrive in this rapidly changing industry.

2. BACKGROUND

The construction industry has faced longstanding challenges related to productivity and technological integration, with recent advancements in Industry 4.0 technologies - such as BIM, VR, AR, and AI presenting significant opportunities for improvement. Du et al. (2020) underscore the need for educational programs to adapt, aligning curricula with industry standards to produce graduates capable of thriving in this dynamic environment. Historically, construction education has evolved from traditional approaches to incorporating innovative methods such as project-based learning (Chinowsky et al. 2006) and service-learning (El-Adaway et al. 2015). These methods aim to develop critical thinking and problem-solving skills essential for modern construction professionals. However, the rapid technological developments of Industry 4.0 have presented new challenges. Zheng et al. (2019) highlighted the need for a skilled workforce capable of adopting new trends, driven by increasing material costs, regulatory changes, and environmental concerns.

2.1 Collaboration Between Academia and Industry

Education plays a crucial role in developing a skilled workforce and advancing construction industry practices (Smith et al. 2018). Construction education aims to prepare students for leadership roles while evolving alongside social, economic, and technological developments. To achieve this, academia-industry collaboration is essential (Zheng et al. 2019). Researchers have explored collaborative research agendas (Lucko and Kaminsky 2016) and the key challenges that hinder effective cooperation (Shapira and Rosenfeld 2011). Smith et al. (2018) found that such collaboration enhances students' awareness of corporate social responsibility. However, Mahasneh and Thabet (2015) highlighted a gap between industry needs and graduates' soft skills, such as communication and teamwork, which are often underemphasized in curricula.

Additionally, gaps persist in visualization, information modeling, and simulation education (Leite et al. 2016). Budget constraints for hardware and software, disconnects between academic research and industry practices, and real-time modeling challenges limit progress in visualization. Information modeling issues include data interoperability and as-built data formalization, while simulation challenges involve credibility, adaptability to real-world changes, and limited interdisciplinary collaboration. Among these, integrating simulation-related education into curricula remains a major concern for both academia and industry (Leite et al. 2016).

Bademosi et al. (2019) assessed skills needed for robotics and automation in construction, identifying four research areas: reality computing (laser scanners, drones), visualization (VR, AR), automation (robotics, prefabrication), and smart technologies (AI, IoT). Required skills include computing skills (BIM, cloud computing, parametric design) and computer science skills (AI, big data, machine learning, database concepts). Addressing these gaps and integrating emerging technologies into curricula are crucial for aligning construction education with industry advancements.

2.2 Teaching Approaches

To bridge the academia-industry gap and address challenges in visualization, information modeling, and simulation, various teaching approaches have been proposed to equip AECO students with essential skills for emerging robotics trends. Chinowsky et al. (2006) identified six teaching methods in AECO programs. The traditional approach relies on lectures and tests, limiting students' ability to integrate new concepts (Dutson et al. 1997). The integrated curriculum approach introduces real-world constraints early, while the model approach simulates construction sites using computer models. The case study approach emphasizes multiple solutions and includes site visits. A non-engineering approach focuses on facility lifecycles, while the process-based approach - deemed the most effective - presents open-ended problems requiring students to seek external resources and synthesize knowledge (Chinowsky et al. 2006).

A practical application of the process-based approach is BIM education, where Wang and Leite (2014) emphasized BIM as a process improvement tool rather than just technology. This method encourages self-directed learning and teamwork (Kymmell 2008; Li and Liu 2004). Similarly, Rahman and Ayer (2018) integrated problem-based activities into BIM education, focusing on common construction site issues such as information transfer and human error. By collaborating with industry partners, their approach exposed students to real-world challenges using industry-generated problem logs. Other researchers advocated for collaborative online platforms that support team-based, project-based, and problem-based learning, fostering interdisciplinary collaboration. Additional studies highlighted the benefits of VR (Alizadehsalehi et al. 2019) and 360-degree videos in flipped classrooms (Mojtahhedi et al. 2020).

As VDC, robotics, and manufacturing technologies become increasingly specialized, it is essential to align construction education with industry expectations. Understanding hiring perspectives for VDC roles positions helps educators better design technology courses that meet labor market demands.

3. RESEARCH METHODOLOGY

This study builds on the work started by the authors in 2020 (Tayeh and Issa 2021). A Delphi study was conducted over five years to systematically evaluate the evolving skill requirements for graduates pursuing VDC roles. The study relied on a panel of 24 experts, evenly split between industry professionals and academic educators, to ensure a comprehensive assessment of both industry needs and academic preparation. Through multiple rounds of data collection and analysis, the study identified key competencies necessary for entry-level VDC engineers and tracked changes in industry expectations over time.

3.1 Panel

The 12 industry professionals on the panel work in VDC departments across construction and engineering firms, contributing to vertical, horizontal, and infrastructure projects. Their educational backgrounds were diverse: five held degrees in construction, four in architecture, two in civil engineering, and one in computer science. Their industry experience ranged from 7 to 15 years, with an average of 9 years specifically in VDC-related roles. This diverse expertise provided valuable insights into the technical and managerial competencies expected from new hires, as well as the practical challenges faced in integrating emerging technologies into construction workflows.

On the academic side, the study included 12 faculty members from various universities, all of whom had research interests aligned with the implementation of Industry 4.0 technologies in the AECO (Architecture, Engineering, Construction, and Operations) sector. The academic panel consisted of eight assistant professors, two associate professors, and two full professors, all specializing in engineering, construction, or architecture education. Their perspectives were instrumental in evaluating how well current curricula align with industry demands and in identifying gaps in the training provided to students.

By engaging both industry and academic experts over five years, the Delphi study provided a longitudinal view of the evolving VDC landscape. The iterative nature of the study allowed for the refinement of key skill categories, ensuring that the findings accurately reflected real-world hiring expectations.

3.2 Design and Analysis

Before initiating the Delphi study, a series of semi-structured interviews were conducted with both industry professionals and academic professors. These interviews centered on how VDC is utilized on construction sites and within departmental courses. The insights gathered from these discussions informed the design of the Delphi study.

Panelists were asked to evaluate the expected level of knowledge that new graduates should have regarding various topics related to construction information systems. These topics were identified through a combination of the semi-structured interviews and a review of existing literature. The topics were categorized into five key sections: (1) BIM modeling skills, (2) GIS skills, (3) model management skills, (4) VDC skills, and (5) collaboration and communication skills. Each skill in these key sections was assessed using a 5-point Likert scale, ranging from “none” to “a great deal,” to measure the depth of knowledge required for each skill.

The responses collected from the panelists were then used to compare the expectations of academia with those of industry professionals. To reach consensus among the panelists, two rounds of the Delphi study were needed, following the consensus-building method outlined by Giannarou and Zervas (2014) and refined by Wu et al. (2018).

As shown in Table 1, three metrics were used to evaluate consensus: standard deviation (SD), interquartile range (IQR), and percent score (PS). In the first round, two levels of agreement could be reached: early consensus (EC) and early strong agreement (ESA). During subsequent rounds, the final round of the Delphi study used five levels of agreement, as outlined by Wu et al. (2018): consensus (C), strong agreement (SA), partial agreement (PA), strong disagreement (SD), and total disagreement (TD). These methods ensured that the panelists’ responses were thoroughly analyzed to identify key areas for curriculum improvement and alignment with industry needs. PS combined refers to the percentage of two adjacent Likert points with respect to the total number of responses. Table 1 shows the level of agreement in ascending order.

Table 1: Criteria for each level of agreement

Level of agreement	Symbol	IQR	SD	PS (single)	PS (combined)
Early consensus	EC	≤ 1	≤ 1	$\geq 60\ \%$	
Early strong agreement	ESA	≤ 1	≤ 1		$\geq 70\%$
Consensus	C	≤ 1	≤ 1	$\geq 60\%$	
Strong agreement	SA	$= 1$	≤ 1		$\geq 70\%$
Partial agreement	PA	$1 < IQR \leq 2$	≤ 1		$\geq 60\%$
Split disagreement*	SD	> 2	> 1	$\geq 25\%$	
Total disagreement**	TD	> 2	> 1	$< 60\%$	

* SD or IQR and PS
** SD or IQR or PS

Besides assessing the expected knowledge levels in various construction information systems topics, the study also aimed to gather insights on emerging trends and topics that are shaping the VDC landscape. Annually, participants were asked to identify and discuss new developments, technologies, and methodologies that are impacting the AECO industry.

4. RESULTS AND DISCUSSION

Table 2 shows the skill level that academia professionals expect a fresh graduate should have to be hired in a VDC job. The skill level is measured on a 5-point Likert scale as follows, 1- None, 2 – Little, 3 –

Moderate, 4 – A lot, and 5 – A great deal. Next to the skill level, the level of consensus (from Table 1) is noted in between paratheses.

Table 2: Academia's perspective on skill level

	What level of knowledge in the following topics should a fresh graduate have to be hired in VDC?	**2020**	**2021**	**2022**	**2023**	**2024**
BIM Modeling Skills	Architectural modeling in Revit	4 (EC)	4 (EC)	4 (EC)	5 (ESA)	4 (ESA)
	Structural modeling in Revit	4 (ESA)	4 (ESA)	4 (ESA)	4 (ESA)	5 (ESA)
	MEP modeling in Revit	4 (ESA)	4 (ESA)	4 (EC)	5 (ESA)	4 (ESA)
	Family editing in Revit	4 (ESA)	4 (ESA)	4 (ESA)	5 (ESA)	4 (ESA)
	Parametric modeling in Revit	4 (C)	4 (ESA)	4 (ESA)	5 (C)	5 (EC)
	Massing in Revit	4 (EC)	4 (ESA)	5 (C)	5 (C)	5 (C)
	Project and shared parameters	4 (EC)	4 (ESA)	5 (C)	5 (C)	5 (C)
GIS Skills	Navigating GIS maps	4 (ESA)	4 (ESA)	5 (C)	5 (C)	5 (C)
	Using Infraworks	4 (ESA)	4 (ESA)	4 (ESA)	4 (ESA)	4 (ESA)
	Using ArcGIS	2 (C)	2 (C)	3 (EC)	3 (EC)	3 (EC)
	Integrating BIM and GIS for visualization	2 (ESA)	2 (ESA)	3 (ESA)	3 (ESA)	3 (ESA)
	Integrating BIM and GIS for model mgmt.	2 (C)	3 (EC)	3 (EC)	4 (C)	4 (C)
Model Management Skills	Quantification in Revit	4 (EC)	4 (EC)	5 (ESA)	5 (EC)	5 (EC)
	Quantification in Navisworks	4 (EC)	4 (EC)	4 (EC)	3 (EC)	3 (EC)
	Quantification in Assemble Systems	4 (EC)	4 (EC)	3 (EC)	2 (ESA)	3 (ESA)
	Scheduling in Project	4 (ESA)	4 (ESA)	4 (ESA)	5 (ESA)	5 (ESA)
	Scheduling in Synchro	4 (EC)	4 (ESA)	4 (EC)	4 (EC)	5 (ESA)
	Scheduling in Primavera P6	4 (EC)	4 (ESA)	4 (EC)	4 (EC)	5 (ESA)
	Clash detection in Navisworks Manage	4 (ESA)	4 (ESA)	5 (ESA)	5 (EC)	5 (EC)
VDC Skills	Using Recap Pro for laser scanning	2 (EC)	3 (ESA)	3 (ESA)	3 (EC)	3 (EC)
	Navigating VR environments	2 (EC)	3 (ESA)	3 (ESA)	3 (EC)	3 (EC)
	Navigating AR environments	2 (EC)	3 (ESA)	3 (ESA)	3 (EC)	3 (EC)
	Using Fusion360	2 (EC)	2 (EC)	2 (EC)	2 (EC)	2 (EC)
	Using generative design	2 (EC)	2 (EC)	3 (ESA)	3 (EC)	4 (ESA)
	Computer programming	2 (EC)	2 (EC)	3 (ESA)	3 (EC)	4 (ESA)
Collaboration and Communication Skills	Understanding level of development	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
	Running a coordination meeting	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
	Communicating through Procore	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
	Developing renderings and walkthroughs	5 (C)	5 (ESA)	5 (ESA)	5 (EC)	5 (EC)
	Using Autodesk Const. Cloud (BIM360)	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
	Using Worksharing in Revit	5 (ESA)	5 (ESA)	5 (EC)	5 (EC)	5 (EC)
	Developing a BIM execution plan	5 (C)	5 (C)	5 (SA)	5 (EC)	5 (EC)

Similarly, Table 3 shows the industry's perspective on the level of knowledge in the listed topic they expected a fresh graduate to have when entering the job market in a VDC role. The table shows the collected results from every year the Delphi study was conducted.

Table 3: Industry's perspective on skill level

	What level of knowledge in the following topics should a fresh graduate have to be hired in VDC?	2020	2021	2022	2023	2024
BIM Modeling Skills	Architectural modeling in Revit	5 (ESA)	5 (ESA)	5 (EC)	5 (EC)	5 (EC)
	Structural modeling in Revit	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
	MEP modeling in Revit	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
	Family editing in Revit	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
	Parametric modeling in Revit	5 (ESA)	5 (ESA)	5 (ESA)	5 (EC)	5 (EC)
	Massing in Revit	5 (ESA)	5 (ESA)	5 (ESA)	5 (ESA)	5 (EC)
	Project and shared parameters	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
GIS Skills	Navigating GIS maps	4 (ESA)	4 (EC)	4 (EC)	4 (EC)	5 (ESA)
	Using Infraworks	4 (ESA)	4 (EC)	4 (EC)	4 (EC)	5 (ESA)
	Using ArcGIS	3 (EC)	3 (EC)	4 (ESA)	4 (ESA)	4 (ESA)
	Integrating BIM and GIS for visualization	3 (EC)	3 (EC)	3 (EC)	4 (ESA)	3 (ESA)
	Integrating BIM and GIS for model mgmt.	3 (ESA)	4 (ESA)	4 (ESA)	5 (ESA)	5 (ESA)
Model Management Skills	Quantification in Revit	5 (ESA)	5 (ESA)	5 (EC)	5 (EC)	5 (EC)
	Quantification in Navisworks	4 (ESA)	4 (ESA)	3 (ESA)	3 (ESA)	3 (EC)
	Quantification in Assemble Systems	5 (EC)	5 (EC)	4 (EC)	3 (EC)	3 (EC)
	Scheduling in Project	3 (ESA)	3 (ESA)	3 (ESA)	3 (ESA)	3 (ESA)
	Scheduling in Synchro	3 (EC)	3 (EC)	3 (ESA)	3 (EC)	3 (EC)
	Scheduling in Primavera P6	3 (ESA)	3 (ESA)	3 (EC)	3 (EC)	4 (ESA)
	Clash detection in Navisworks Manage	4 (ESA)	4 (EC)	5 (ESA)	5 (EC)	5 (EC)
VDC Skills	Using Recap Pro for laser scanning	4 (ESA)	4 (ESA)	5 (ESA)	5 (ESA)	5 (ESA)
	Navigating VR environments	4 (ESA)	4 (ESA)	4 (ESA)	5 (EC)	5 (C)
	Navigating AR environments	4 (C)	4 (C)	4 (C)	4 (C)	4 (C)
	Using Fusion360	4 (ESA)	4 (ESA)	4 (EC)	4 (EC)	4 (EC)
	Using generative design	4 (EC)	4 (EC)	5 (EC)	5 (EC)	5 (EC)
	Computer programming	4 (EC)	4 (EC)	5 (EC)	5 (EC)	5 (EC)
Collaboration and Communication Skills	Understanding level of development	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
	Running a coordination meeting	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
	Communicating through Procore	5 (EC)	5 (EC)	5 (EC)	5 (EC)	5 (EC)
	Developing renderings and walkthroughs	5 (ESA)	5 (ESA)	5 (EC)	5 (EC)	5 (EC)
	Using Autodesk Const. Cloud (BIM360)	5 (C)	5 (C)	5 (EC)	5 (EC)	5 (EC)
	Using Worksharing in Revit	5 (C)	5 (C)	5 (EC)	5 (EC)	5 (EC)
	Developing a BIM execution plan	5 (ESA)	5 (ESA)	5 (EC)	5 (EC)	5 (EC)

Based on the results in Table 2, academic experts have raised the expected proficiency for BIM modeling skills, with many ratings moving from 4 to 5 over the five-year period. Notably, several skills now reach Early Consensus (EC) - the strongest level of agreement - which underscores a robust, immediate agreement that these skills are indispensable. This top-tier consensus (EC) highlights that mastery of BIM tools like Revit is seen as essential for fresh graduate VDC engineers. GIS-related skills began with lower ratings and standard Consensus (C), reflecting moderate agreement on their importance. Over time, certain areas have improved in both rating and consensus, shifting toward Early Strong Agreement (ESA); however, they generally do not reach the top-tier EC level. This suggests that while GIS integration is increasingly recognized, it is still considered secondary to core BIM and model management competencies. Skills such as quantification, scheduling, and clash detection consistently receive high ratings, and many of these areas achieve either Early Consensus (EC) or Early Strong Agreement (ESA). This strong alignment demonstrates that academia firmly believes in the critical role of robust model management for successful VDC operations. The prevalence of EC in this category emphasizes that these skills are non-negotiable, with immediate, strong agreement among experts. VDC-specific competencies, including navigating VR/AR environments and using emerging tools like generative design and computer programming, initially received lower ratings with a standard Consensus (C). Over time, some of these skills have seen their consensus shift toward Early Strong Agreement (ESA), reflecting growing recognition of their value. However, they rarely achieve the top-tier Early Consensus (EC), indicating that while these skills are on the rise, they are not yet considered as critical as core BIM and model management abilities. Collaboration and communication skills are consistently rated at the highest level (5) throughout the five-year period. They uniformly achieve the strongest consensus level, Early Consensus (EC), demonstrating an immediate and unanimous agreement on their critical importance. This unwavering EC status confirms that effective teamwork and communication are non-negotiable foundations for any fresh graduate stepping into a VDC role.

Based on the results in Table 3, industry professionals rate BIM modeling skills at the highest level, with many sub-skills consistently achieving a rating of 5 and securing Early Consensus (EC). This immediate, strong agreement indicates that tools like Revit for architectural, structural, and MEP modeling are seen as essential for any fresh graduate entering a VDC role. The firm EC across these skills underscores an industry-wide expectation that proficiency in BIM is non-negotiable. GIS-related skills in the industry receive moderate ratings - typically in the 3 to 4 range - reflecting their supportive role relative to core BIM competencies. The consensus here generally falls in the Early Strong Agreement (ESA) or Consensus (C) range, signaling that while GIS is recognized as valuable, it isn't deemed as critical as BIM. This level of agreement suggests that industry professionals expect a working knowledge of GIS integration, but it remains a secondary priority. Model management skills such as scheduling, clash detection, and quantification consistently earn high ratings (often 4 or 5) from industry experts. Many of these skills secure the top consensus levels (EC or ESA), highlighting that there is an immediate and robust industry-wide agreement on their importance. This strong consensus confirms that effective model management is central to achieving efficient, error-free project execution in VDC operations. VDC-specific skills - like navigating VR/AR environments, using laser scanning software, and engaging with emerging tools such as generative design and programming - typically started with lower ratings (around 2 to 3). The consensus for these skills is evolving, generally falling between Early Strong Agreement (ESA) and Consensus (C), which indicates a growing but not yet fully mature recognition of their importance. This shifting consensus suggests that while industry professionals acknowledge the emerging value of these technologies, they are still in the process of integrating them as core requirements. Collaboration and communication skills are consistently rated at the highest level (5) across the board, and the industry uniformly assigns them an Early Consensus (EC). There is immediate, strong agreement on the importance of skills like running effective coordination meetings, clear communication through project platforms, and developing comprehensive execution plans. This unwavering EC consensus reinforces that regardless of technological advances, the ability to collaborate and communicate effectively remains a foundational requirement in VDC roles.

When comparing academia and industry opinions, two key similarities emerge. First, both groups consistently rate collaboration and communication skills at the highest level (5) with the strongest consensus (EC), underlining the shared belief that effective teamwork is indispensable in VDC roles. Second, both academia and industry place a premium on BIM modeling and model management skills, demonstrated by high ratings and immediate, robust consensus, which reflects a mutual understanding of their critical role in modern construction processes.

However, two notable differences also stand out. Industry professionals tend to assign higher ratings and stronger consensus to emerging VDC-specific skills, such as generative design and computer programming, compared to academia, suggesting that the industry views these competencies as more immediately valuable. Additionally, while academia shows a progressive increase in expectations for GIS skills (with ratings moving upward and consensus strengthening over time), industry regards GIS as a supportive tool with moderate ratings and consensus (typically ESA or C), emphasizing a more conservative approach in prioritizing GIS relative to core BIM functions.

Based on these insights, it is recommended that academic programs adjust their curricula to more closely align with industry needs by incorporating enhanced training in emerging technologies like generative design and computer programming. Moreover, establishing stronger partnerships, through internships, collaborative workshops, and joint projects between academia and industry can help ensure that graduates are well-prepared to meet both the robust technical demands (e.g., BIM and model management) and the evolving expectations for advanced digital tools in the field. Finally, while refining technical skills, maintaining the strong focus on collaboration and communication will continue to be essential.

5. CONCLUSION AND FUTURE STUDIES

This study aimed to investigate the evolving skills and competencies required for a fresh graduate to be hired in a VDC role, as perceived by both academia and industry professionals. Through a Delphi study conducted annually over a five-year period, the research identified key skill gaps between academia's curriculum offerings and the skills demanded by the industry, particularly in emerging technologies such as AI, generative design, and BIM tools. Findings highlight that while both academia and industry recognize the importance of foundational BIM modeling, the growing significance of advanced technologies requires a shift in educational approaches to prepare students for the future workforce.

The study's primary goal was not only to identify these gaps but also to propose actionable solutions for bridging them. The results indicate that academic institutions should integrate emerging technologies more deeply into curricula, offering hands-on experiences with tools like Autodesk Fusion 360, generative design, and AI-based applications for VDC. Furthermore, closer collaboration between academic programs and industry professionals will be key to ensuring the relevancy of educational content and better aligning graduates' skills with industry needs.

The panel of 24 experts comprising both academic faculty and industry leaders was carefully selected based on their extensive experience in VDC and their involvement in shaping educational practices and industry trends. This diverse panel provided valuable insights into the competencies required in VDC roles, ensuring the study's findings reflect a broad spectrum of perspectives. As highlighted by the Delphi results, while academia and industry share common priorities regarding essential VDC skills, differences in their focus on emerging technologies, such as generative design and AI, suggest a need for curriculum updates. The findings have significant implications for both academia and industry. For educators, this study serves as a call to action to redesign curricula that emphasize practical, industry-relevant skills, particularly in new technologies. By incorporating these tools and methodologies, academic institutions can better prepare students for the dynamic VDC job market. For industry stakeholders, the research underscores the importance of continuing dialogue with academic institutions to ensure that graduates are well-equipped to meet the evolving demands of the field. In doing so, both sectors can collaborate more effectively to bridge the gap between education and practice, fostering a workforce ready to thrive in the fast-evolving world of VDC.

Based on the results of this study, the authors' current research efforts are focusing on developing a roadmap for educators with actionable items to strengthen the VDC skills of their students to meet industry requirement. This study will focus on skills mapping between software, BIM roles, and construction role to design better VDC courses. Future studies will explore the impact of integrating emerging technologies like AI, generative design, and advanced BIM tools into VDC curricula and their effectiveness in bridging the skills gap between academia and industry. Another avenue for research will involve surveying recent VDC graduates and employers to assess how well academic training aligns with real-world job performance, providing data on the long-term success of curriculum changes.

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