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A PRELIMINARY REVIEW OF THE OPPORTUNITIES AND CHALLENGES IN TRAINING AND CERTIFICATION FOR COMPUTING IN CONSTRUCTION

Vishal Singh[1], Yiannis Xenidis[2], Fadi Castronovo[3], Sunil Suwal[4], Angelo Luigi Camilo Ciribini[5], and Andrius Jurelionis[6]
[1]Indian Institute of Science, Bangalore, India
[2]Aristotle University of Thessaloniki, Thessaloniki, Greece
[3]University of Brighton, Brighton, United Kingdom
[4]Metropolia University of Applied Sciences, Helsinki, Finland
[5]DICATAM University of Brescia, Brescia, Italy
[6]Kaunas University of Technology, Kaunas, Lithuania

Abstract

This paper presents findings from a preliminary review of the status of training and certification in computing in construction. A review of the academic literature, market trends, and a questionnaire-based survey validate the demand for training and certification in computing in construction. The findings reveal the need for a detailed articulation of areas within computing and construction that require training and certification. There is an expectation that academia and professional associations will lead training and certification to ensure quality. There is a need to train and certify trainers to ensure quality and build capacity to decentralize the training and certification ecosystem.

Introduction

Over the last three decades, computers and computing has pervaded nearly all industries including significant inroads of computing, Information technology (IT), and digitalization in the Architecture, Engineering and Construction (AEC) sector. Beginning with Computer-Aided Design (CAD) tools in the 1990s to wider dissemination of Building Information Modelling (BIM) in the 2010s, computational tools were typically designed such that the AEC professionals could use the tools for their activities as CAD or BIM users and modellers, without necessarily needing to know details of the computing process or software programming. At the same time, many commercial and non-commercial tools and applications were also designed to allow AEC professionals with computing and software knowledge and skills to extend, customize, and further develop the tool's capabilities and functionalities. In parallel, during this period, professionals from a computing background have contributed to the research and development of the AEC domain-specific software and applications over the years. Now, with growing digitalization in AEC in recent years across multiple areas ranging from CAD and BIM to the growing use of Artificial Intelligence (AI), Machine Learning (ML), Data Science (DSC) and the Industry 4.0 approaches, there is unprecedented growth and need for computing knowledge, skills, and abilities in the AEC sector. Therefore, this paper focuses on the topic of training and certification for computing in construction.

The topic of computing in construction has increasingly become mainstream research and educational area in itself. While the Journal of Computing in Civil Engineering was established way back in 1987, highlighting the early recognition of computing in construction as a research field, the formation of BuildingSMART International, formerly known as International Alliance for Interoperability (IAI), in 1994 demonstrated the emerging significance of computing in the commercial AEC software domain. However, the establishment of bodies such as the European Council of Computing in Construction (EC3) in recent years reflects the growing maturity of computing in the construction field at the interface of research and development, education, and practice. While research and development around computing in construction have existed over the last couple of decades, in recent years, there appears to be an exponential growth in the demand for trained personnel in a range of computing in construction topics to work across both industries and academia. Hence, this paper specifically focuses on investigating the status and demand for training and certification for computing in construction, especially in Europe.

Background and Context

The growing significance of the topic of computing in construction is reflected in the publication trends, emerging new courses and programs at the academic institutions, online courses offered by different training providers, training and certifications offered by professional and industry associations, training and certification offered by software providers, and so on. The trend is further reinforced and observed in the objectives and projects funded by the European Commission as well as other collective efforts such as the formation of EC3. It is important to note that as certification processes include training programs of various content and duration, and training courses grant certifications of different level and value (e.g. from degrees to certificates of participation), training and certification tend more and more to considered as parts of a single process, rather than two distinct ones. More importantly, computing in

construction remains an umbrella term that covers a wide range of knowledge, skills and abilities across a range of topics, even though some specific topics such as BIM may have received more targeted effort. For the purpose of this research, "computing in construction remains" remains purposefully a broad umbrella term subject to individual interpretation instead of adopting a specific definition within rigid bounds. While this approach indeed groups altogether quite different fields of computing in construction (e.g. CAD, BIM, machine learning, etc.), it was deemed appropriate for two reasons. First, because, these fields often collide in everyday's practice thus rendering boundaries between them rather indistinguishable. Second, because, this research, ultimately, seeks to understand the general trends observed in training and certification from a broader perspective, as reflected in both within and outside the academic settings.

Furthermore, as noted by some authors, there are semantic and pragmatic differences in terms such as certificate and certification. For the purpose of this research, the authors not delve into these differences yet, allowing the audience reviewers and research participants to use these terms interchangeably. In addition, the authors recognize that given the wide-ranging topics under the computing in construction umbrella term, multiple certification modules and mechanisms will have to be considered in practice. While acknowledging these issues, the authors also recognize that the current research objectives are still at a broader level, asking them questions such as 'do we need certification', before even venturing into the details such as, how.

Research Methodology

This research seeks to build a preliminary understanding of the status of training and certification in the areas of computing in construction. To achieve a broad, comprehensive and holistic view based on the complementarity of results, the research design incorporates the following diverse tools:

1. **Literature review:** A preliminary literature review is conducted within the academic literature, including both journal and conference papers. The papers were initially collected via search using keywords such as "certificate, "certification", "education", "training", "accreditation", "competence", "construction skills", "computing in construction", "IT in construction", "digitalization in construction", and "BIM skills". Initial filtering of the collected papers was done through a qualitative review of the abstract to assess the relevance of the paper. The shortlisted papers were qualitatively analysed to identify the broad patterns in the data.
2. **A desktop review for market trends:** A preliminary desktop review was conducted using online searches outside academic databases or outside of academic articles. The search used similar keywords as used for querying academic articles, but all relevant websites, online forums, online training providers, company brochures, communities reports, etc that appeared and were found to be relevant were considered for review. This part of the review was conducted to assess patterns and market trends in training and certification for computing in construction outside of the academic boundaries.
3. **An empirical survey** was conducted to investigate the current state of educational certification in computing in construction. The survey was based on Colvin et al. (1980), which focused on assessing the requirements of higher education reading certification. The survey by Colvin et al. (1980) was chosen as the base of this study because educational researchers internally and externally validated it. The survey was composed of three parts. The first part asked for participants' ***Demographic*** information, such as age, gender, location, current employer (e.g., professional organization, governmental organization, academic institution, etc.), current role, years of experience, and if their educational institution taught courses related to computing in construction. The last question of the ***Demographic*** section asked if the participant's country offered some certificate for computing in construction education. Based on the answer to this previous ***Demographic*** question, the participant was either taken to a ***Certified*** or ***Not-Certified and Certified*** section. The ***Certified*** section asked: what type of organization provides certification (e.g., professional organization, governmental organization, academic institution, etc.), who is the certificate for (e.g., undergraduate, graduate, faculty, etc.), and how long was the certificate for. The ***Not-Certified and Certified*** section asked questions about the favorability and benefits of certification. Additionally, this last section also asked who should be responsible for providing certification (e.g., professional organization, governmental organization, academic institution, etc.), who it should be for (e.g., undergraduate, graduate, faculty, etc.), how long should the certificate be valid for, and if academics should be certified in teaching computing in construction. The goal of this survey was to capture early data related to the certification related to computing in construction. The terms certification was left vague to cast a wide net. Therefore, the survey needs to be expanded further to capture the different types of certifications, the methods of achieving the certification, and topics covered in the certification.

Survey Administration

The survey was administered online with the use of Google Forms. The survey was sent to the members' email list of the European Council on Computing in Construction, the BuildingSMART Professional Certification, and the Co-operative Network of Building Researchers. The selection of the specific organizations

aimed at the collection of data from various audiences (i.e., professionals, academia, etc.) to avoid bias in the research results. The survey was emailed to these members on the 12th of November 2021 and was closed on the 12th of December 2021. The survey was open to anyone that was part of the mailing list and no limitations on age, gender, role, etc., were put on the responses. A total of 46 responses were collected, however, one response had to be discarded as the respondent did not fill out the questionnaire but only added their email address. Therefore, only 45 responses were analyzed.

Results and Findings

Summary and Findings from the Literature Review

Charef et al., (2019) acknowledge that BIM adoption, maybe the most discussed aspect of computing in construction, has turned from a novelty to a necessity (especially in the EU), thus rendering quite obsolete that part of previous research arguing about its need. Smith (2014) and Wen et al., (2021) present an informative review of the BIM implementation progress that supports the previous statement. Therefore, this literature review has built upon previous similar attempts that were published only in the last five years to summarize their findings and set the basis for the most recent and fresh views on the field. The search of sources was limited to SCOPUS database, which is considered credible and rich, in terms of content, source of publications (Charef et al., 2019). The search that was based on the keywords mentioned in the "Research Methodology" section returned 12 representative publications that when thoroughly studied have proven adequate in, collectively, covering a significant part of the respective field and, adequately providing an insight into the specific issues of interest in the context of this preliminary stage of the research.

The literature review's objective was to identify the current situation of the AEC industry in relation to education, training, and certification on computing in construction as tracked through research. The comparison of the findings with those of other approaches on the same objective would help in the formulation of a preliminary view of the respective challenges and opportunities, especially in the European context. Therefore, the literature review's findings are the following:

- Digital methods, technologies, and tools are becoming more prevalent in the AEC industry due to their positive impact on efficiency, productivity, risk mitigation and, eventually, profitability in projects' execution (Anderson et al., 2020; Charef et al., 2019; Uhm et al., 2017). This development coupled with other current societal needs gradually creates new content for engineering education and profession (Lupi at al., 2022). Moreover, the growing familiarization of construction management staff with the new roles or the development of traditional ones based on the introduction of IT in construction promotes a new organizational plan that will gradually prevail over existing ones (Bosch-Sijtsema et al., 2019). This plan is further supported or formed by the implementation of proposed protocols that aim at specializing roles in the new context of construction projects delivery (Ariyachandra et al., 2020).
- Projects in the AEC industry are increasingly taking place in distributed environments, often internationalized (Charef et al., 2019), where knowledge and information are shared and reproduced and collaboration among various stakeholders that work in distributed teams is imperative (Ariyachandra et al., 2020; Anderson et al., 2020).
- Conceptual knowledge of digital methods and technologies is more important for the AEC industry compared to the sole acquirement of application skills as it can build the necessary background for developing diverse competencies that emerge in a still advancing environment (Lee et al., 2021; Bosch-Sijtsema et al., 2019; Yakami et al., 2018; Uhm et al., 2017). Obtaining a knowledge acquisition rather than a skill development approach is compatible to proactive skill development, which is critical for achieving adaptability in an advancing professional environment (Ostmeier & Strobel, 2022; Bosch-Sijtsema et al., 2019).
- Accreditation bodies in the field are adjusting to address the requirements of the new environment, thus bringing forward the need for training and education in computation in construction (Anderson et al., 2020), especially for new roles and disciplines that are added to the traditional ones in the construction process (Ariyachandra et al., 2020).
- Certifications, in general, are not yet a requirement for employability in the construction industry, although they can be acknowledged as valuable tools for career advancement. Especially certifications in computing in construction are even less required even in mature industries such that of the US (Barrows et al., 2020), while standardization is not concurrently advancing throughout the EU (Charef et al., 2019). An important aspect is the relatively short period of existence of such certifications, which has not allowed them to become widely accepted by the profession and the public at large (Barrows et al., 2020).

The findings from the preliminary review raise a number of important issues, which, when analyzed against the findings from other sources, can provide an indication of the opportunities and priorities in advancing the field of training and certification for computing in construction.

Summary of findings from the desktop review of market trends

A preliminary desktop review of market trends in certification and training suggests rapid growth in training

providers in the last decade. Commensurate with the general trend of the dominance of BIM in computing in construction literature, a significant portion of the offered training programs and certifications, both online and offline, are targeted towards BIM. Almost all notable BIM software vendors (e.g. Autodesk, Bentley, Trimble, Graphisoft) offer their own training and certification. In addition, several private BIM and computing-related courses, training modules, and certifications are being offered, besides the courses accredited and/or offered by construction and professional associations (e.g. Canadian Construction Association, Associated General Contractors of America).

In addition, several free and paid online training courses are available, though certification is typically associated with paid online programs. Given the range of courses that are cropping up at local levels (physically) as well online courses by independent private actors, the quality control and standardization of offered modules remains a concern. Nonetheless, the rapid growth in the number of actors, both formally recognized and unrecognized actors, suggests that there is demand from practice where skill sets are more important than the authenticity of the training provider. Moreover, the variety in training modules, courses and their structure reaffirms that a range of different certification and training areas within the broader umbrella of computing in construction needs to be considered.

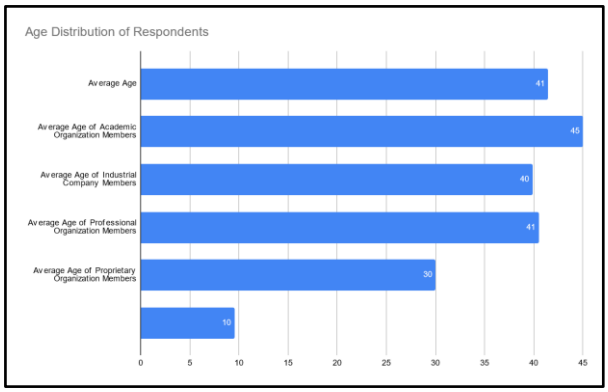
More recently, both online and offline training courses have also begun to emerge in other areas of computing in construction, extending beyond BIM to areas such as generative design, analytics, machine learning and general Information technology and programming skills for AEC professionals. Though the number of such courses is relatively much small compared to the number of courses on BIM, the market trend also indicates growing demand for computing in construction training and certification that extends beyond BIM and such established areas.

Results from the empirical survey

This section briefly summarizes the key findings from the surveys in the form of descriptive statistics, and wherever applicable, a qualitative interpretation of the patterns observed in the responses.

Demographics

Based on the 45 responses that were analysed the average age was 41, a more detailed breakdown of the age distribution can be found in Figure 1a. The average age of academics was 45 years and that of members of proprietary organizations was 30 years. The gender distribution reflected current trends in the construction industry and academia. A total number of 37 males, 7 females, and 1 undisclosed answered the survey, see Figure 1b. The ratio of female to male respondents (9.5%) was lower in academia than the ratio for industry members (44.4%). The sample size was composed of the majority



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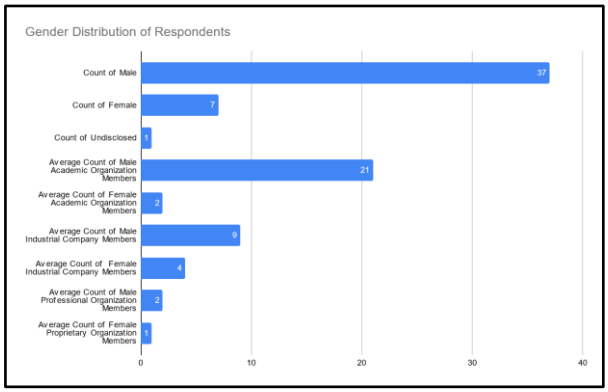

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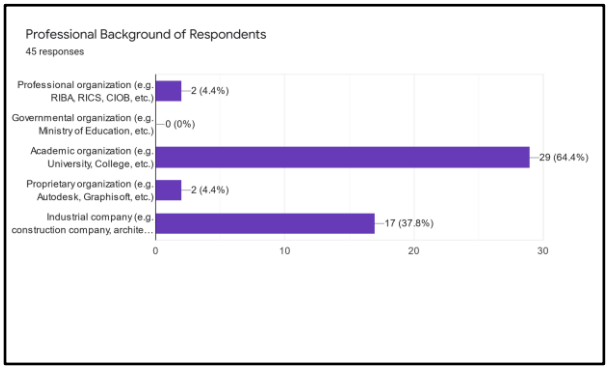

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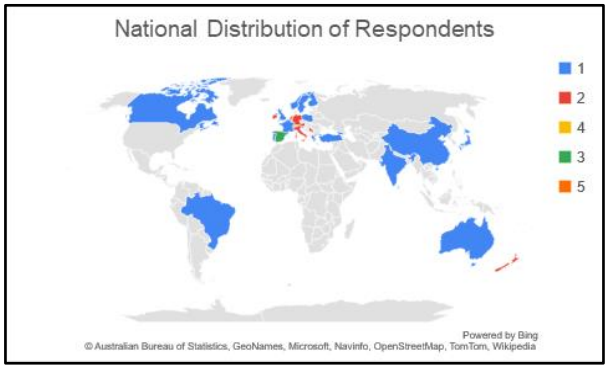


(d)

Figure 1: Demographic Results

of academics (64.4%) and/or industry members (37.7%), and/or a few members of professional and proprietary members (4.4%), see Figure 1c. Some respondents were both working in the construction industry and academia,

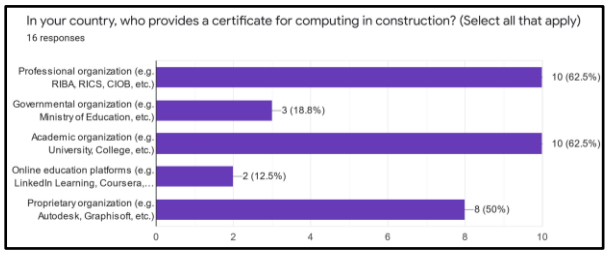
hence they were considered in both groups in these cases.Figure 1d illustrates the country-wise distribution of the respondents, with the Netherlands having the highest number of respondents (a total of 5) and Switzerland second (a total of 4). When asked if academics were teaching courses related to computing in construction, 36 answered "Yes", 6 answered "No", and 3 answered, "Don't Know". Lastly, when asked if their country offered a certificate for computing in construction education 16 answered "Yes", 20 answered "No", and 9 answered, "Don't Know". These results illustrate the further study needs to be conducted to expand the demographic and capture additional data from professionals, governmental institutions, and proprietary organizations.

Existing Certification

Certification within an educational or training scenario is considered important. Certification is a way to attest one's level of knowledge or competence in the specific domain of the profession. BIM is considered one of the digital innovations that have influenced the construction industry at large. Different training providers have their own certification scheme depending on the verse, content, and procedures of training. BuildingSMART International as an organization that looks toward the overall global BIM standardization and development focuses on the certification scheme. To understand the need for certification for computing in the construction industry, BIM certification schemes and processes were investigated by the authors. However, to understand the user perception of certification in computing in construction, the participants were provided with the possibilities to answer to (i) if such certification is existing, (ii) for whom the certificate is provided, (iii) validity of certificates, and (iv) if the academics teaching computing in construction is certified. The survey results show that both academic organizations and professional organizations are offering certification through their training and education schemes, see Figure 2a - 2d. The respondents also note the product-specific training and certification being provided by proprietary organizations such as Autodesk and Graphisoft. The survey results also show that a large part of reported certifications in computing and construction are either at the postgraduate level or for professionals. In addition, most of the certification is reportedly valid for an unlimited period, which must be investigated given that computing-related domains tend to require frequent upskilling and training. Further, nearly half of the respondents reported that academics teaching computing in construction have some sort of certification.

Desirability and perceived usefulness of Certification

The last section of the survey sought respondents' perception of the desirability and usefulness of some sort of certification in computing in construction. An 80% of



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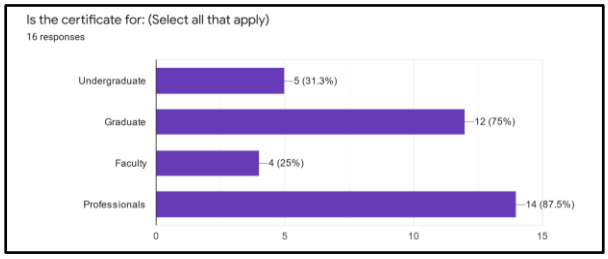

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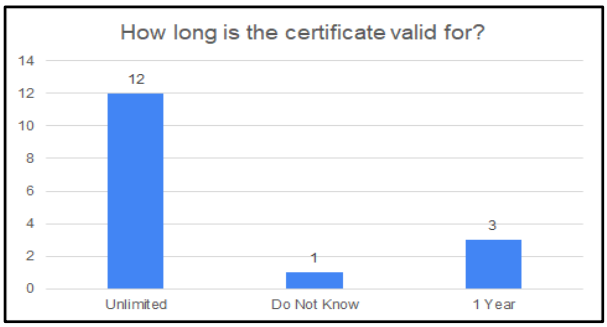

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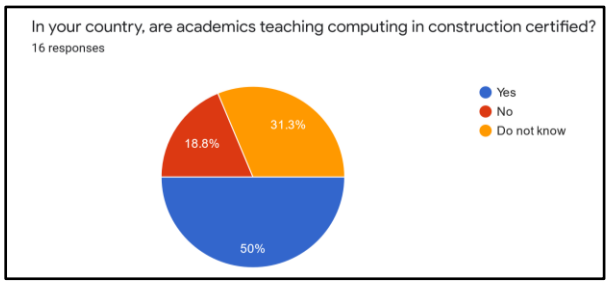

(d)

Figure 2: Results from questions on existing certification

of respondents express desirability of such certification, with 40% marking it as "*Very Favorable"* while the other 40% marking it as "*Favorable"* (40%), see Figure 3a. While 17.8% were "*Neutral*" towards the desirability of certification, only 2.2% marked it to be "*Very Unfavorable*". Consistent with the responses on the desirability of the certification, 75.6% of respondents also expect such a certification in computing in construction to be beneficial (40%) or very beneficial (35.6%), see Figure 3b. While a 20% express "*Neutral*" sentiments towards potential benefits of such certification, only a 4.4% perceive it to be non-beneficial. The respondents have a strong preference for certification from established organizations as compared to online training providers or proprietary software companies. An 80% of respondents favour certification from academic organizations, a 66.7%

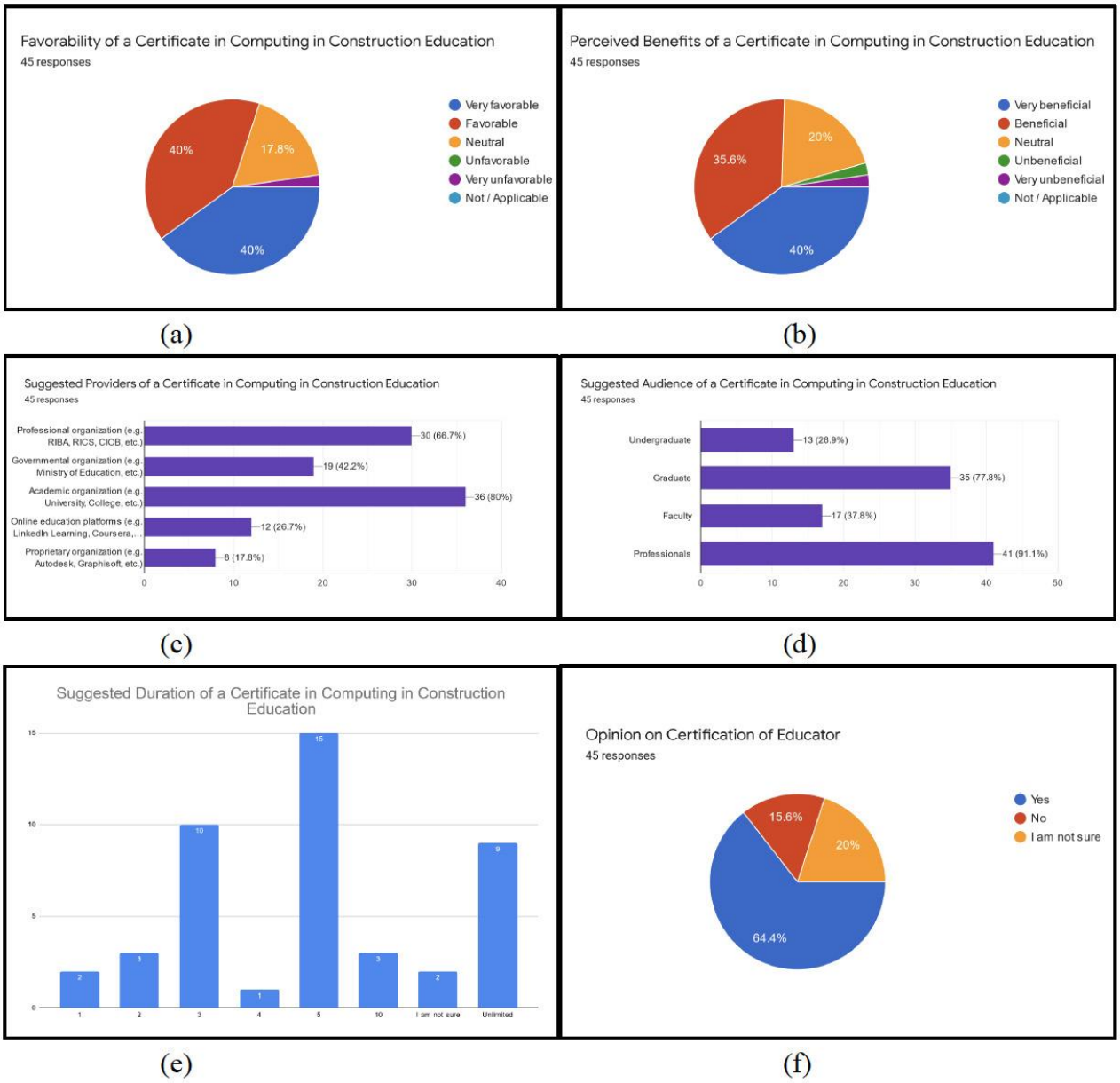

Figure 3: Example of a double-width image

favour certification from professional organizations, and 42.2% favour certification from governmental organizations, see Figure 3c. The corresponding numbers for online certification providers and proprietary software companies are as low as 12% and 8% respectively. With regard to the target groups to certify, 91.1% believe that there should be certification for professionals, while 77.8% believe that there should be certification for graduate students, see Figure 3d. The corresponding numbers for certification of undergraduate students and faculty are 28.9% and 37.8% respectively. With regard to the desired validity period of the certification, a 3–5-year validity period was most desirable, with 33% preferring a 5-year period of validity and 22% preferring a 3-year period, Figure 3e. While 18% of respondents prefer unlimited validity, the survey responses clearly indicate that most respondents recognize that unlimited validity of certification may not necessarily be a good idea in a domain like computing in construction. Finally, most of the respondents (64.4%) believe that academics teaching computing in construction topics should have a certification, see Figure 3f.

Discussion and future work

The results from this preliminary study confirm the growing need and demand for certification and training in computing in construction, both across industry and academia. The independent findings from each of the three research datasets, namely, academic literature, market trends observed online, and a preliminary survey conducted with academics and professionals independently establish the demand for certification and

training in computing in construction. Collectively the findings from each of the three approaches validate the results obtained so far and reflect some common patterns with regard to the opportunities and challenges that need further investigation.

First, while there is a general recognition that computing and construction is an umbrella term that accounts for a range of competencies, expertise areas, and skill sets, a large part of training and certification in this area is still concentrated towards BIM training and certification. Hence, there is a need to define and outline what 'computing in construction' means and what kinds and levels of training and certification are required in the various sub-areas associated with computing in construction.

Second, findings suggest that with the increasing demand, several different actors have emerged who are offering training and certification, with limited checks and balances to ensure quality. Despite the uncertainty of quality, the market trends suggest that people are getting trained and certified through multiple channels. Whereas the survey results suggest that people seek quality assurance through training and certification organized by academic institutions and professional associations. Thus, it appears that there is inadequate training and certification on computing in construction from academia and professional associations now. At the same time, it appears the construction sector benefits from the decentralization of training and certification, where private actors also actively play their part in training and certification. Therefore, to benefit from such a decentralized training and certification ecosystem, novel mechanisms of quality control and quality assurance may be required.

Third, the findings suggest that majority of the certificates offered currently are valid for a lifetime, whereas in a field like computing in construction, the tools, processes, and skillsets may need regular up-gradation because of the pace of development in these areas. These findings suggest that the current training and certification ecosystem is inadequately planned, and calls for a rigorous SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis to plan the way ahead.

It should be noted that despite the empirical survey's design, the academia's views on the topic could create some bias in the above-mentioned research's results.

Propositions for future work

The findings from this study also suggest that the current training and certification are geared towards individuals, either students or professionals, with the objective to impart and recognize their competence to work in these areas. In contrast, given the demand for training and certification, it appears that there is also the need to train and certify actors who can train and certify others such that the decentralized training and certification ecosystem offers greater quality control and quality assurance. Therefore, it is proposed that the research and development efforts on training and certification in computing in construction adopt a holistic view, targeting different audiences, including institutions and organizations, teachers, and instructors, and working professionals and students, as summarized in Table 1.

Table 1: Proposed approach to enhance quality in decentralized training and certification ecosystem

Certification module	Target group	Value proposition	Mechanisms & steps towards certification
Course accreditation and certification	Higher education institutions and organizations	Accredited courses- Quality check. Receive support and guidance, if required.	Audit review, recommendation reports, training, and certification
Trainer certification	Teachers and Instructors	Validation of expertise and ability to teach.	Review, exams/ interviews, and trainer training programs
Skill and knowledge certification	Students and professionals	Training & recognition of skills, knowledge, and abilities	Direct exams, course modules

For instance, a neutral, non-profit association such as the EC3 can offer independent quality checks, accreditation and training to institutions and organizations that offer courses, training, and certification in computing in construction. Such institutions and organizations may require an independent assessment, accreditation, and support, especially when the requirements may change more frequently than the traditional courses. Similarly, the training and certification of teachers and instructors can follow the "training the trainer" approach. Such an approach can be particularly useful in the decentralization effort by creating a pyramid model that can allow rapid scaling to meet the increasing demand for training and certification in the emerging areas of computing in construction.

The proposed approach is likely to benefit the different stakeholders in different ways. For instance, institutions can expect validation of their courses, which in turn can lead to greater program attractiveness, marketability, and greater employability of students graduating from their programs. Similarly, trainers, teachers and instructors may benefit from the formal recognition of their expertise and ability to teach, which will enhance the marketability of their courses, while also enhancing their potential employability in the training and certification ecosystem. Whereas the typical benefits for students and working

professionals are already well documented, including the acquisition of new knowledge, skills and abilities; and the potential for greater employability. Overall, the industry can benefit in multiple ways, including access to trained and certified professionals who can take the industry forward with the knowledge, skills and abilities in the different areas of computing in construction. Nonetheless, the proposed benefits are conjectures that need further research and investigation.

Conclusions

The research findings suggest the need for a sustained effort in formulating the training and certification requirements and mechanisms in computing in construction. Four major areas of concern emerge, which need detailed investigation. First, how do we define the different areas and sub-areas of computing in construction that require training and certification modules. Second, how do we create mechanisms to meet demand-supply balance in the rapidly growing areas of training and certification in computing in construction. Third, how do we help academia and professional associations in taking the lead in ensuring quality control in the range of online and offline courses offered by different actors, while at the same time allowing decentralization such that there are enough certified trainers to meet the demand-supply gap. Fourth and last, what kind of roles can associations such as EC3 play in creating an effective training and certification ecosystem in the areas of computing in construction. The next steps of this research will seek to provide credible answers to these areas of concern in the benefit of the AEC community.

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