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BIM INTEGRATION IN HIGHER EDUCATION: A GLOBAL ASSESSMENT

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SUMMARY: *Building Information Modelling (BIM) has contributed significantly to the integration of the architecture, engineering, and construction (AEC) industry by enhancing collaboration and breaking down barriers between disciplines. Earlier research suggested that BIM should also transform AEC higher education, proposing several levels of curricular change. This paper presents empirical findings on how BIM has affected education beyond the replacement of traditional drafting tools. It is based on a global survey of 125 active professors and researchers, supplemented by five semi-structured interviews. Our findings reveal a growing integration of BIM in course curricula, particularly in areas such as CAD, project management, and sustainability, alongside emerging pedagogical practices such as project-based learning and interdisciplinary collaboration, which have also begun to break down traditional silos between subjects. However, significant regional variations exist, with European institutions generally exhibiting higher levels of integration compared to their American and Asian counterparts. A structured scoring framework was developed to classify BIM adoption across five levels, providing a quantitative basis for comparison and benchmarking. Key challenges to deeper integration include resource limitations, faculty training, institutional resistance, and insufficient industry collaboration. The paper offers practical recommendations for educators and institutions seeking to advance BIM integration, supporting curriculum reform through a structured, stage-based approach. While the findings offer valuable insights, further research with a more representative sample is recommended to deepen the analysis.*

KEYWORDS: *BIM, Education, AEC industry, Survey.*

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1. INTRODUCTION

Building Information Modeling (BIM) has emerged as a transformative force in the Architecture, Engineering, and Construction (AEC) industry, revolutionizing design, construction, and facility management (McGlinn et al., 2019). Governments around the world have supported its adoption through mandates and standards, recognizing BIM's potential to improve project efficiency, sustainability, and collaboration (Bradley et al., 2016, Chihib et al., 2019, Sotelino et al., 2020).

As BIM becomes integral to AEC practice, higher education institutions face increasing pressure to realign their curricula with evolving industry demands. While its inclusion in academic programs is broadly encouraged (Shelbourn et al., 2017, Agirbas, 2020), questions remain regarding how thoroughly BIM has been adopted, which disciplines it reaches, and what pedagogical changes it has triggered (Scott, 2015, Sotelino et al., 2020).

Previous work has explored these challenges conceptually. In particular, Turk and Istenič-Starčič (2020) introduced a five-level framework for assessing how BIM can reshape AEC education—from basic tool adoption to full curricular transformation. Their research highlights the need to bridge the gap between industry integration and the still siloed structure of academic programs.

This study builds upon that foundation with an empirical investigation, examining how BIM is integrated into AEC curricula at the undergraduate level. Using a mixed-methods approach that includes survey data and expert interviews, the study explores integration depth, teaching methods, and course positioning across different regions.

While our study aims to assess global trends, we acknowledge limitations in regional representation, which are discussed in the methodology and reflected in the interpretation of results. Nevertheless, the findings contribute to understanding the current landscape of BIM education and offer direction for more coordinated curricular innovation.The paper is organized as follows. Section 2 gives a literature review on related works. In Section 3 the methodology of the survey is described. The results of the survey are presented in Section 4 and discussed in Section 5. The conclusions of the study are detailed in Section 6.

2. RELATED WORK

Research on the integration of Building Information Modeling (BIM) into education has explored diverse angles. Scholars have examined BIM instruction within information technology-focused courses (Ibrahim, 2007; Barison & Santos, 2010; Sacks & Pikas, 2013; Salgado, 2022; Maharika et al., 2020), its impact on architectural and design pedagogy (Cheng, 2006; Brown, 2008), and its influence on construction management education (Clevenger et al., 2010; Kim, 2011; Peterson et al., 2011; Migilinskas et al., 2013). Broader studies have assessed curricular adaptation to BIM (Becerik-Gerber et al., 2011; Macdonald, 2012; Agirbas, 2020; Sotelino et al., 2020), while global assessments have highlighted the uneven nature of adoption (Olowa et al., 2019; Banh, 2024).

The most recent international report by Banh (2024) provides a comparative snapshot of BIM education worldwide. It reveals continued regional disparities, ranging from comprehensive graduate programs in Australia and parts of Europe to minimal integration in regions such as Africa and parts of Asia. The report also notes the expansion of curriculum themes to include sustainability, openBIM, and emerging technologies, underscoring the growing complexity of BIM education.

A prominent conceptual framework for understanding how BIM can transform AEC education was proposed by Turk and Istenič-Starčič (2020). They argued that traditional engineering curricula are often siloed—organized into compartmentalized courses and disciplines—and that BIM, as a model-centric and integrative technology, can help break these silos. Their framework outlines five progressive levels of transformation in how BIM reshapes teaching and learning:

1. *BIM Modernizes Teaching of CAD*: Traditional design communication courses evolve to integrate BIM modeling tools, producing skilled BIM modelers and operators. Elective courses might focus on Building Information Management or programming languages for BIM-related tasks.

2. *BIM Modernizes Construction Management*: Courses involving construction processes adapt to incorporate BIM principles. Project planning shifts to 4D BIM models, quantity take-offs rely on BIM data, and financial management encompasses 5D BIM. BIM Execution Plans become central, and

management courses include training for future BIM coordinators and managers.

3. *Shallow BIM is Used in Vertical Courses*: BIM tools are employed for documentation in specialized courses like Roads and Bridges and Steel Structures. Although separate topics, BIM software is used for conveying designs, enabling students to discuss concepts using BIM-specific language.
4. *Deep BIM is Used in Vertical Courses*: Vertical engineering courses integrate BIM concepts and standards. Attributes within BIM data structures align with equations discussed in courses, enabling seamless information exchange between analysis software and BIM databases.
5. *Knowledge is "BIMified"*: BIM evolves into a repository of professional knowledge, best practices, and standards. Vertical engineering knowledge is encoded as machine-readable software extensions, allowing students to engage with the underlying principles behind design checks and alternative proposals within the BIM framework.

While this framework is conceptually comprehensive, it remains theoretical and does not account for regional or institutional variation, nor does it include empirical evidence of its uptake or applicability across diverse programs. The present study builds on this model by examining how far BIM integration has progressed along these levels in real-world curricula, based on survey and interview data. In doing so, it addresses a critical gap in the literature: the absence of empirical, cross-institutional research on BIM's pedagogical impact and integration depth across disciplines.

3. METHODOLOGY

3.1 Research Objectives

This study sought to investigate the transformative impact of BIM on higher education AEC curricula worldwide. Specifically, it aimed to:

Explore the extent and nature of BIM integration in AEC curricula.
Understand global variations in BIM education approaches, including differences in time of adoption, course duration and contact hours, and the intensity and depth of BIM integration within curricula.
Assess the current status of BIM education in relation to the transformative education scenarios proposed by Turk and Istenič-Starčič (Turk and Istenič-Starčič, 2020).

3.2 Data Collection

To address the research objectives, a mixed-methods approach was adopted combining a structured survey with qualitative interviews.

A survey was administered using Google Forms (see Appendix A) and distributed globally as part of a master thesis project (Correa, 2023). This method has been successfully applied in prior studies (Azhar et al., 2011; Agirbas, 2020) and allowed for broad data collection across diverse institutions.

Participants were contacted through two main channels: some were reached via publicly available email addresses found in academic papers, while others were invited through the professional network of Prof. Žiga Turk. These contacts originated from academic websites, conference participant lists, and institutional affiliations. This combination of approaches constitutes a convenience and snowball sampling method, commonly used in exploratory educational research.

However, we acknowledge that this recruitment strategy may not provide a fully representative sample of all global AEC educators. It introduces sampling bias, as it draws from established networks, and self-selection bias, as participation was voluntary and may have attracted individuals more engaged with BIM education. These limitations, particularly the overrepresentation from certain geographic zones, are discussed further in Section 5.

To supplement the survey data, five semi-structured interviews were conducted to gather in-depth insights from selected respondents. Participants were chosen based on their willingness to be interviewed and to ensure diversity across institution types and regions.

The interviews explored specific dimensions of BIM education, including teaching strategies, curriculum integration, interdisciplinary collaboration, tool use, and implementation barriers. Interviews were conducted online via Zoom, recorded with consent, and thematically analyzed manually. A full outline of the interview questions is included in Appendix B.

3.3 Sample Demographics

To contextualize the findings, the demographic characteristics of the study sample are summarized below. A total of 125 respondents completed the survey.

Geographic distribution:

The respondents were geographically diverse. Most came from Western Europe (39) and North America (35), followed by Southeast Asia (11), the Middle East and North Africa (11), Eastern Europe (8), and the Rest of Asia (10). Australia and Oceania (6) and South or Central America (5) had the lowest response rates.

The geographic breakdown of respondents is shown in Figure 1.

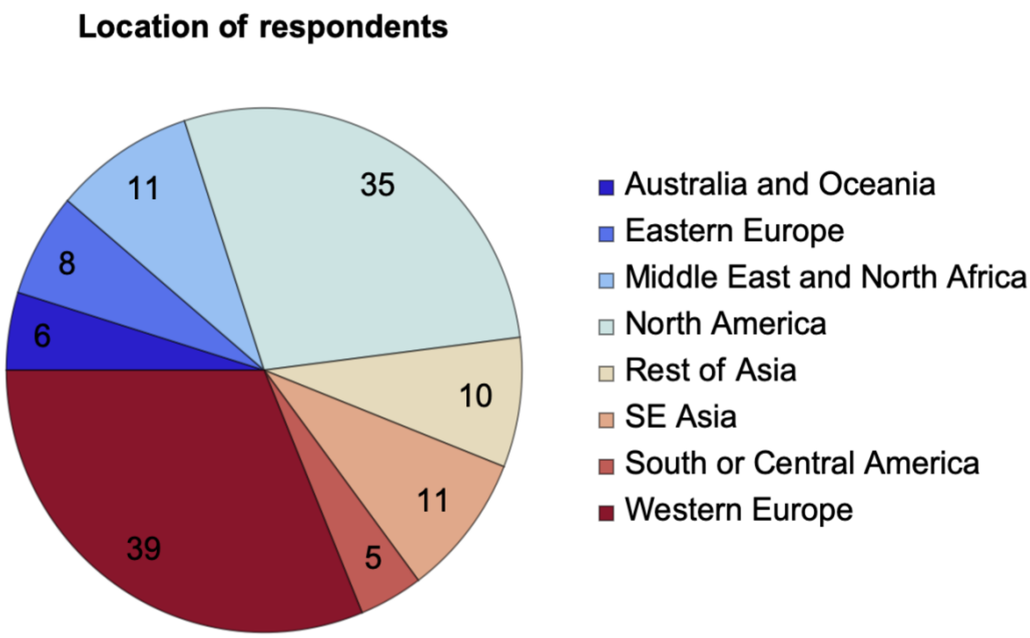

Figure 1: Geographic Distribution of Respondents.

Professional roles:

The survey included respondents involved in teaching construction-related Information Technology (IT) subjects because these courses often serve as a foundation for BIM training. Including IT-related roles helps capture the broader digital infrastructure supporting BIM adoption, even when BIM is not the primary course focus. This distribution of roles aligns with the study's objective to assess BIM integration in higher education by encompassing both foundational digital education (IT) and specialized BIM instruction.

The majority of participants identified as Teachers of construction IT-related subjects (52) and Researchers in construction IT topics (48). Another 23 respondents were teachers or researchers not primarily involved with IT in construction. Two respondents did not specify their primary job role. While many participants were involved in teaching IT-related subjects, others held roles in BIM-related instruction, research, or curriculum coordination, contributing relevant insights into institutional practices.

Figure 2 illustrates the professional roles of the participants.

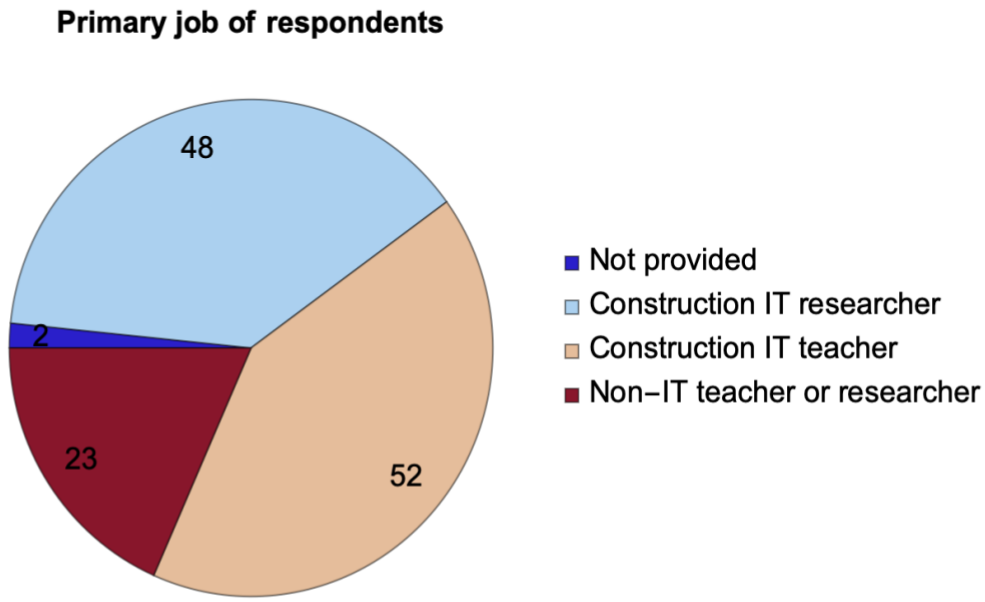

Figure 2: Primary Job Roles of Respondents.

Age distribution:

Most participants were mid-career professionals aged between 30 and 50 (88). Smaller groups were either under 30 (6) or over 50 (27).

The age distribution of respondents is presented in Figure 3.

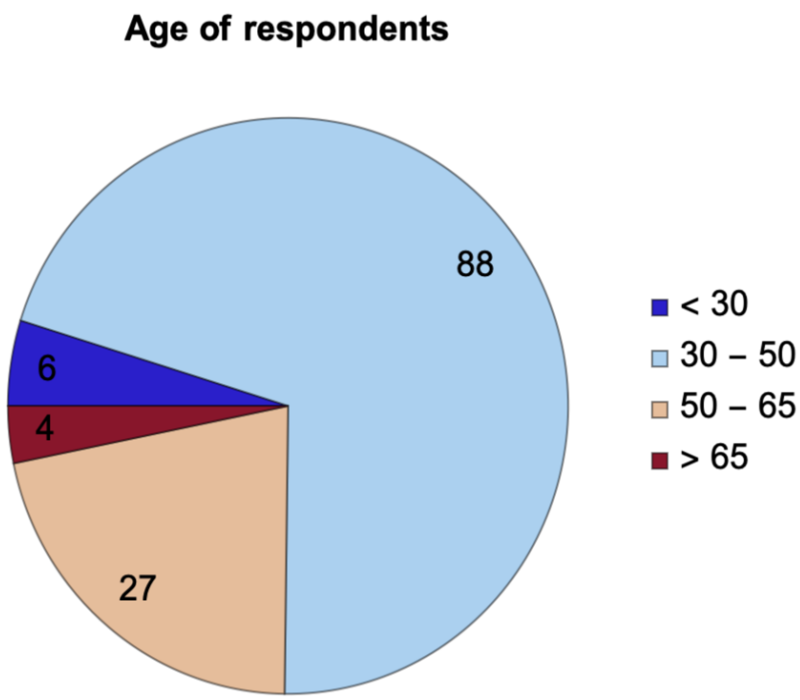

Figure 3: Age Distribution of Respondents.

Although the study targets the broader AEC domain, the survey design may have skewed responses toward construction-related perspectives. While participants included individuals from various fields, such as architecture, engineering, and construction, questions such as Question 12 (listing course types; see Appendix A) and Question 18 (faculty collaboration; see Appendix A) were phrased in a way that may not have fully captured the disciplinary breadth of BIM-related teaching. For example, the absence of "Civil" or "Structural Engineering" as selectable options in Question 18 could have led respondents from non-construction disciplines to select "within faculty" as a proxy, inadvertently underreporting cross-disciplinary collaboration. This design limitation is acknowledged, and care has been taken in the analysis to interpret results accordingly.

3.4 Data Analysis

The survey included a variety of question types, including multiple-choice, ranking, and open-ended items. Quantitative data were analyzed using Microsoft Excel (Microsoft Corporation, 2024) and Wolfram Mathematica 13.1 (Wolfram Research, Inc., 2023).

For visualization and extended statistical insight, Mathematica was used to generate BoxWhiskerCharts and BarCharts with error bars, illustrating variability across regional and curricular groupings. Error bars were computed using grouped standard deviations or standard errors, based on the spread of numeric responses. Excel was used to produce descriptive statistics and to construct a correlation matrix for exploring relationships between BIM-related courses and curriculum characteristics. The matrix was employed as a descriptive exploratory tool, used to highlight observable associations rather than to infer latent factors.

Qualitative data, gathered from open-ended survey questions and semi-structured interviews, were analyzed using a manual inductive thematic coding approach. Responses were reviewed line by line, and recurring patterns were grouped into categories such as teaching challenges, curriculum integration, and BIM tools used in teaching. Themes emerged organically from the data and were collaboratively refined by the research team. To enhance reliability, two researchers independently coded the responses, and discrepancies were discussed until full consensus was reached. This ensured consistency and minimized subjective interpretation.

While no qualitative software (e.g., NVivo) was used, the systematic and collaborative coding process strengthened thematic coherence. Key qualitative themes were triangulated with quantitative findings to enrich interpretation and ensure alignment across methods.

Although care was taken to design clear and consistent instruments, measurement errors may have occurred due to respondent misinterpretation or regional differences in educational systems. Nevertheless, the combined use of quantitative and qualitative methods provided a robust foundation for assessing BIM integration in AEC curricula globally.

3.5 BIM Adoption Level Scoring

To enable structured comparisons of BIM integration across institutions, a quantitative scoring model was developed based on the five-tiered framework of curriculum transformation proposed Turk and Istenič-Starčič (Turk and Istenič-Starčič, 2020). This model translates survey data into a numeric BIM adoption level, ranging from *Level 0* (no meaningful integration) to *Level 5* (full, transformative integration of BIM across courses and teaching practices).

The scoring framework draws on responses to three key survey questions:

- **Question 12**: *"Have these courses taken into account BIM technology, and is this reflected in their content, ways of teaching, and practical work?"*
  Respondents rated 13 AEC-related courses on a 0–3 scale:
  - 0 = I do not know
  - 1 = Not at all
  - 2 = A little
  - 3 = A lot

- **Question 13**: *"How has BIM affected those courses?"*
  Respondents selected all that applied from four binary indicators:
    - BIM used as input for analysis/planning/estimating
    - BIM used for modelling, communication, representation
    - Courses referencing object libraries or specific BIM elements
    - Courses discussing collaboration with other specialists
- **Question 16**: *"Are the students practicing project-based learning, where resources of many courses are pooled together, in the sense of collaborating with your colleagues while teaching BIM?"*
  Responses were binary (Yes/No), later mapped to 1/0.

Each respondent's score was computed using the following logic, where each higher level was only assigned if all preceding levels were satisfied:

- **Level 0**: Assigned to all cases where none of the criteria for higher levels were met. Represents minimal or no BIM integration.
- **Level 1**: Awarded if the *Computer-Aided Design* course received a rating of 3 in Question 12, reflecting strong adoption of BIM in design communication.
- **Level 2**: Awarded if either *Project/Construction (Site) Management* or *Project, Risk Management, Quality Assurance* scored 3 in Question 12, indicating BIM integration in project execution and planning.
- **Level 3**: Awarded if at least two of the following courses scored 3 in Question 12: *Structural Design*, *Surveying and GIS*, *Roads/Bridges/Transportation*. This reflects applied use of BIM in domain-specific instruction.
- **Level 4**: Awarded if:
    - At least two of the following vertical engineering courses scored 3 in Question 12: *Structural Mechanics and Dynamics*, *Geotechnics*, *Earthquake Engineering*, *Construction Materials*, and
    - At least two indicators from Question 13 were selected.
- **Level 5**: Awarded if:
    - The response to Question 16 was positive (indicating project-based learning), and
    - *Collaboration* was selected in Question 13, and
    - At least three different courses from Question 12 scored 3.

The scoring was implemented programmatically using Python and manually validated on a random sample of responses to ensure consistency with the conceptual framework.

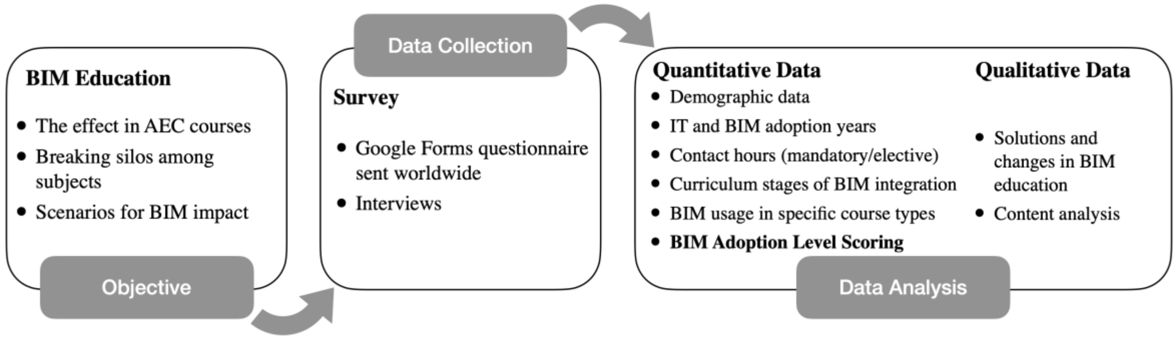

Figure 4: Methodology overview illustrating the research objectives, data collection via global survey and interviews, and the mixed-methods data analysis encompassing both quantitative and qualitative components.

3.6 Methodological Summary

This mixed-methods approach, as illustrated in

Figure 4, combined quantitative and qualitative data to provide a comprehensive understanding of the impact of interdisciplinary collaboration on AEC education.

4. RESULTS

4.1 Introduction Timeline of IT and BIM Courses

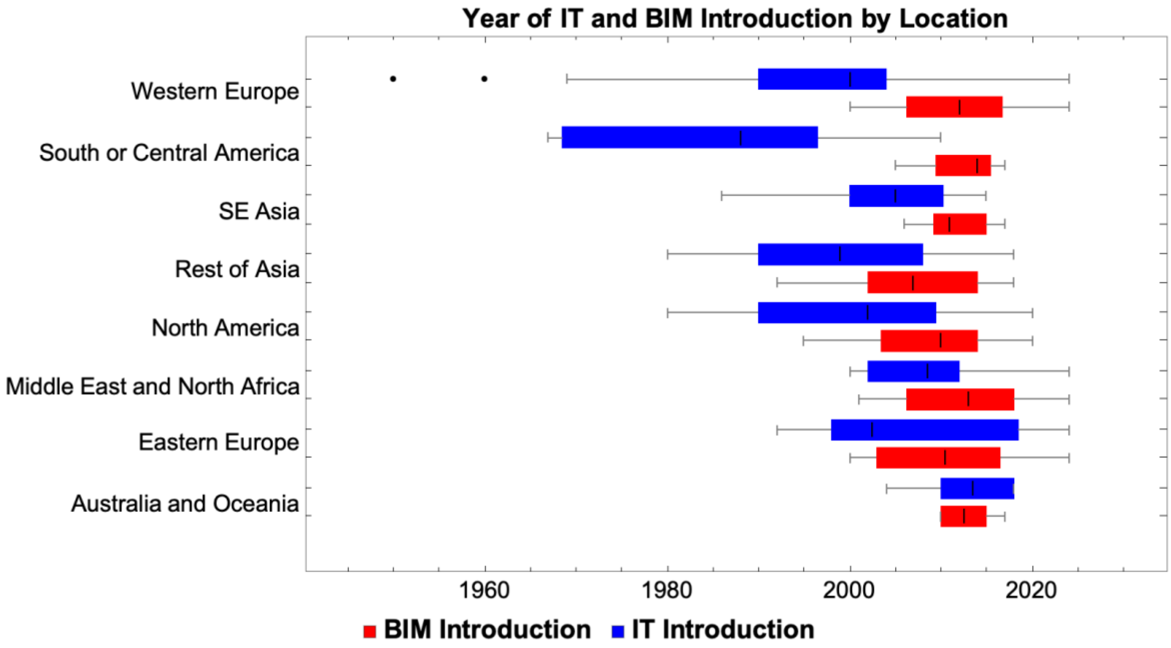

Figure 5: Box-whisker plot depicting the distribution of years IT and BIM were introduced by location.

IT-related variables were collected not to measure IT integration per se, but to contextualize BIM education and assess whether digital construction foundations were in place within AEC curricula.

The box-whisker plot in Figure 5 illustrates the distribution of years IT and BIM courses were introduced across different regions, based on the responses to questions 4 and 5 presented in Appendix A.

Overall, IT courses were introduced on average in the year 2000, with a wide range spanning from 1950 to 2024. BIM courses, on the other hand, were introduced on average in 2010, with a range from 1992 to 2024. This suggests a noticeable gap of approximately 10 years between the introduction of IT and BIM courses.

Regional variations in introduction years were also observed. In Australia and Oceania, both IT and BIM courses were introduced simultaneously in 2012. In South or Central America, IT courses were established earlier in 1985, while BIM courses were introduced nearly three decades later in 2012. Western Europe saw IT courses introduced in the 1990s, followed by BIM courses in 2011, resulting in a 15-year gap. In North America, IT courses were introduced in 2001, and BIM courses followed in 2009, indicating an 8-year gap. In general it would seem that those late in introducing IT were then faster to introduce BIM.

4.2 Curriculum Time Allocation for IT and BIM

Figure 6 illustrates the distribution of average combined IT and BIM contact hours across different regions, based on the responses to questions 6, 7, 8 and 9 presented in Appendix A. The total combined contact hours range from approximately 100 to 350 hours.

European regions, Eastern Europe (349 hours) and Western Europe (315 hours), have the highest combined contact hours. The Americas (South or Central America with 252 hours and North America with 249 hours) also have significant contact hours. Other regions with substantial contact hours include Rest of Asia (197 hours) and Australia and Oceania (197 hours). Middle East and North Africa have slightly fewer hours at 160, while Southeast Asia has the least contact hours at 98. It is important to note that these contact hour values reflect self-reported estimates across institutions with potentially diverse program structures. For example, the high contact hours reported in European regions may reflect full undergraduate curricula, while lower totals in Southeast Asia may correspond to shorter postgraduate programs.

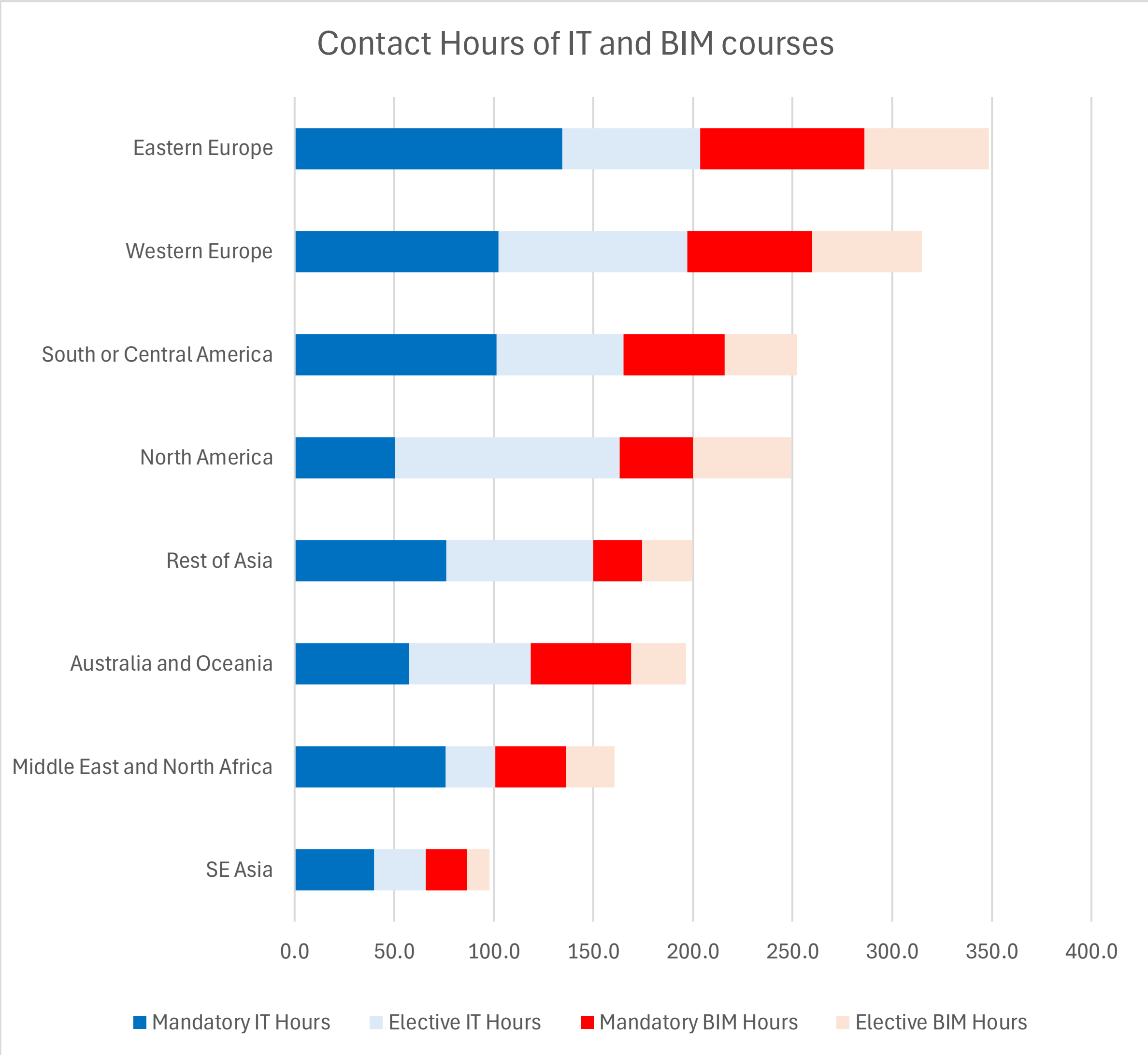

Figure 6:Distribution of IT and BIM contact hours by location.

These values represent self-reported contact hours specific to IT and BIM-related instruction and do not reflect full program durations. As such, no normalization against total program hours was performed. The percentages discussed (e.g., proportion of BIM vs. IT hours) refer to internal distributions within the combined digital education hours, not to the entire curriculum.

In terms of the allocation of hours between IT and BIM, the majority of contact hours, ranging from 58% in Eastern Europe to 75% in Rest of Asia, are dedicated to IT courses. The remaining portion is allocated to BIM courses. European regions tend to have a higher proportion of mandatory hours, while North America and Australia have a more balanced distribution between elective and mandatory courses.

It's worth noting that regions where IT and BIM were introduced more recently, such as SE Asia and Australia, generally have fewer contact hours. It should also be noted that more hours do not necessarily mean the BIM use scenarios are more advanced.

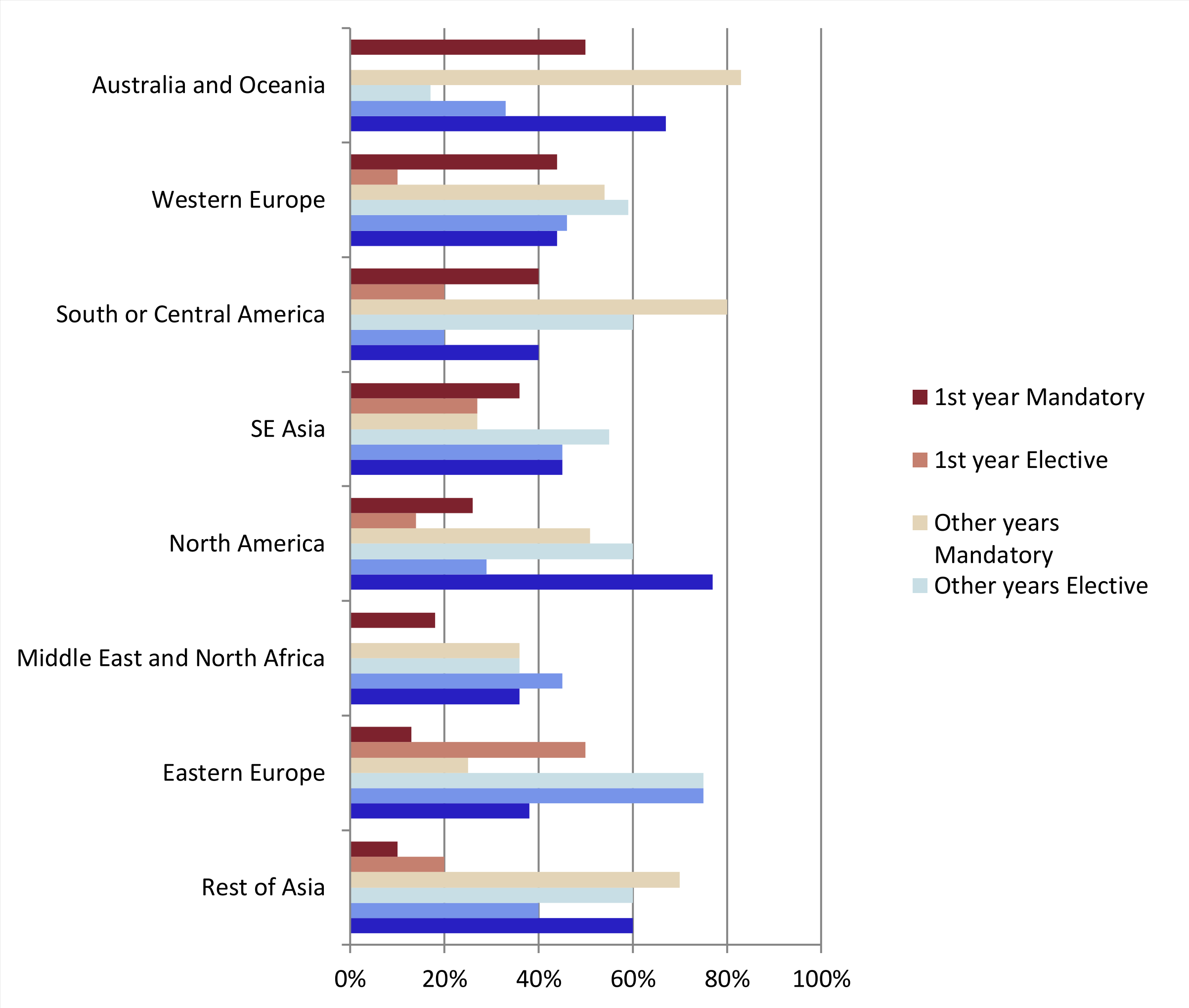

Figure 7: BIM Course Integration in AEC Curricula.

Figure 7 illustrates the percentage distribution of BIM course integration in different years of AEC curricula across various regions and it is based on the responses to question 11 presented in Appendix A. The bars represent the proportion of respondents who reported offering mandatory or elective BIM courses in the first year, other undergraduate years, and graduate years. Overall, the data highlights a trend where most regions focus on integrating BIM courses in later undergraduate years or at the graduate level, with notable regional variations in how early and rigorously BIM is introduced.

First-year BIM integration is less common across regions. Australia and Oceania (50%), Western Europe (44%) and South or Central America (40%) have the highest percentages of mandatory BIM courses in the first year, while North America (26%) and Southeast Asia (36%) show moderate levels of first-year mandatory course integration. Elective BIM courses in the first year are rare, with Southeast Asia (27%) and South or Central America (20%) reporting the highest proportions.

In the undergraduate years beyond the first, Australia and Oceania (83%) and South or Central America (80%) lead in mandatory BIM course integration, while the Rest of Asia (70%) and North America (51%) also show significant adoption. Elective courses are more common in Eastern Europe (75%) and the Rest of Asia (60%).

Graduate-level integration is prominent, especially for elective courses, with regions like North America (77%) and Australia and Oceania (67%) showing a strong emphasis on BIM electives. In contrast, Eastern Europe (75%) and South or Central America (80%) prioritize mandatory BIM courses at the graduate level, reflecting a focus on advanced, specialized training.

Regarding the regional trends, Western Europe consistently integrates mandatory BIM courses across all academic stages, providing a comprehensive educational experience. Eastern Europe places less emphasis on BIM in the first year and other undergraduate years, but focuses heavily on graduate-level mandatory courses, indicating a priority on advanced BIM training. North America shows moderate integration in the first year and other undergraduate years, but with less focus on mandatory BIM hours at the graduate level, suggesting early introduction but a reduced emphasis at advanced stages.

4.3 BIM Adoption Indicators

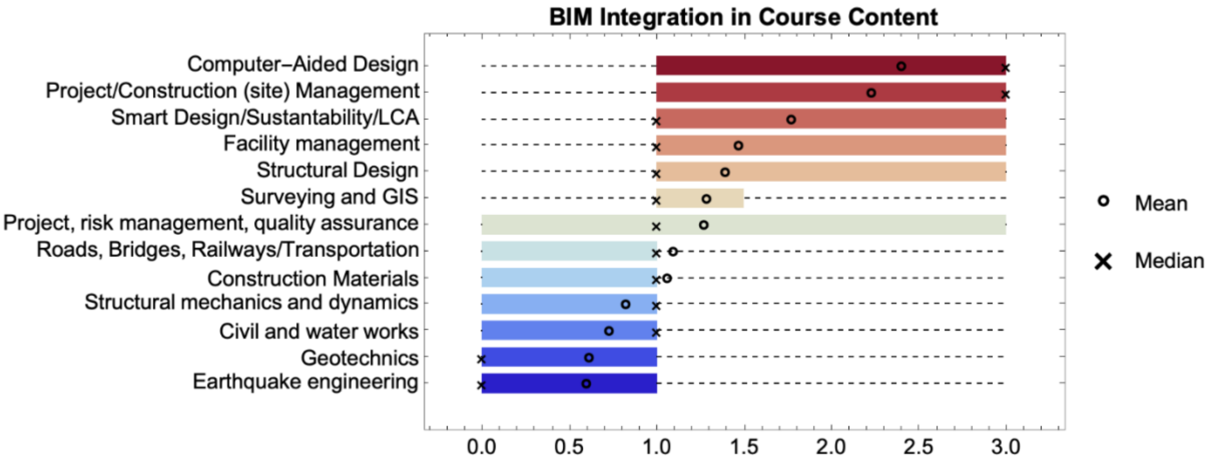

Figure 8: BIM integration in course content. The values corresponding to responses: 0 - I do not know, 1 - not at all, 2 - a little, 3 - a lot.

Figure 8 presents a box-whisker plot illustrating the extent to which BIM technology has been integrated into various courses, based on the responses to question 12 presented in Appendix A. Respondents were asked to rate the level of BIM integration in course content, teaching methods, and practical work on a scale of 0 to 3, with 0 indicating no knowledge and 3 indicating a high level of integration.

The results reveal that BIM has had the most significant impact on courses related to Computer-Aided Design (CAD), project management, and sustainability. Notably, there is also an influence of BIM on courses such as facility management, structural design, surveying and Geographic Information Systems (GIS), and risk management and quality assurance.

Conversely, the impact of BIM on courses focused on roads, bridges, railways/transportation, construction materials, structural mechanics and dynamics, civil and water works, geotechnics, and earthquake engineering appears to be minimal or negligible.

Figure 8 maps well to the five stages of Turk and Isteničč, with least ambitions BIM uses (replacement of CAD) being most popular and provides a validation of those levels by showing little impact on the specialized vertical courses.

4.4 BIM Adoption Levels: Framework-Based Scoring

To better understand the depth and variability of BIM integration in higher education curricula, each survey response was assigned a BIM adoption level from 0 to 5 based on a structured scoring framework (see Section 3.5). The distribution of these levels across all respondents is shown in Figure 5. The largest share of respondents were categorized at Level 3 (31%), reflecting moderate BIM integration in multiple domain-specific courses. Levels 1 and 2 followed closely, with 22% and 21.6%, respectively, suggesting that many institutions have made foundational progress but have not yet adopted more comprehensive or collaborative approaches. Notably, 25 respondents (20%) exhibited no substantial BIM adoption and were classified as Level 0, while only a small minority reached the most advanced categories: Level 4 (4%) and Level 5 (0.8%).

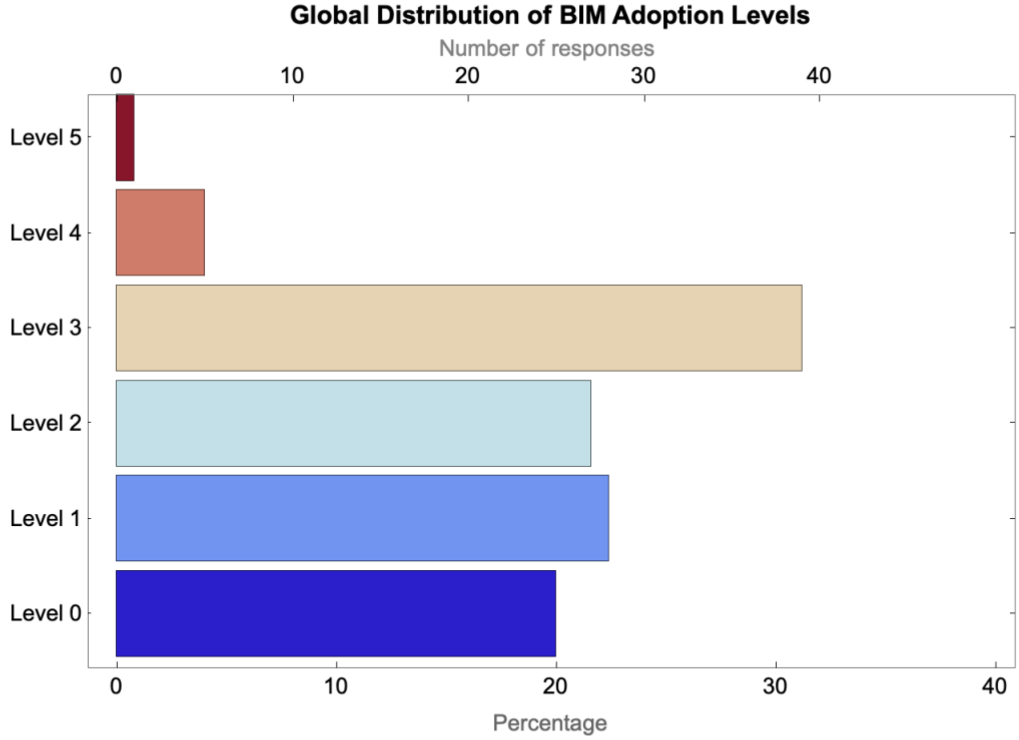

Figure 5: Distribution of BIM adoption levels among all respondents, based on a scoring framework from Level 0 (no integration) to Level 5 (full integration).

Regional differences in BIM adoption are illustrated in Figure 6 and detailed in Table 1. Respondents from Australia and Oceania reported the highest average adoption level (mean = 2.33), followed by Western Europe (2.00) and Rest of Asia (1.90). These regions also exhibited relatively wider spreads, suggesting more diverse curricular implementations. North America had a moderately high average level (1.86) but with tighter clustering around the median. In contrast, Eastern Europe (1.25) and Middle East and North Africa (1.27) demonstrated lower adoption levels, with many respondents clustered at Levels 0 and 1. These results highlight regional disparities in BIM curriculum transformation and suggest that while some institutions have moved toward holistic BIM integration, a majority remain in the early-to-mid stages of adoption.

Table 1: The distribution of BIM adoption levels across different world regions based on survey responses. It includes the number of respondents (count), average BIM adoption level (mean), standard deviation (std), and the minimum, maximum, and quartile values.

Location	**Count**	**Mean**	**Std**	**Min**	**25%**	**50%**	**75%**	**Max**
Australia and Oceania	6	2.33	1.37	1	1.25	2.00	3.50	4
Eastern Europe	8	1.25	1.04	0	0.75	1.00	2.00	3
Middle East and North Africa	11	1.27	1.01	0	0.50	1.00	2.00	3
North America	35	1.86	1.14	0	1.00	2.00	3.00	3
SE Asia	11	1.36	0.92	0	1.00	1.00	2.00	3
South or Central America	5	1.80	1.30	0	1.00	2.00	3.00	3
Western Europe	39	2.00	1.43	0	1.00	2.00	3.00	5
Rest of Asia	10	1.90	1.29	0	1.00	2.05	3.00	3

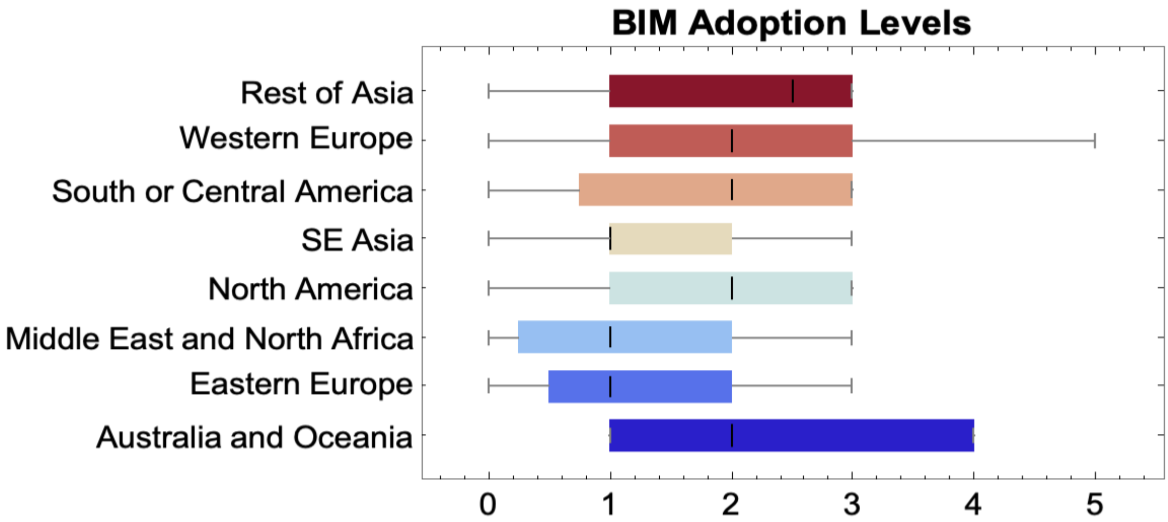

Figure 6: Box-whisker plot depicting the BIM adoption levels by location.

4.5 Correlation of BIM Adoption Across Disciplines

Figure 9:BIM integration correlation matrix.

Figure 9 presents a correlation matrix heatmap illustrating the relationships between various courses in terms of their integration of BIM technology. The heatmap visualizes the correlation coefficients between different courses, indicating how closely they align in terms of BIM adoption.

The analysis reveals that all correlation factors are positive, suggesting a strong association between BIM integration in different courses at the same institution. This implies that if BIM is used in one course, it is more likely to be used in related courses, and similarly, if BIM is employed for one task, it is more probable that it will be utilized for other relevant tasks. It would seem to be related to institutional attitude to BIM and not to the attitudes of individual professors.

Although Smart Design/Sustainability/LCA did not statistically stand out as an outlier, it demonstrates a uniquely balanced pattern of integration across both technical and managerial disciplines. Its strongest correlations with planning-oriented and lifecycle-focused courses (e.g., Construction Management, Facility Management) suggest that sustainability principles are being embedded particularly in courses with a broader system-level or project coordination focus. This pattern aligns with BIM's evolution toward supporting environmentally responsible construction practices.

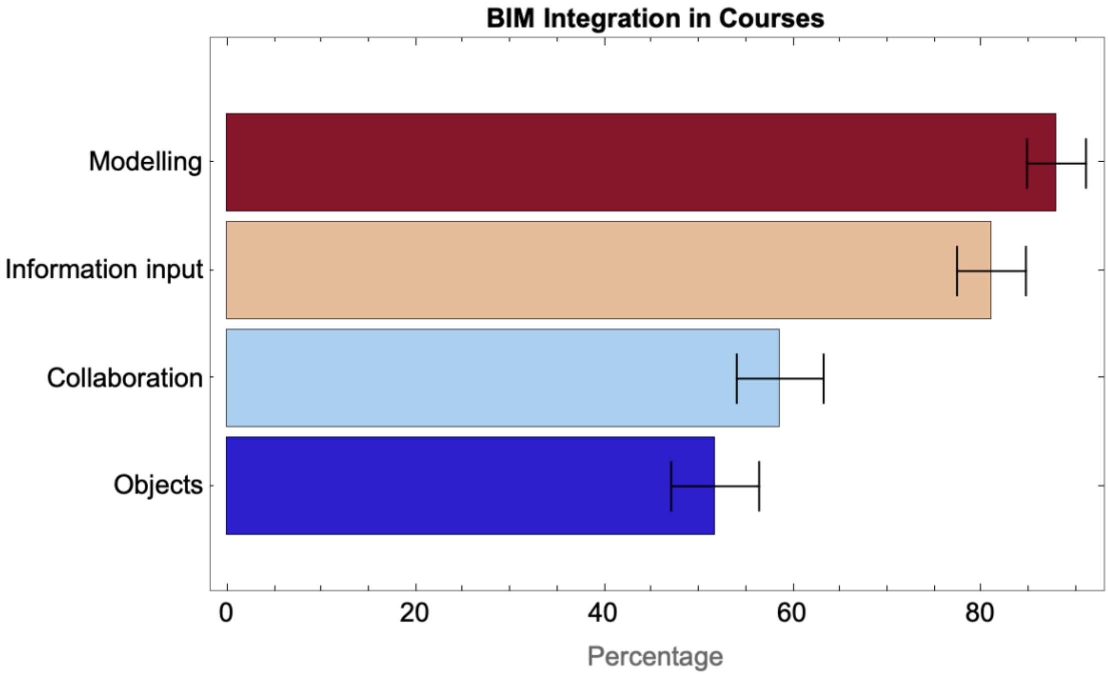

Figure 10: BIM Integration in Courses: Impact on Modeling, Information Input, Collaboration, and Objects. "Modeling" refers to the use of BIM tools primarily for geometric representation, visualization, and communication of designs. "Object Integration" pertains to the use of intelligent BIM objects or elements (with embedded metadata) from object libraries. These may support more complex design tasks, simulations, or analyses, reflecting a more data-centric application of BIM.

Figure 10 presents a bar chart illustrating the various ways BIM has affected courses, with standard error bars indicating the uncertainty associated with the estimates. Participants were asked to select the options that best describe how BIM is integrated into their courses; see question 13 in Appendix A.

The results indicate that the most common application of BIM in courses is for modeling, with 88% of respondents reporting its use in this area. Information input for tasks such as analysis, planning, and estimating is also widely adopted, with 81% of respondents indicating its relevance. Collaboration with other specialists is another significant aspect of BIM integration, with 59% of respondents highlighting its importance. Finally, discussing specific objects or elements as represented in BIM or available in object libraries is a less prevalent but still significant application, with 52% of respondents acknowledging its relevance.

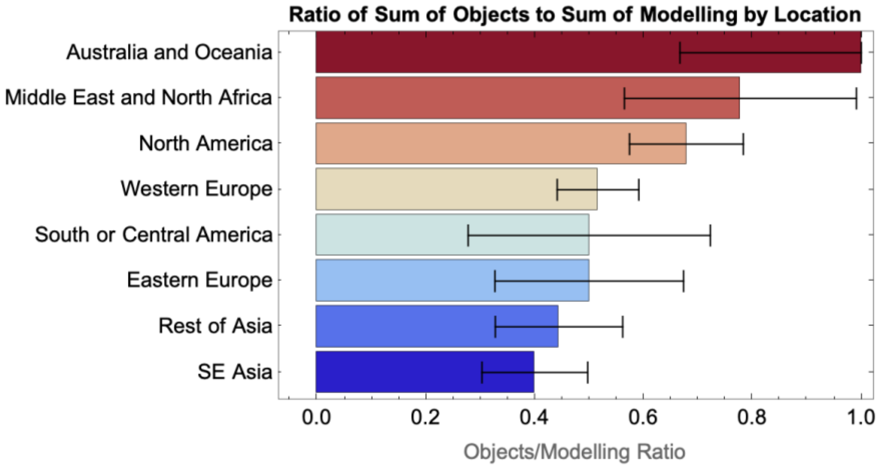

Figure 11: Advanced uses of BIM. While the ratio of object-related to modeling-related BIM usage may suggest deeper integration of BIM's information components, it does not universally indicate more advanced use. A high ratio may reflect more data-centric workflows, but should be interpreted alongside other educational factors such as course structure, project-based learning, and interdisciplinary collaboration.

Figure 11 presents a bar chart illustrating the advanced uses of BIM technology across different regions. The chart depicts the ratio of the sum of objects to the sum of modeling for each region, with higher values indicating more advanced BIM applications.

The analysis reveals that advanced BIM usage is less prevalent in Asia and Europe. Regions such as North America, Australia and Oceania, and the Middle East and North Africa demonstrate significantly higher levels of advanced BIM adoption, suggesting a more sophisticated utilization of BIM technology in these areas. However, the large standard errors associated with these estimates indicate that these differences may not be statistically significant, and further research is needed to confirm these findings.

4.6 Interdisciplinary Collaboration

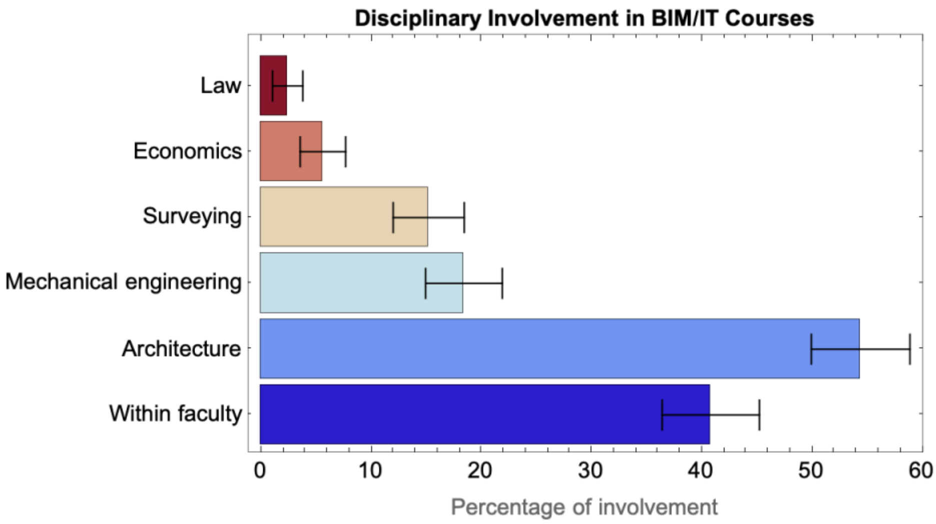

Figure 12: Disciplinary Involvement in BIM/IT Courses.

Of the 125 participants, 47 (38%) reported that students engage in project-based learning (question 16 in Appendix A) where resources from multiple courses are pooled together, indicating collaboration among instructors in the context of BIM education.

Figure 12 presents a bar chart illustrating the extent of collaboration between the IT/BIM classes and other faculties and it is based on the responses to question 18 in Appendix A. Respondents were asked to indicate whether and with which faculties their courses collaborate. While the survey included options for collaboration with Architecture, Mechanical Engineering, and other external faculties, it did not provide an option for Civil or Structural Engineering, disciplines that are often central to BIM integration. This omission likely affected responses from participants outside of civil or structural engineering, such as those from architecture or related fields, who collaborate with these disciplines but had no way to indicate it. As a result, some may have either skipped the question or selected “within faculty” to reflect such collaboration, potentially skewing the data toward internal partnerships and underreporting interdisciplinary links with core engineering departments.

The data shows that while there is some collaboration with other faculties, a significant portion of project-based learning (42%) takes place within the faculty itself. That is, internal collaboration among departments housed within the same academic unit. In many institutions, this may include civil engineering, construction management, architecture, or surveying programs, depending on how faculties are structured. Among external collaborations, architecture emerges as the most frequent partner, with 54% of respondents reporting collaboration in this area. Mechanical engineering and surveying faculties also demonstrate notable levels of collaboration, at 18% and 15% respectively. Conversely, collaboration with economics and law faculties is minimal, at 6% and 2% respectively.

4.7 Curriculum Changes Due to BIM Integration

This section draws on qualitative insights obtained from both open-ended survey responses and follow-up interviews (see Appendix B) to explore how BIM adoption has influenced curriculum design and teaching strategies across institutions.

The integration of BIM technology has led to significant transformations in course curricula and teaching methodologies. One of the most notable changes is the *incorporation of new software tools* into the learning process. Many educators have recognized the importance of hands-on experience with BIM software and have incorporated practical training sessions to equip students with the necessary skills for real-world applications. This sentiment was shared by several instructors, one of whom noted:

> *“Incorporated hands-on training with industry-standard BIM software to better prepare students for real-world applications.”*

Another significant change is the *increased emphasis on interdisciplinary collaboration*. BIM projects often involve a variety of stakeholders, necessitating effective teamwork and communication. Courses have been restructured to reflect this collaborative nature, with a focus on project-based learning that simulates actual BIM workflows. As reflected in multiple interviews, instructors are adapting their teaching to promote cross-disciplinary teamwork. One educator described their approach as follows:

> *"Emphasized interdisciplinary collaboration, bringing together architecture, engineering, and construction management students in joint projects."*

A third major change is the *shift to project-based learning*. By engaging students in team-based projects that mirror real-world BIM scenarios, educators are fostering critical thinking, problem-solving, and communication skills. This approach also promotes interdisciplinary collaboration. Several educators highlighted this as a core pedagogical shift. One instructor remarked:

> *"Shifted to project-based learning, where students work in teams on projects that simulate actual BIM workflows."*

Furthermore, *sustainability principles* have been integrated into BIM courses. Teachers are utilizing BIM tools to teach life cycle assessment, energy efficiency, and sustainable construction practices. This reflects the growing importance of environmentally responsible design and construction. Sustainability themes were often discussed in relation to system-level and lifecycle-focused courses. One response indicated:

> *"Introduced sustainability and smart design principles, using BIM tools to teach life cycle assessment and energy efficiency."*

In summary, the integration of BIM technology has led to a more *holistic educational approach*. These changes ensure that students are not only proficient in BIM technologies but also equipped to make environmentally responsible decisions in their careers. Echoing the broader shift toward practical integration and critical thinking, another participant summarized:

> *"Restructured courses to integrate more practical BIM applications, fostering critical thinking and problem-solving skills."*

4.8 Challenges to BIM Integration in Education

The widespread adoption of BIM technology in the construction industry has created a demand for skilled professionals. However, several obstacles hinder the effective teaching of BIM in academic institutions. These challenges were consistently reported in both survey and interview responses.

Resource limitations pose a significant challenge. Inadequate funding and access to necessary software and hardware can restrict the ability of educational institutions to provide students with the necessary tools and resources to learn BIM effectively. As noted by respondents across multiple institutions:

> *"Lack of funding and inadequate access to necessary software and hardware are major barriers."*

Another obstacle is the *challenges associated with faculty training*. Many faculty members may not have the necessary expertise in BIM technologies, making it difficult for them to effectively teach these subjects. This concern was emphasized in several interviews. As one respondent stated:

> *"Training faculty who are not proficient in BIM technologies is a significant obstacle."*

Institutional resistance can also impede the adoption of BIM in academic programs. The inertia of existing curricula and resistance to change can make it difficult to incorporate new technologies. Respondents highlighted that institutional culture often lags behind technological advancements. As one respondent observed:

> *"Institutional resistance and the inertia of existing curricula make it difficult to adopt new technologies."*

Finally, a *gap in industry collaboration* can hinder the alignment of academic programs with industry standards. This can result in graduates who are not fully prepared for the demands of the real world. This was especially noted by educators engaged in curriculum reform. As one respondent noted:

> *"A gap in industry collaboration makes it challenging to align academic programs with industry standards."*

5. DISCUSSION

This discussion reflects on the study's findings in light of the research questions outlined in Section 3.1, including the timing, depth, and challenges of BIM integration across institutions and regions.

A key contribution of this study is the development and application of a scoring framework to quantify BIM adoption levels across institutions. By translating survey data into a structured scale (Levels 0–5), we were able to capture varying depths of BIM integration and compare results across geographic regions. This framework revealed that most institutions are situated at moderate adoption levels (Levels 1–3), with few reaching comprehensive integration.

Key Findings. Our study provides valuable insights into the integration of BIM technology in higher education. A key finding is the interdisciplinary nature of BIM, fostering collaboration among various AEC sectors. This aligns with the collaborative nature of the AEC industry, emphasizing the importance of teamwork and communication skills.

Furthermore, our results highlight the holistic understanding of BIM that is essential for its successful implementation. As emphasized in prior research (Borkowski, 2023), BIM is not merely a set of tools but a philosophy that integrates design, construction, and management processes. This underscores the need for a comprehensive approach to BIM education.

Statistically significant findings revealed that institutions with a history of early IT and CAD adoption were also sooner to embrace BIM. Additionally, European schools demonstrated earlier adoption of BIM compared to American and Asian institutions, although the latter rapidly accelerated their adoption. This suggests a correlation between technological readiness and BIM implementation.

However, our study also uncovered several challenges hindering the widespread adoption of BIM in higher education. Technical barriers associated with the complexity of BIM tools necessitate substantial technical support and training. A gap between theoretical knowledge and practical application highlights the need for more experiential learning opportunities. Moreover, curricular integration presents challenges, as aligning BIM principles with existing curricula without overhauling traditional educational frameworks can be difficult. This was echoed in interview responses, where participants noted institutional inertia and rigid program structures as barriers to integrating BIM.

These findings align with earlier studies on BIM education. For example, Turk and Istenič-Starčič (Turk and Istenič-Starčič, 2020) emphasize that meaningful BIM education should support interdisciplinary learning and integrate project-based and model-based approaches. Their "T-shaped curriculum" model illustrates how courses can break traditional disciplinary silos, reinforcing the importance of interdisciplinary and collaborative approaches, strongly reflected in our study's findings.

Our results on regional differences in BIM adoption levels are consistent with global trends reported in (Banh, 2024), which identified Western Europe and Oceania as early adopters of structured BIM curricula, often supported by national strategies and industry-academia collaboration.

The observed link between early IT/CAD adoption and BIM implementation echoes Borkowski's (Borkowski, 2023) historical analysis of BIM's evolution, which describes how foundational digital tools paved the way for more integrated BIM practices in both industry and academia.

Moreover, challenges identified in this study, such as institutional inertia, faculty training deficits, and gaps in real-world application, reflect persistent issues raised in prior evaluations of BIM education strategies (Agirbas, 2020).

Limitations. While this study provides valuable insights into the integration of BIM in higher education, several limitations should be acknowledged. The sample is not globally representative; participation was skewed toward certain regions, particularly Europe, while others, such as South or Central America (5 participants) and Australia and Oceania (6 participants), were underrepresented, limiting the generalizability of regional trends. The recruitment process, which relied on email contacts from academic networks and prior publications, may have introduced sampling bias. Additionally, self-selection bias is possible, as those more actively engaged with BIM may have been more inclined to respond. Variability in how academic terms and curriculum structures are understood across countries may also have introduced interpretation differences or measurement errors. Certain survey design choices may have constrained responses. For instance, Question 18 did not include Civil or Structural Engineering among its selectable collaboration partners, possibly leading some respondents to select "within faculty" as a proxy, thereby underreporting interdisciplinary collaboration. Despite these limitations, care was taken to interpret results within context, and the findings nonetheless provide a meaningful snapshot of global BIM educational practices. Future research would benefit from a more balanced geographic and disciplinary sample, and expanded survey options.

Future Research Directions. Based on our findings, several areas warrant further investigation. Longitudinal studies tracking the evolution of BIM integration in higher education over time could provide valuable insights into the effectiveness of current strategies. Comparative studies between different regions or institutions could shed light on factors influencing the variation in BIM adoption rates. Additionally, in-depth case studies of successful BIM implementation can provide valuable lessons and best practices for others.

Policy Implications. Our research highlights several obstacles hindering the effective integration of BIM in higher education. Addressing these challenges requires concerted effort from policymakers, educational institutions, and industry stakeholders.

To overcome siloed curricula, institutions should consider interdisciplinary course modules and co-teaching strategies that bridge architecture, engineering, and construction disciplines.

Additionally, limited contact hours can be mitigated by integrating BIM content across existing courses, rather than relying solely on standalone BIM modules.

Resource limitations can be mitigated through increased funding and access to necessary software and hardware.

Faculty training challenges can be addressed by providing professional development opportunities and resources to equip faculty members with the necessary skills.

Institutional resistance can be overcome by fostering a culture of innovation and encouraging experimentation with new technologies.

For regions where BIM integration is less advanced, such as Southeast Asia or South America (as indicated in our findings), policy interventions could include national curriculum guidelines, funding for faculty training, and industry-academic consortia to co-develop BIM learning pathways. Pilot programs and regional hubs for BIM education could help bootstrap adoption in such areas.

Finally, industry collaboration can be strengthened through partnerships between academic institutions and industry representatives to ensure curricula align with industry needs.

By addressing these obstacles, policymakers can create an enabling environment for the successful integration of BIM in higher education, preparing future professionals for the demands of the AEC industry.

Implications for educators and institutions. The findings of this study offer actionable insights for course coordinators, teaching faculty, and academic leadership seeking to enhance BIM integration. First, mapping curricula against the five-level BIM adoption framework allows educators to identify how deeply BIM is currently embedded and what pedagogical steps can be taken to advance to higher levels. Second, early investment in IT and CAD courses has shown to correlate with more advanced BIM integration; educators can build upon existing digital literacy to scaffold BIM across multiple years and disciplines.

Furthermore, deeper integration is more likely when BIM is introduced not only in horizontal or managerial courses (e.g., CAD or project management), but also in vertical technical courses such as structural mechanics or materials science. To facilitate this, institutions should promote joint assignments or co-teaching models that connect traditionally siloed subjects. Project-based learning is another proven strategy which allows educators to simulate real-world BIM workflows by designing interdisciplinary projects involving architecture, engineering, and construction students.

Faculty training remains a cornerstone of BIM curriculum development. Institutions should invest in upskilling staff, for example through industry workshops or collaborative pilot programs. Finally, the increasing emphasis on sustainability offers a strategic opportunity to integrate BIM into courses focused on life cycle assessment, energy efficiency, and smart design. This not only supports educational objectives but also aligns academic programs with evolving industry priorities.

6. CONCLUSION

Based on our international survey of educators and institutions, we can draw several key conclusions regarding the integration of BIM technology in higher education.

While the findings provide meaningful insights into global trends, we acknowledge that the sample was not fully representative of all regions. The use of voluntary and convenience-based sampling may limit the generalizability of the conclusions and should be taken into account when interpreting the results.

Our findings suggest that many courses and curricula have made significant progress in integrating BIM technology. Aligning with the framework proposed by Turk and Istenič-Starčič (Turk and Istenič-Starčič, 2020), the strides were made to levels 2 (BIM Modernizes Construction Management), 3 (Shallow BIM is Used in Vertical Courses) and 4 (Deep BIM in Vertical Courses). However, there is still a significant gap towards level 5, where BIM becomes a repository of professional knowledge.

Our analysis reveals some regional variations in BIM education. European schools tend to be more advanced in BIM integration compared to American and Asian schools, although the latter have been rapidly catching up. This may be attributed to factors such as earlier exposure to BIM technologies and a stronger emphasis on digitalization in European construction industries.

Despite these advancements, several challenges remain. Resource limitations, faculty training, institutional resistance, and industry collaboration gaps continue to hinder the widespread adoption of BIM.

Addressing these obstacles requires concerted effort from policymakers, educational institutions, and industry stakeholders. By providing adequate resources, training faculty members, fostering institutional innovation, and strengthening industry collaboration, we can create an enabling environment for the successful integration of BIM in higher education. This will equip future professionals with the necessary skills to drive the transformation of the AEC industry towards more efficient, sustainable, and collaborative practices. In particular, the increasing presence of sustainability-related content in BIM curricula signals a positive shift toward environmentally responsible design becoming a core component of BIM education.

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APPENDIX A - QUESTIONNAIRE IN GOOGLE FORMS

The full questionnaire used in this study is available online at: https://forms.gle/HAZwPPiBZb2pB1JN8

How is BIM affecting undergraduate education ?

First a few questions about you ...

1. Where is your faculty located?

□ Western Europe Eastern Europe

□ Middle East and North Africa SE Asia

□ Rest of Asia North America

□ South or Central America Australia and Oceania Africa

□ Other: ___________________

2. What is your primary job?

□ Teacher of construction IT related subjects

□ Researcher of construction IT topics

□ Teacher or researcher not primarily involved with IT in construction

3. What is your age?

□ Below 30

□ 30 - 50

□ 50 - 65

□ more than 65

Next, we want to know how much is BIM taught in dedicated courses or as a part of courses related to IT, CAD, programming etc.

When reference IT, it means when a certain course deals with Information Technology itself, processes, electronic data of any type.

Unless asked otherwise, please report on sum of the undergraduate plus graduate programs, that is 8-10 semesters of study.

4. Since what year is IT taught at your faculty?

Enter 9999 if not at all. _________________

5. Since what year is BIM taught at your faculty?

Enter 9999 if not at all. _________________

6. How many contact hours (lectures and exercises in class or lab) do students have for mandatory IT related courses?

This is the sum of hours. Not per week, total. ________________

7. How many contact hours do students have for elective IT related courses?

This is the sum total of hours. Not per week, total. ________________

8. How many contact hours do students have for mandatory BIM content within BIM/IT courses?

This is the sum of hours. Not per week, total. ________________

9. How many contact hours do students have for elective BIM content within BIM/IT courses?

This is the sum of hours. Not per week, total. ________________

10. Would you tell us more about the existing hours for IT/BIM subjects in the curriculum? In the sense of, how much time do students dedicate in disciplines that involve this type of content?

____

11. When is BIM taught?

	Mandatory	Elective
First year.	□	□
Other undergraduate years	□	□
Graduate study	□	□

Next we want to know if BIM made an impact on individual courses at your faculty outside of the dedicated IT, CAD, BIM ... courses.

We will be asking if BIM brought courses together or created interdisciplinary approaches later.

12. Have these course taken into account BIM technology, and this is reflected in their content, ways of teaching and practical work:

	Not at all	A little	A lot	Don't know
Computer-Aided Design	□	□	□	□
Surveying and GIS	□	□	□	□
Structural mechanics and dynamics	□	□	□	□
Geotechnics	□	□	□	□
Structural Design	□	□	□	□
Earthquake engineering	□	□	□	□
Construction Materials	□	□	□	□
Smart Design/Sustantability/LCA	□	□	□	□
Roads, Bridges, Railways/Transportation	□	□	□	□

Civil and water works	□	□	□	□
Project/Construction (site) Management	□	□	□	□
Project, risk management, quality assurance	□	□	□	□
Facility management	□	□	□	□

13. How has BIM affected those courses?

□ BIM is used as information input e.g. for analysis, planning, estimating ...

□ BIM tools are used for the modelling, communication, representation of results.

□ Course discusses specific objects/elements as represented in BIM or available in object libraries

□ Course addresses collaboration with other specialists

□ …think of more… ___________

□ Other __________

14. More about previous question. What have the teacher of the above courses changed in their teaching approach due the advent of BIM?

____

15. If there is no change in the courses, what are the most significant obstacles you can list, to offering BIM in your undergraduate curriculum?

____

Finally, BIM is about integration and collaboration. We want to know if you practice project- based learning (or similar methods) where the courses are integrated into interdisciplinary, collaborative project work likely to be supported by BIM technology.

16. Are the students practicing project based learning, where resources of many courses are polled together, in the sense of collaborating with your colleagues while teaching BIM?

□ Yes

□ No

17. If you answered the previous question with yes, please explain when (what period/year) this practice is introduced to the students, and what content is pulled together?

____

18. Is the collaboration just among the topics of your faculty or is another faculty involved? If so, which ones?

□ Architecture

□ Mechanical engineering

□ Surveying

□ Economics

□ Law

Other: _______________

That was it! Just two more things

19. Would you like to tell us something important which we missed to ask you?

____

20. Would you be open to a personal interview on these issues online? If so, please write your email below. If you would like to stay anonymous, submit this form and you will be presented with another one - in which you answer only this question.

____

APPENDIX B – INTERVIEW PROTOCOL

These interviews followed a consistent protocol and were conducted online using Zoom. Participants were selected based on their willingness to be interviewed and to ensure a representative cross-section of academic roles and geographic regions.

The interviews lasted approximately 30–45 minutes and included the following themes:

1. **Current Role:** Clarifying the participant's academic role (e.g., teaching, research, or curriculum coordination)
2. **Teaching Strategy:** How BIM is integrated into the teaching plan or learning objectives.
3. **Effects of BIM Integration:** Anticipated or observed impact on student learning outcomes or institutional practices.
4. **Course Siloing and Integration:** Views on whether courses are taught in isolation or in integrated formats, and the effect of this structure.
5. **Use of Project-Based Learning (PBL):** Application of PBL and collaborative approaches in BIM-related instruction.
6. **Perception of BIM:** Whether BIM is presented as merely a modeling tool or as a broader information system.
7. **Faculty Experience:** Staff training and familiarity with BIM tools and concepts.
8. **Barriers and Challenges:** Institutional or pedagogical challenges in BIM adoption.
9. **Curriculum Influence:** Degree of influence participants have in shaping BIM-related curriculum and areas for improvement.