Pedagogical shifts: integrating data-driven digital transformation and fundamental principles in construction management and surveying curricula

PEDAGOGICAL SHIFTS: INTEGRATING DATA-DRIVEN DIGITAL TRANSFORMATION AND FUNDAMENTAL PRINCIPLES IN CONSTRUCTION MANAGEMENT AND SURVEYING CURRICULA

Amidst the allure of cutting-edge technologies, there's a common inclination among students in higher education to seek out ostentatious tools thinking they can effortlessly handle construction management and surveying tasks with just a few clicks. This mindset has its merits as it encourages students to nurture both their creative and technical hemispheres. However, there is potential significant risk in solely relying on technologies in executing tasks without considering the fundamentals and core principles related to construction management and surveying. It is imperative for construction managers and surveyors, to look back and revisit the foundational principles to propel themselves forward in the digital era. Reconnecting with these fundamental principles becomes the cornerstone for the advancement within the digital landscape. This study, therefore, explores the extent to which technology should be integrated into the construction curricula. A focused group discussion approach involving construction industry professionals served as a qualitative method to comprehensively explore the topic. The insights derived from this research study will play a pivotal role in shaping the curriculum, ensuring it aligns more closely with industry requirements and demands.

Keywords: construction management, surveying, digital education, pedagogical shift, software, technology.

INTRODUCTION

Background and context

As technology and digital adoption rapidly advance in the construction industry, higher educational institutions are increasingly integrating these innovations into their curricula. In recent years, the integration of technology in education has been the subject of much discussion for several popular reasons. Firstly, these technological advancements are not only promising but also proven to enhance learning experiences and yield improved educational outcomes (Chan et al. 2023). Within the context of construction education, these positive outcomes have provoked educators to investigate into more innovative ways of teaching and learning (Kiroff and Puolitaival 2021) that help prepare graduates that possess skills and knowledge dimensions that are demanded and valued by the prevailing construction industry. However, despite the potential benefits, the effective integration of technology into construction education remains a complex and challenging mission that requires scrutinization with subtle comprehension of how technology, pedagogy and content knowledge intersect and interact to facilitate an impactful learning experience (Loof et al. 2021). In recent years, while technology integration in educational settings has become more widespread, educators often grapple with striking a healthy balance between leveraging technology and emphasizing foundational learning concepts. This dilemma doesn't imply doubt among educators regarding the importance of teaching foundational concepts through traditional approaches. Rather, it reflects uncertainty about the extent to which this adoption adequately meets the evolving needs of students and the employers who are going to take over the careers of these students. This is the second popular reason that sparked considerable debate.

Purpose of the study

Amidst the aforementioned discussions and debates, this paper aims to investigate the extent to which the technologies (i.e. digital technologies) should be integrated into the curriculum to yield effective and meaningful outcomes. The Technological Pedagogical Content Knowledge (TPACK) framework is utilised (further explained in the methodology chapter) to inform and facilitate the integration of technology in construction education, aligning with findings from prior research (Fahadi and Khan 2022). As the first objective, the study attempts to understand the current technological trends, digital practices and the state of the art of them to make sure the content in the curriculum is up-to-date, to meet the industry demands. By evaluating the insights given by industry professionals, the study intends to identify the key skills and competencies that the students need to be equipped with to excel in the rapidly changing job market. Secondly, the study evaluates the effectiveness of existing strategies (i.e. ascertain the strengths, weaknesses and opportunities) to integrate technology into the construction and surveying curriculum and then improve the delivery of it. Building upon the insights accumulated from industry professionals and the evaluation of existing integration strategies, the study finally envisions proposing actionable recommendations for enhancing curriculum integration with digital technology and fundamental principles.

LITERATURE REVIEW

The role of technology in construction management and surveying practices

The construction industry is currently experiencing a massive change, popularly termed the Industry 4.0 agenda which is used to describe the trend towards automation and digitisation of construction processes (Oesterreich and Teuteberg 2016) facilitated by the use of technology. Industry 4.0 in the built environment context comprises a variety of technologies to enable the automation and digitisation of construction processes (Oesterreich and Teuteberg 2016) and has been a catalyst in propelling the expansion of many industries in such as manufacturing and aerospace (Moshood et al. 2024). The shift from conventional craft-based construction methods is receiving significant attention from academic and industry practitioners alike and concepts such as the Internet of Things (IoT), Artificial Intelligence (A1), Building Information Modelling (BIM), Digital Twins (DT), Smart Robotics, Modularisation and Offsite Manufacturing and more.

Embracing digitisation in the construction sector has been reported to enhance efficiency, productivity and collaboration and ultimately reducing information fragmentation due to inconsistency (Moshood et al. 2024). While some of these technologies are still arguably in their infancy in the construction sector (Xu et al.

2021), they are now starting to be implemented in construction processes. There has been substantial growth in the work being done on the use of and application of wearable technologies (Oesterreich and Teuteberg 2016), Building information modelling and use of software use of AI for automating manual processes, big data analytics (Xu et al. 2021) in construction.

With these changes in how construction processes are undertaken and how assets are delivered, some of these new technologies are starting to be introduced in higher education settings in various universities. However, there are still questions on the future of construction education curriculum and how much of the traditional teachings should be retained vis a vis the amount of technology to be introduced to students.

Technology integration in construction education

Introducing technology and digital tools in construction education is an undeniable choice given the ongoing digital revolution in the sector, which rapidly replaces some traditionally professional skill sets (Adesi et al. 2019). According to Thompson and Waller (2017), many tasks undertaken by quantity surveyors will be influenced by mechanisation either fully or partially. This also applies to many construction management professional tasks (Llale et al. 2020).

The increasing advancement in computer software programmes to replace manual traditional processes in construction has equipped practitioners with powerful means of reducing time, and human error, and facilitating information sharing in their day-to-day tasks (Gerber et al. 2015). Academia faces the challenge of adapting to industry trends, as seen in the integration of BIM education into academic curricula (Abdirad and Dossick 2016) as well as the integration of virtual reality (VR) to satisfy the educational demands in the industry (Xu et al. 2021). Consequently, there are current discussions on the potential of educational curriculum to prepare and train future practitioners, and why the educational community need to set the pace rather than trail the industry (Fahadi and Khan 2022). Additionally, the 'Generational Z' students are characterised by their savviness in the use of technological gadgets and there are increasing complexities in engaging these tech-savvy students in the classroom environment using traditional approaches (Azhar et al. 2018).

This rapid evolvement in the industry has thus, been received by the academic community through curriculum redesign and integration of digital technologies in the learning and assessments of students (Azhar et al. 2018). It is evident that today's construction graduates are expected to have strong collaboration and teamwork skills, and there is an added advantage with being technology savvy and skills in the use of relevant digital tools (Fahadi and Khan 2022). However, there are still some gaps on how to achieve a balance between traditional manual know-how and the use of digital technologies, especially for subjects involving manual calculation principles. This challenge applies to both the quantity surveying and construction management curricula where manual measurement and quantification principles are taught, as well as the requirement to teach skills in estimating and other decision-making on programmes. The importance of foundational principles and know-how cannot be overemphasised. The knowledge of fundamental principles which as the basis of software programmes is increasingly being considered irrelevant by students, with arguments of it not being what is used in everyday practice at the workplace.

Current practices in integrating technology into construction curricula

Currently, higher educational institutes utilise multifaceted approaches aimed at equipping students with the necessary skills to tackle the increasingly changing digital landscape in the construction industry. Lim et al. (2023) emphasize the importance of balancing tradition and innovation, endorsing the need for the integration of emerging technologies while maintaining a strong foundation in core principles. Blended learning, gamification, collaborative learning, and personalised learning are some of those techniques used by educators to integrate technology into the curriculum. The role of experiential learning and hands-on projects in enhancing students' technological proficiency, with industry partnerships facilitating real-world applications is also widely mentioned in the literature. Lim et al. (2023) further purport that Open educational resource (OER) is a great way of integrating technology without compromising the core principles. Tan et al. (2017) stresses the fact that a curriculum will only be sustainable if it is continuously evaluated and adapted to keep pace with technological advancements. This entails establishing a framework that continuously adapts to industry relevance, aligns with industry standards, and incorporates practical insights and diverse perspectives. This is the primary reason why the objective of the study is to prioritize the development of a curriculum that is informed by industry professionals. However, challenges such as resource limitations and faculty training remain prevalent (Tan et al. 2017). Despite these obstacles, ongoing efforts to integrate technology into construction curricula reflect a commitment to preparing students for success in an increasingly digitalized industry.

METHODOLOGY

Methodological Framework

This study is grounded in the framework of Technological Pedagogical Content Knowledge (TPACK) strategy. The TPACK framework has frequently been employed in empirical studies about digital-assisted teaching especially when educators require a strong conceptual knowledge of the interactions that occur between technology, pedagogy, and content in curriculum development (Hilton, 2016). Researchers have applied this framework in the context of construction and surveying education as a type of knowledge shared by members of a teaching community for curriculum integration (Fahadi and Khan, 2022). Thus, TPACK integrates three essential components: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) while highlighting the importance of fundamental principles in construction education. The importance of the framework lies in the interaction and interdependence of the three above base knowledge domains resulting in three more secondary knowledge domains such as, Technological Pedagogical Knowledge (TPK); Technological Content Knowledge (TCK); and Pedagogical Content Knowledge (PCK). These six knowledge domains interact with each other and form the seventh knowledge domain, Technological, Pedagogical, Content Knowledge (TPCK). Within the domain of construction education, this study explores how technology can be strategically integrated into the curriculum and enhance teaching and learning outcomes. Additionally, this foundational framework helps ensure alignment with industry requirements and demands.

Participants Selection

The study employed a purposive sampling technique to select individuals who possess expertise and experience in various aspects of construction education, including members of Industry Advisory Boards (IAB), representatives from professional bodies such as the Royal Institution of Chartered Surveyors (RICS) and the Chartered Institute of Building (CIOB), visiting lecturers and policymakers for industry standards, and accreditation requirements. Participants were identified through professional networks comprising of academic institutions and industry associations. Professionals from various fields such as construction management, surveying, technology specialists, and engineering were chosen to partake in focused group discussions, offering diverse perspectives and enriching insights on integrating technology into construction education. Moreover, measures were made to include individuals with varied levels of experience, ranging from new and emerging professionals to well-experienced professionals to capture a spectrum of viewpoints and facilitate robust discussions. This approach aimed at improving the relevance and applicability of the study to the broader construction community. The inclusiveness of this approach also helped dispense a comprehensive understanding of the subject matter. Table-1 shows the selected participants for the focused group discussion.

Table 1: Demographics of participants

P#	Experience (Years)	Sector	Job role	Affiliation to HE/Professional Membership
P1	15	Infrastructure Development	Project Manager	External Examiner for HE, MRICS
P2	6	Building Construction	Commercial Manager	MRICS, MCIOB
P3	20	Infrastructure Development	Quantity Surveyor	FRICS, FCIOB APC Assessor
P4	10	Water and Wastewater Management	Commercial Manager	FRICS, APC Assessor
P5	14	Transportation and Highways	Structural Engineer	Member of IAB for HE, FCIOB,
P6	35	Energy and Power Plant Construction	Construction Manager	Member of IAB for HE, FCIOB
P7	20	Industrial Construction	BIM Manager	FCIOB
P8	10	Environmental Remediation and Restoration	Civil Engineer	Member for CDBB
P9	8	Commercial Real Estate Development	Estimator	MRICS
P10	15	Residential Housing Development	Quantity Surveyor	MRICS

While academics (i.e. educators and lecturers) undoubtedly possess valuable insights and knowledge into curriculum design, and pedagogical strategies that shape construction education, the decision to involve only industry participants in the focus group discussion is grounded in the specific objectives of the study and the need to prioritise industry perspectives. The need for industry relevance, industry alignment, practical insights and diverse perspectives were the paramount objectives of this study as mentioned in the literature.

Focused Group Discussion

A focus group discussion method was chosen as the most appropriate methodology for this study due to several reasons. Firstly, as there are participants with varying levels of experience, who work in different disciplines and with varying backgrounds, a focus group discussion could provide a comprehensive understanding of their varying viewpoints. A study employing the TPACK framework for research methods education, which involved focus groups with anglophone scholars (Class, 2024), concluded that this research method is suitable for similar studies. Secondly, a focus group discussion encourages a two-way exchange of opinions fostering interactive conversations. One's viewpoint is often challenged, questioned and corroborated as immediate feedback which can facilitate follow-up questions and help researchers better understand participants' perspectives. Thirdly, as the aim of this study is to explore the industry alignment to inform technology-integrated curriculum development, the open-ended insights gathered from industry professionals on their attitudes, perceptions, and experiences can directly inform the design and implementation of educational programs.

The focus group discussion was conducted in a semi-structured format targeting 1) TPK; 2) TCK; and 3) TPCK constructs, as the aim of this research is to explore participants' perspectives on the integration of technology into construction education. The majority of questions were open-ended to encourage in-depth discussions and allow participants to share their insights freely.

Data Collection and Analysis

The qualitative data collected were transcribed and analysed using content analysis to identify recurring themes, patterns, and discrepancies. To ensure reliability and validity, member checking was conducted by providing participants with a summary of the discussion for review and verification. Additionally, the findings were validated against existing literature.

FINDINGS AND DISCUSSION

The focus group discussion findings were categorized into three broad topics based on the methodology's constructs: 1) TPK, 2) TCK, and 3) TPCK.

Construct 1- Integration of Technology and Pedagogic Knowledge (TPK)

Pedagogic knowledge often pertains to the 'delivery' aspect of higher education rather than the 'content'. The discussion highlighted several innovative pedagogic approaches as listed in Table 2. Apart from the specific pedagogic approaches targeted at the subject areas mentioned in Table 2, participants also emphasised the importance of promoting personalised learning tailored to different learner types. Although the exact term "personalised learning" did not emerge from the discussion, the suggestions align closely with pedagogic techniques such as 'blended learning' and 'flipped classroom models' that encourage self-paced learning. The generated ideas were very much aligned to Loof et al. (2021) 's use of Learning Management Systems like Blackboard or Canvas to provide course materials, conduct assessments, and facilitate discussions that allows different learner types to collaborate on projects and share resources online in their most effective way. A noteworthy finding from the discussions was the recognition that blended learning offers students the opportunity to maximise valuable class time by focusing on hands-on training rather than solely on material delivery.

Promoting mobile learning and micro-learning techniques is increasingly embraced due to their fast-paced nature. Since students constantly have their mobile devices at hand, bite-sized videos can help them grasp more information in less time. This approach as a habit could train them to leverage construction-related apps for on-site learning and real-time data collection such as for building codes, standards, and construction calculators.

Table 2: How Technology and Pedagogic Knowledge can be integrated to different subject areas in construction management and surveying

Subject Area	Pedagogic approach	Integration Technique
Architectural and Structural Design	hands-on training sessions; project-based learning.	Use of Revit/ AutoCAD/ Tekla Structures to design and manage building projects, learning to collaborate and coordinate in a virtual environment. Assignments can include real-world scenarios where students can develop and present detailed construction plans.
Virtual and Augmented Reality (VR/AR)	immersive learning experiences and simulation-based learning.	VR and AR can be used to simulate construction site environments, allowing students to practice safety protocols, site inspections, and spatial understanding without physical risks. Create virtual site visits to explore different construction phases and techniques.
Drones and Robotics	case studies and experiential learning projects.	Operate drones for site surveys and inspections, providing real-time data collection and analysis. Use robots in classroom demonstrations to showcase automated construction techniques.
3D Printing	Inquiry-based learning and design thinking.	Designing and creating prototypes of construction elements using 3D printers. This can help in understanding materials, structural integrity, and design efficiency.
Geographic Information Systems (GIS)	Spatial analysis and problem-solving exercises	Practical operation of GIS software for site analysis, planning, and environmental impact assessments. Develop projects that require students to analyse geographic data and make informed decisions.
Project Management and project Planning	Problem-based learning and scenario analysis.	Software like Primavera, MS Project, or Asta Powerproject (for planning) and Procore; Autodesk BIM 360; Aconex for project management allow students to plan, schedule, and manage construction projects in a simulated environment. Analyse project outcomes and optimize processes based on simulated data.
Quantification; Contract Evaluation; Construction Cost Estimation and Cost Planning	Problem-based learning	Software like CostX, Bluebeam Revu, Planswift, CCS Candy, Causeway Estimating, and QSPro tackle real-world construction and surveying problems, developing critical thinking and problem-solving skills while applying theoretical knowledge to practical scenarios

Use of Online Collaborative Tools is another important point emerged from the discussions. One participant noted that during an interview on MS Teams, a student struggled to share content on screen showcasing a lack of proficiency in basic communication tools. It was suggested that all construction and surveying students should be encouraged to engage in collaborative learning and peer feedback tasks facilitated using tools like Microsoft Teams, Slack, or Trello for project collaboration. This would allow students to work together on group projects, share documents, and communicate effectively.

Another important aspect mentioned by many participants is the developing and maintaining e-Portfolios. Encouraging students to create e-portfolios to document their learning journey, project experiences, and skill development would support reflective learning and continuous assessment.

Construct 2- Integration of Technology and Content Knowledge (TCK)

While technology-specific modules will have their own syllabus focused on the saturated technology domain, other modules that include an element of technology must be carefully designed in terms of their content. A frequently discussed subject area was quantification and costing, where the majority of the module content has traditionally focused on the foundational principles of measurement and their application. All participants were in agreement that while technological tools are essential in modern quantification and costing practice, they should not overshadow the foundational principles of core content knowledge. In this example, principles of measurement, building technology, and contract law should not be obscured by the technology element. Therefore, a balanced approach is necessary in integrating technology into construction and surveying curricula. When questioned about the ideal percentage of digital technology integration in non-technology-focused modules, they stressed that the content of a module should not surpass 20% digital technology, in line with the views of several industry professionals. This perspective is corroborated by Fahadi and Khan (2022), who emphasize the importance of maintaining a balance between technology and core principles in education.

However, the key issue was designing the content for this 20%. It was recommended that every module include digital literacy. The focus group identified essential 'routine knowledge dimensions' to prioritise (discussed in subsequent paragraphs), with a narrowed focus on 'quantification and costing,' a fundamental RICS competency. These knowledge dimensions are applicable to any construction management and surveying module.

Data analytics and visualisation: In response to current industry demands, students must cultivate proficiency in collecting, analysing, and visualising construction cost data using digital tools (as detailed in Table 2). This enables them to make informed decisions and optimise construction processes based on identified patterns. Loof et al. (2021) who investigated the effectiveness of data science-integrated STEM education in engaging students also suggested similar approaches. What stands out in the present paper is that discussions suggested integrating the data analytics content as a complement to core knowledge rather than a separate entity to fundamental concepts taught in construction and surveying courses. Examples include the use of historical project data to forecast future construction costs.

Collaboration: As effective teamwork is crucial in digital transformation, encouraging collaborative projects and team-based assignments through tools such as MS Teams, BIM collaborative platform that stimulates real-world construction scenarios will help students develop their digital collaboration skills. Examples include learning the collaborative nature of 5D BIM with all other BIM dimensions.

Industry Trends: Directing students towards the latest industry trends not only keeps them informed but also cultivates a habit of continuous learning and staying up-to-date with industry developments. An example include analysing case studies of innovative cost estimation techniques used in recent construction projects, to match the industry standards or building codes related to cost measurement, or examining emerging trends in construction procurement methods affecting project costing.

Sustainability and Green Construction: Encourage students to incorporate sustainable practices in design, quantification, and costing, focusing on energy efficiency, renewable energy systems, green building certification, and environmental impact assessment tools.Needless to say, the remaining 80% should ideally be comprised of the core content ensuring that students grasp fundamental concepts essential for their roles in the industry. This approach ensures that students have a strong theoretical foundation upon which to apply any of the prevalent technological tools effectively. This view aligns with the findings of Kiroff and Puolitaival (2021), who stress the importance of providing students with a robust theoretical understanding alongside practical skills to tackle the dynamics of the modern construction industry. Emphasising the synergy between technology and fundamental knowledge reminds students that while technology is a powerful tool that streamlines most of the 'management tasks', it is most effective when combined with a strong foundation of core principles. Without this foundation, students may struggle to leverage technology efficiently and accurately in their work. This sentiment aligns with the findings of Tan et al. (2017) who emphasise the importance of providing students with a robust theoretical understanding alongside practical skills to navigate the complexities of the modern construction industry.

Construct 3- Integration of Technology, Pedagogic Knowledge and Content Knowledge (TPCK)

When Technology, Pedagogy, and Content are integrated, students gain both theoretical knowledge and practical application, preparing them to effectively utilise digital tools in their future careers. To emphasise the importance of balancing technology and core principles, the students must be able to understand that digital tools cannot replace the need for human judgment and expertise. Soft skills such as decision-making and problem-solving are honed through a thorough understanding of foundational principles and mastery of conceptual learning/ foundational learning (Lim et al. 2023). Such understanding provides students with a strong theoretical basis, critical thinking skills, problem-solving skills, and strong adaptability skills in using any software.

The discussion underscores the vital role of industry partnerships and guest lectures in enriching students' understanding of technology's real-world applications in construction and surveying. By fostering collaboration with industry professionals, students gain valuable insights into industry demands and standards, enhancing their preparedness for the workforce.

CONCLUSION

The integration of technology, pedagogic knowledge, and content knowledge (TPCK) in construction and surveying education is paramount to preparing students for the evolving demands of the industry. Through focus group discussions and analysis, it was evident that there is no one-size-fits-all approach to technology integration for content or pedagogy. Depending on the subject area, innovative pedagogical strategies can be applied to an acceptable extent making sure the content element is not compromised. By embracing mobile learning, micro-learning techniques, collaborative platforms, and embedding routine skills and knowledge dimensions educators can create dynamic and engaging learning environments that empower students to acquire essential skills and knowledge. Leveraging digital tools with appropriate pedagogical approaches, and fostering industry partnerships are key to enhancing students' learning experiences and ensuring their readiness for the workforce. This study recommends further exploring an approach to effectively convey to students the limitations of digital tools and the importance of human judgment and expertise in construction and surveying practices as a future research avenue.

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