



AI in Architecture Education-Importance of AI and its Integration into Architecture Education Curriculum

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Abstract : The aim of this research is to emphasize the significance of introducing AI technology into undergraduate Architecture education in Punjab and to determine the appropriate timing and approach for its inclusion in the Outcome Based Curriculum (OBC). A survey was conducted among Architecture department students, professionals, and faculty members to achieve this goal. The study suggests that it is crucial to incorporate AI technology into Computer Application courses alongside other software tools and recommends introducing it in the first year of the undergraduate program to establish a fundamental understanding of architectural design and drafting. The research underscores the importance of prioritizing a clear understanding of related content and providing practical demonstrations.

Additionally, the study assesses the prevalence of AI tool integration in undergraduate Architecture programs across 10 top-ranked universities and institutes worldwide, as per the 2019 QS world ranking and NIRF ranking. The research recognizes the vital role played by AI tool training in promoting economic growth among students and aims to foster individuals with diverse expertise in specialized areas, who are well-rounded and creative. The study aims to address the fact that Architecture is increasingly technology-driven and demands a digital approach to tackle emerging challenges that cannot be confined to a single discipline. The study results are expected to offer insights into the current usage of AI tools in Architecture education and guide future efforts to enhance the curriculum.

Keywords: Architecture education , Artificial Intelligence, curriculum , Building Information model (BIM) , Softwares

I Introduction

The use of technology in architecture has been significant, with architects leading the way in integrating new technologies into their workflows(Gensler, 2018). The emergence of highly technological advancements such as AI, ML, IoT, and digital twins have made significant changes and improvements to the way we work and interact with each other (Oladimeji & Olawande, 2020). AI has the potential to revolutionize the field of architecture by providing architects with new tools and techniques to design, analyze, and optimize buildings. The introduction of AI in architecture education can bring many benefits but also requires an understanding of ethical and societal implications, as well as the limitations of the technology. Traditional design skills and a deep understanding of architecture should still be emphasized to create meaningful, context-sensitive designs(Gürer et al., 2021).

The realm of architecture has witnessed a notable upswing in the adoption of technology and automation. To stay competitive, architecture firms are increasingly finding it imperative to integrate artificial intelligence (AI) into their operations.. AI can provide architecture with data processing capabilities and generate forms that would not be possible without computation.. AI also offers quick and effective methods for visualization and prototype production, and can assist in automating parts of the design process, analyzing building performance, designing smart buildings, improving collaboration, and making predictive analytics. However, there is a gap between traditional architecture education and the depth of knowledge required for the successful application of AI in architecture design. To bridge this gap, professional development opportunities and interdisciplinary programs that combine aspects of architecture and AI are emerging. Graduates who have a good understanding of AI technology and its applications will be better equipped to take advantage of new opportunities in the field, and to create environmentally responsible and user-friendly buildings.

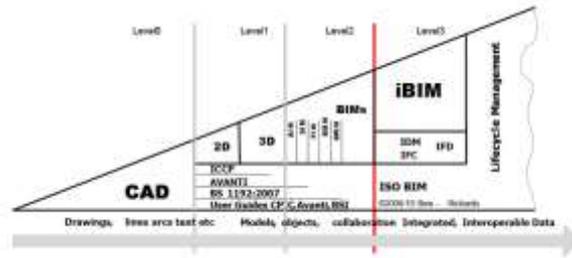


Fig 1: Life cycle scenario of AI
 source:<https://blog.ario.io/content/images/2015/11/BIM-wedge-1.png>

II.Literature

The University of Cambridge conducted a study in 2021 which developed an AI system that can generate architectural designs based on specific user requirements and constraints. The system uses machine learning algorithms to analyze and learn from previous architectural designs, and can generate designs that meet the user's requirements(University of Cambridge (2021, April 27). BIM is a digital process that helps improve collaboration, reduce errors and inconsistencies, and increase efficiency throughout the entire project life cycle(John Wiley & Sons,2018). BIM is becoming increasingly important in the architecture industry as a tool for improving the design process, reducing construction costs and time, and ensuring that buildings meet performance and sustainability goals. The global BIM market is expected to grow at a CAGR of 11.2% from 2019 to 2026, and is expected to be worth \$9.81 billion by 2026(*ResearchAndMarkets.com, 2020*). In India, BIM adoption will be focused on the AECO industry, with AI and BIM helping to cut down the time it takes to plan and design a structure significantly. BIM works with other design software programs to give a full picture of a structure from conceptual design to maintenance and even renovation or demolition plans. The shift from 2D CAD drawings to 3D models has revolutionized the construction and architecture industry, with BIM models providing accurate visualization and integration of project information (Sanguinetti et al., 2020; El-Diraby et al., 2021; Succar, 2009). BIM also enhances communication among project stakeholders and enables the use of advanced technologies like AI and robotics (Eastman et al., 2011; Chuang et al., 2021). The adoption of BIM has been influenced by policies and construction standards (Azhar et al., 2012), and BIM is a central information management system for all projects. In architectural education, BIM can enhance student learning, collaboration, design quality, cost savings, efficiency, and industry preparation (Eastman et al., 2011; Succar, 2009).

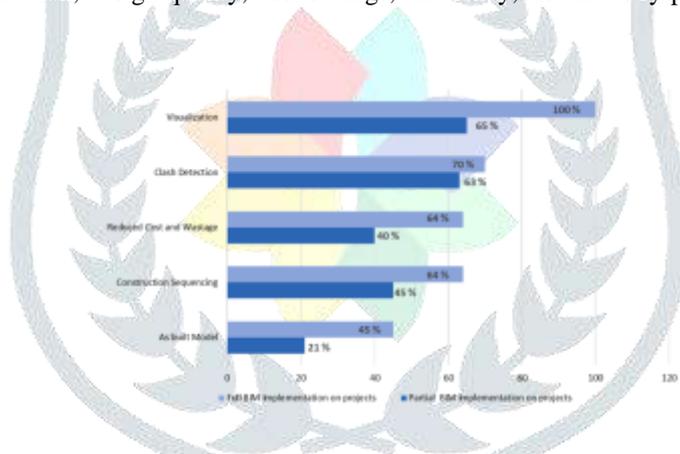


Figure :2 Comparative Percentage when AI got implemented in Projects source:<https://excelize.com/blog/journey-of-bim-in-the-indian-aeco-industry>The five research papers studied are about the application and implications of artificial intelligence (AI) in the field of architecture. The first two papers provide an overview of the main areas of AI application in architecture, including generative design, performance optimization, user analysis, and design collaboration. The third and fourth papers focus on the potential impact of AI on architectural education, discussing the benefits and challenges of integrating AI into the curriculum and the need for new teaching methods. The fifth paper discusses how AI is already changing the field of architecture and how it will transform the role of architects, requiring them to develop new skills and knowledge. Overall, the papers highlight the potential of AI to revolutionize architectural design and construction, while also emphasizing the need for further research and development to fully realize this potential

Courses of AI offered in global Institutes/Universities along with softwares used:

S.no	International Institutes along with semesters	Softwares used
1	University of Berkeley, California (Sem-3,5,8)	Autocad,Revitt,HTML,Python,R,Blackboard,Adobe Creative Suite,ArcGIS, 3DSMax
2	University of Calgary, Canada (winter arch 690.3, Fall arch 792.3)	Adobe Creative Suite, ArcGIS,Autodesk, Blender, Rhino7, Grasshopper, SketchUp, QGIS, Vectorworks, Microsoft Teams, Microsoft Office 365
3	Harvard school of Design (Part 1,2,3,4)	Adobe Creative Suite, ArcGIS,Autocad, Rhino7, Grasshopper, SketchUp, Maya, Solid works, Revitt
4	Carnegie Mellon University ,Pittsburg (Sem 1,2,3,4)	Miro,Goggle Suite,Creative cloud all app,Rhino,V-ray,Autocad,Photoshop,InDesign CC 2021, Microsoft Office 365
5	University of Cambridge (Year 1 part 1, Year 2 part 2, Year 3 part 3)	Autocad,Rhino,V-Ray,Laser cutter,Photoshop, InDesign CC
6	National University of Singapore (Year 2 part 3,4)	AutoCAD, SketchUp, Rhino, Revit, and Adobe Creative Suite
7	Georgia Institute of technology (Core B,Core F)	AutoCAD, SketchUp, Rhino, Revit, and Adobe Creative Suite, 3DSMax
8	Delft Institute of technology, Netherland (Year 1,Year 2)	AutoCAD, SketchUp, Rhino, Revit, and Adobe Creative Suite,3DMax
9	ETH Zurich (Year 1,Year 2 all semesters)	AutoCAD, Rhino, SketchUp, Revit, ArchiCAD, 3DSMax, V-Ray, and Adobe Creative Suite.
10.	University of Sydney (All 4 years)	AutoCAD, SketchUp, Rhino, Revit, and Adobe Creative Suite,3DMax

Table 1: Global universities/Institutes along with AI tools

Courses of AI offered in national Institutes/universities along with software used:

S.no	National Institutes along with semesters	Softwares used
1	IIT,Roorkee (Sem-2,3,4,5)	AutoCAD, Rhino, SketchUp, Revit, ArchiCAD, 3ds Max, V-Ray,Adobe Photoshop,Adobe illustrator,Lumion
2	SPA, Vijayawada(Sem-4)	AutoCAD, Rhino, SketchUp, Revit, 3ds Max, V-Ray,Adobe Photoshop,Adobe illustrator,Vector works ,Maya
3	NIT,Calicut (Sem-3,5,8)	AutoCAD, Rhino, SketchUp, Revit, 3ds Max, V-Ray,,Adobe Creative Suite ,Maya
4	SPA,Delhi (Sem-1,2,3,4)	AutoCAD, Rhino, SketchUp, Revit, 3ds Max, V-Ray,Adobe Photoshop,Adobe illustrator,Vector works ,Maya
5	NIT, Trichy (Sem- 2,3,5)	AutoCAD, Rhino, SketchUp, Revit, 3ds Max
6	SPA,Bhopal (Sem-3,4,5,6)	AutoCAD, Rhino, SketchUp, Revit, 3ds Max,Adobe Creative Suite
7	Manipal University (Sem-4)	AutoCAD, SketchUp, Rhino, Revit, 3ds Max, Adobe Photoshop, and Adobe Illustrator
8	Birla Institute of Technology, Mesra (Sem 3 onward then it is elective)	AutoCAD, 3D modeling software like SketchUp or Revit, and graphic design software like Adobe Photoshop or Illustrator.
9	Amity university (Sem-4)	AutoCAD, SketchUp ,Revit, Rhino Adobe Creative Suite
10.	RV college of Architecture (RVCA) Bangalore	AutoCAD, SketchUp, Rhino, Revit, 3ds Max, Adobe Photoshop, and Adobe Illustrator.

Table 2 : Global universities/Institutes along with AI tools

III.Research Methodology:

The article discusses a research study conducted to strengthen the understanding of BIM (Building Information Modelling) education in the current educational system. The study included a literature review, questionnaire survey at national and international levels, curriculum analysis of universities, and sample case studies of BIM tool usage. The authors utilized a systematic review methodology with five steps: question formulation, locating studies, study selection and evaluation, analysis and synthesis, and reporting results and using the results.

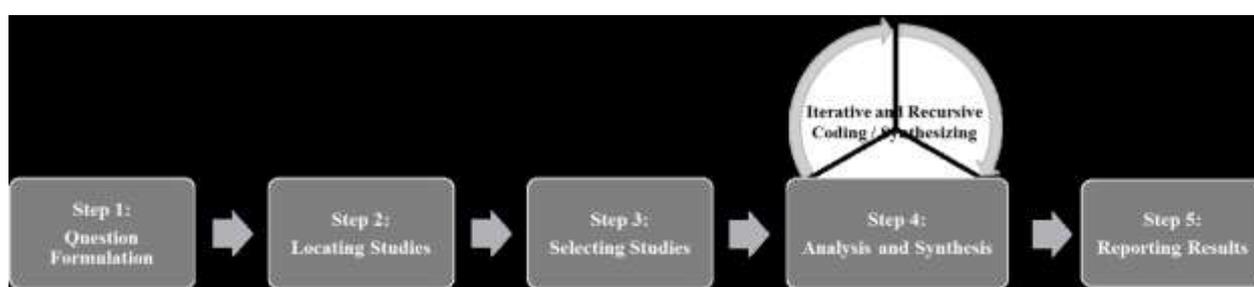


Fig 3:Steps of Systematic Review in this Research (adapted from Denyer and Tranfield, 2009)

The authors also employed an analytical research methodology and quantitative study using primary and secondary sources. The study targeted students, faculties, and alumni as professionals from the field of architecture education, aiming to train graduates with high-quality standards and efficient resource management within the stipulated time period. The study used probability simple random sampling to extract a sample from the population, with 500 respondents selected. Data was primarily collected through questionnaires from students, faculties, and professionals, while secondary data was obtained through a literature review and internet-based sources such as published data available on the websites of the sample universities along with the sample case studies of graduates and professionals.

IV.Results and evaluation (Findings and Analysis)

The integration of Building Information Modeling (BIM) into architectural education can provide significant benefits for students and industry professionals, such as improving communication and collaboration and enabling more efficient and sustainable building designs. Studies by Hammad et al. (2020) and Su et al. (2019) found that BIM education can also improve students' understanding of building systems and design principles, as well as critical thinking and problem-solving skills. The research methodology employed by Hammad et al. was analytical and quantitative, focusing on the analysis of the importance of BIM in architecture education. The sample size for the study was limited to 500 respondents, including 130 students and 26 faculty members. The study's findings can guide academic coordinators in recommending necessary changes to curricula to incorporate BIM education.

4.1 Student Questionnaire survey Findings

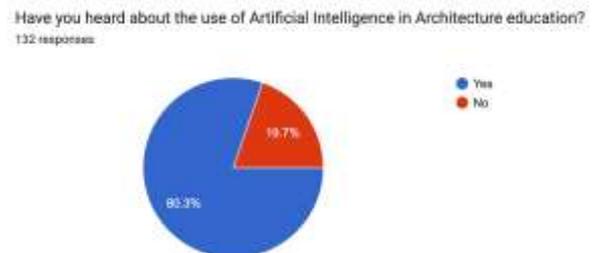
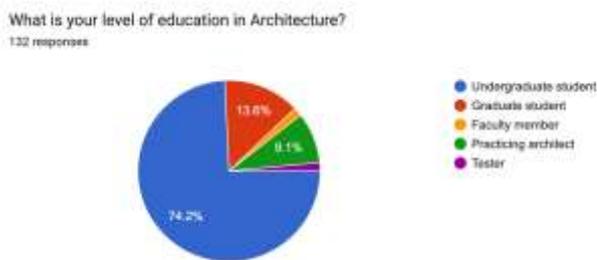


Fig 4: Level of Education

Fig 5: AI in architecture education

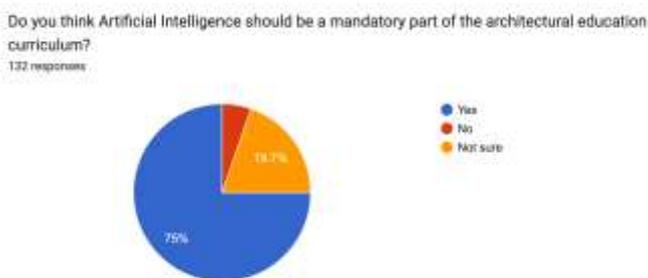


Figure 6: AI as part of Architecture Curriculum

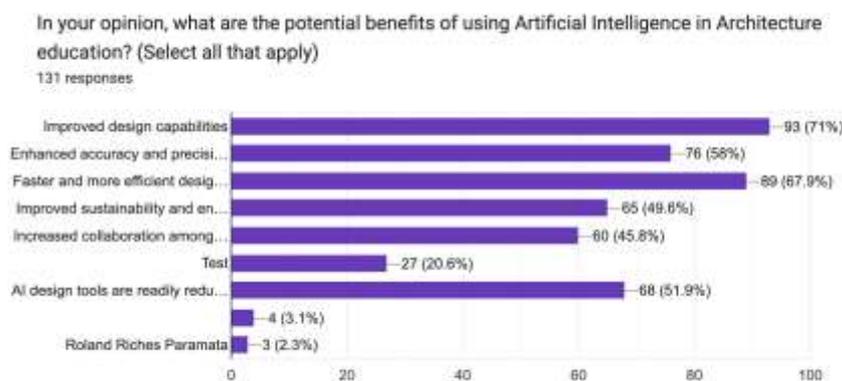


Figure 7: Potential benefits of AI tools

Have you used any Artificial Intelligence powered tools or software in your Architecture education or practice? (Choose one)
132 responses

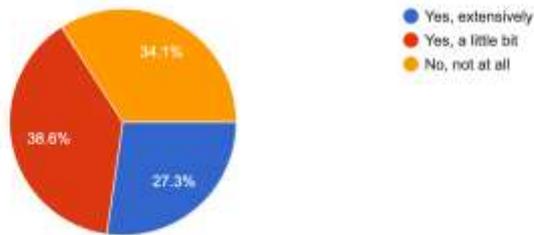


Figure 8: Role of AI tools

How can Artificial Intelligence be integrated into the curriculum of Architecture education? (Select all that apply)
132 responses

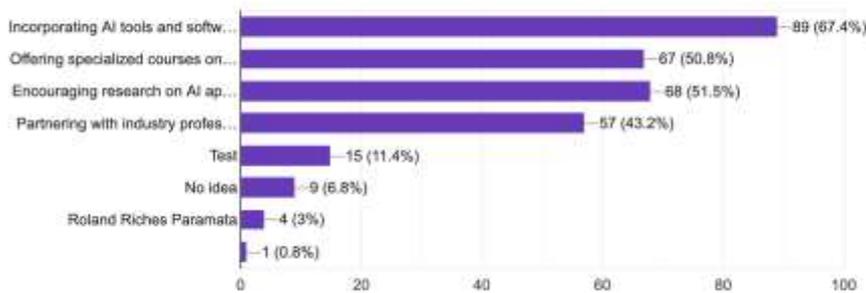


Figure 9: Integration of AI in Architecture curriculum

Do you think that AI should be taught as part of undergraduate Architectural education?
132 responses

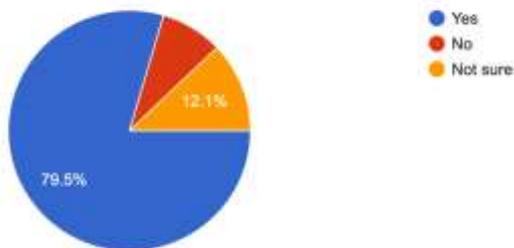


Figure 10: AI in education

How many semesters do you think an undergraduate student should study AI in Architecture?
132 responses

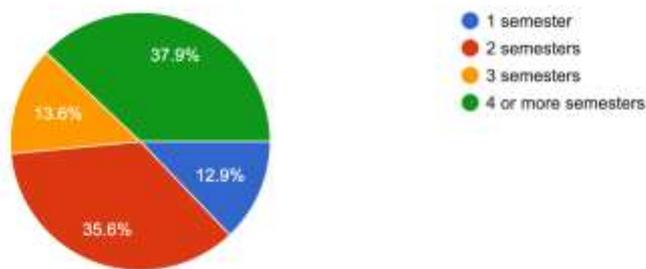


Figure 11: Duration of AI

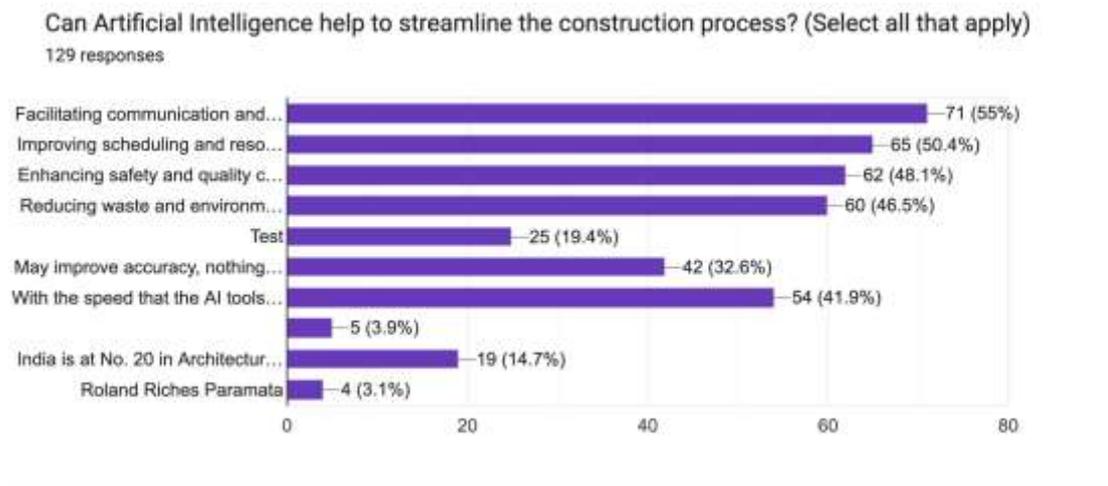


Figure 12: Role of AI in construction

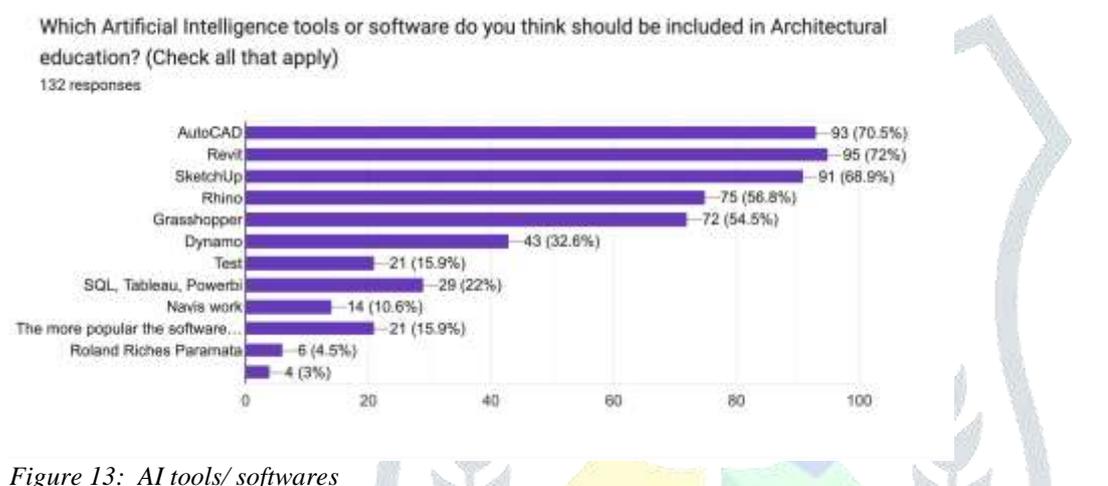


Figure 13: AI tools/ softwares

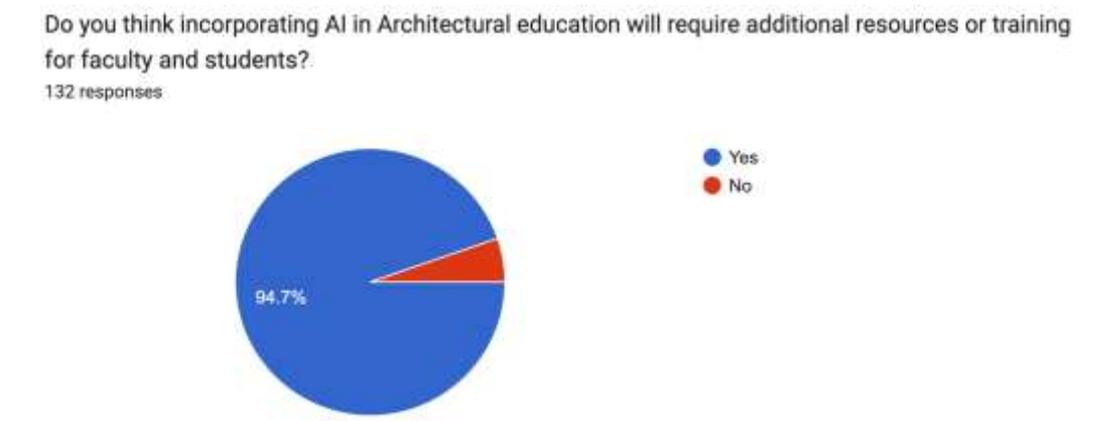


Figure 14: AI resources /training

Do you think that including Artificial Intelligence in the architecture curriculum will make graduates more competitive in the job market?

132 responses

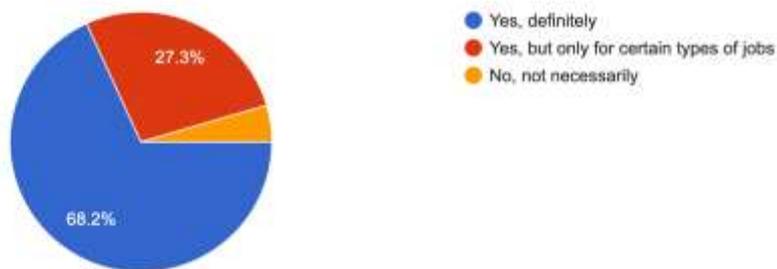


Figure 15: Job opportunities with AI

4.2 Faculty Questionnaire survey Findings

In your opinion, is Artificial Intelligence (AI) applicable to the field of Architecture?

26 responses

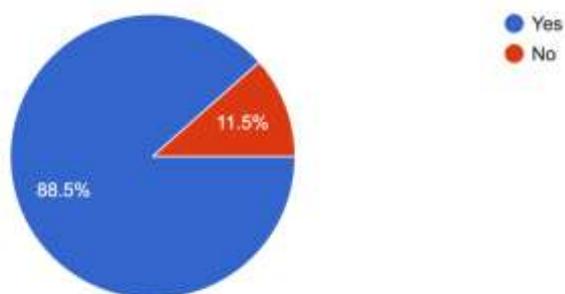


Figure 16: Faculty opinion on AI

How would you rate your knowledge of Artificial Intelligence (AI)?

26 responses

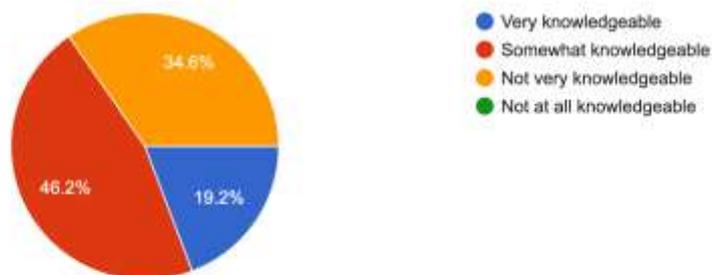


Figure 17: Familiarity with AI

Have you taught a course or conducted research in the field of AI?

26 responses

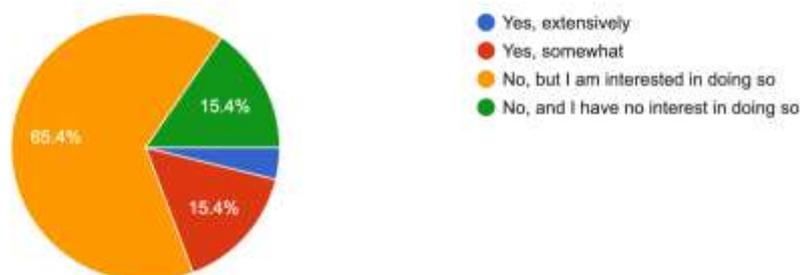


Figure 18: Faculty Research in AI

Have you used any AI tools or software in your research or teaching?

26 responses

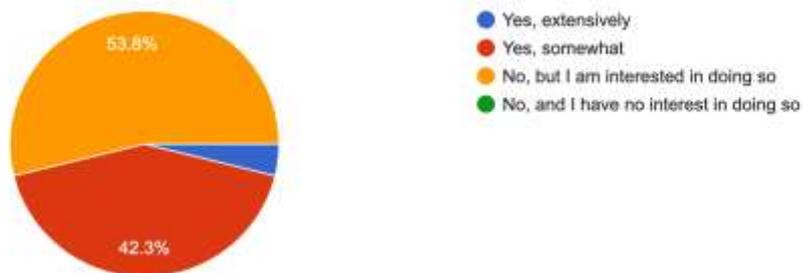
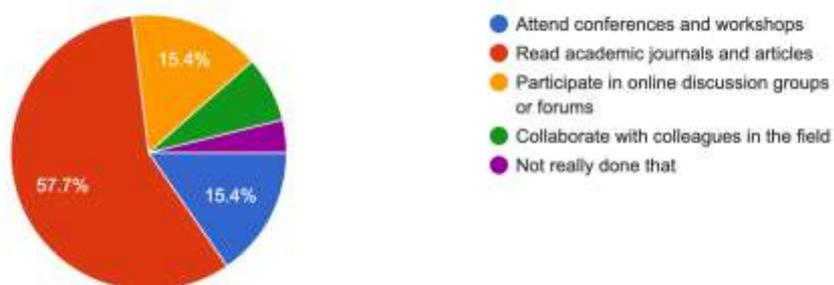


Figure 19: Role of AI tool

How do you stay up-to-date on developments in the field of AI?

26 responses



Do you feel that your institution provides adequate support for teaching and researching AI?

26 responses

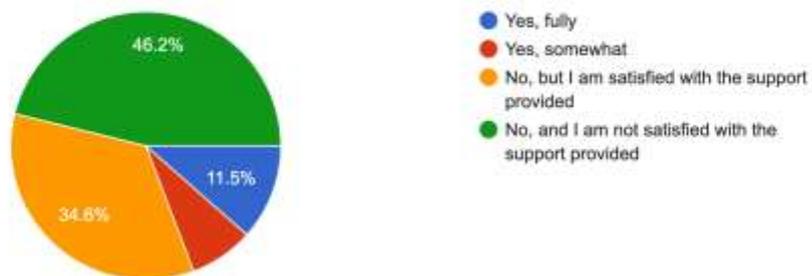


Figure 21: Resources provided by Institutes

Have you ever used AI tools or technologies in your Architectural Design work?

26 responses

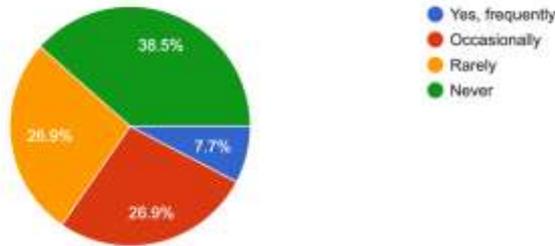


Figure 22: Utilization of AI tools by faculty

Do you think AI has the potential to revolutionize the Architectural Industry?

26 responses



Figure 23: AI potential to revolutionize Industry

What AI applications do you think are the most relevant to Architectural Design?

26 responses

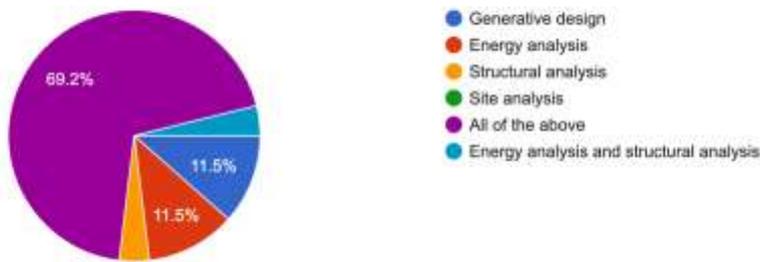


Figure 24: Relevant AI processes

Have you received any formal training on AI in Architecture?

26 responses



Figure 25: Faculty formal training acquired

How important do you think it is for architects to have knowledge of AI in today's Industry?

26 responses

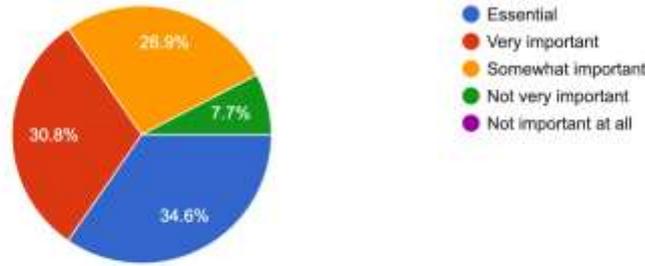


Figure 26: Importance of AI for Architects

What do you think are the potential risks or downsides of using AI in Architecture?

26 responses

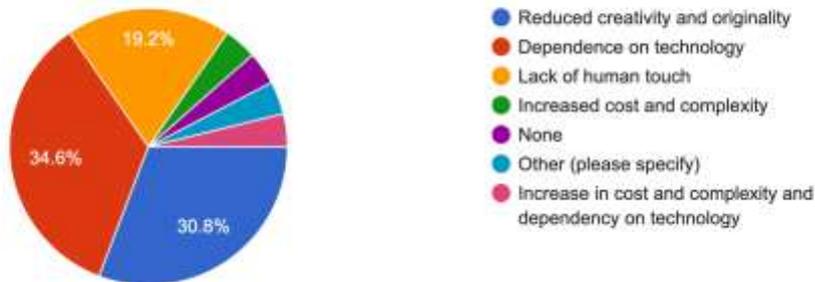


Figure 27: Potential Risk of AI

What do you think are the potential benefits or upsides of using AI in Architecture?

26 responses

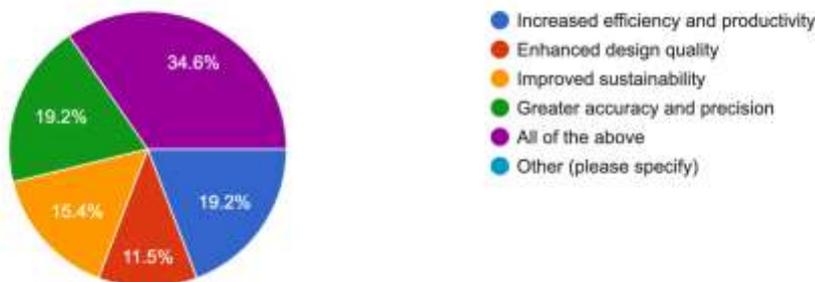
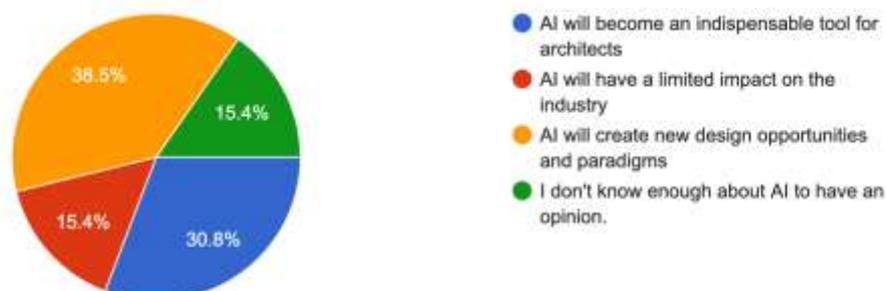


Figure 28: Potential benefits of AI

What do you think is the future of AI in Architecture?

26 responses



Do you believe that AI should be a compulsory component of the Architecture syllabus?

26 responses

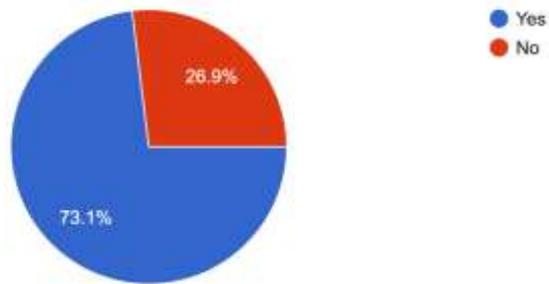


Figure 30: AI as major component



4.3 Sample case studies prepared using AI software

Enclosed are samples of drawings to aid in comprehending and evaluating the distinctions among models produced with BIM software. These drawings depict the impact of lighting and shading, as well as the textures of walls, buildings, and their surroundings within the natural environment.

4.3.1 Sample drawing by Alumini's



Figure 31: Work done by graduate students using AI

4.3.2 Sample drawing by undergraduates students



Figure 32: Work done by undergraduate students using AI

The paper discusses the importance of integrating Building Information Modeling (BIM) into architecture education and the different levels of BIM (Level 1, 2, and 3). It suggests starting with Level 1 and progressing towards Level 2 and 3 as students become more advanced. Collaboration and data sharing are also essential components of BIM and should be incorporated into the curriculum. The study also examines the curricula of ten leading undergraduate architecture programs worldwide to comprehend the offerings of pioneer architecture institutions. The syllabus for BIM programs typically covers a range of topics related to the design, construction, and management of buildings using BIM technology. Commonly used software programs in BIM courses include Autodesk Revit, ArchiCAD, SketchUp, Bentley MicroStation, Navisworks, Rhino, Dynamo, Grasshopper, Tekla, and SolidWorks.

V. CONCLUSION AND PROPOSAL

The research paper focuses on the use of digital education in architecture education and evaluates the need for artificial intelligence (AI) educational approaches. The author conducted a literature review, questionnaire survey, and examination of university curricula worldwide to determine the inclusivity and status of Building Information Modeling (BIM) in the current scenario. Based on the findings, the author proposed a roadmap to produce well-equipped individuals who can meet the growing demand of the market.

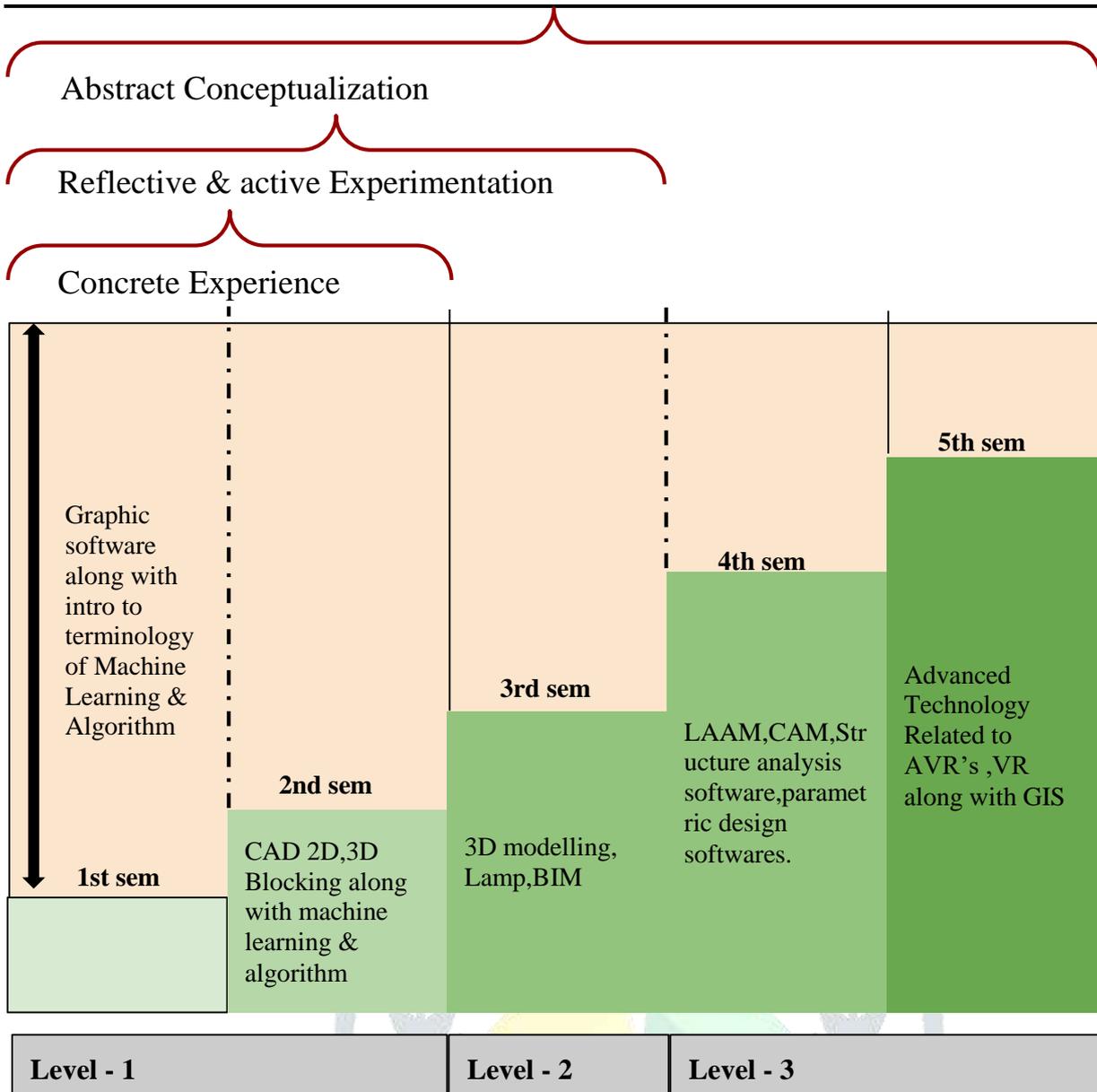


Fig 33: Proposed roadmap of AI tools to be incorporated in the syllabi

The proposed roadmap includes three levels, and each level has multiple modules. In level 1, students are introduced to the fundamental usage of graphic software applications as well as the basic terminology associated with machine learning and algorithms. The second stage of level 1 focuses on acquiring rudimentary drafting skills, creating 3D models, and receiving more comprehensive education about machine learning and algorithms, particularly through the use of Python.

Level 2 involves learning how to design models and incorporate textures and effects and related software. Once students become proficient in 3D blocking at this level, they progress to the next stage.

Level 3 involves applying previous learning. The first stage of level 3 focuses on equipping students with the necessary skills to create a complete model of the structure while considering the suitability of the site and the surrounding environment. In the final stage, students learn how to use AVr technology, which enables them to visually experience the actual scenario of the structure, exploring every nook and cranny.

The author also proposed modules for each level that provide a detailed overview of the topics covered and the expected learning outcomes. These modules cover topics such as multimedia software, basic image editing techniques, graphic design software, machine learning algorithms, and their applications in architecture, 2D and 3D design and modeling using CAD software, programming concepts and their application in architecture, and advanced 3D modeling and visualization techniques.

Overall, the study provides insights into the importance of incorporating digital education and AI approaches in architecture education to produce well-equipped individuals who can meet the growing demands of the market. The proposed roadmap and modules can help educators and institutions develop an effective curriculum that aligns with changes occurring in the contemporary world while providing students with the necessary skills and knowledge to excel in the field of architecture.

The authors of the research paper have also developed a module for integrating AI tools into architectural education curriculum for various semesters based on a literature review, analysis of undergraduate architecture program curricula worldwide, and a questionnaire survey.

5.1 Proposed Module of AI tools

Semester 1:Introduction to multimedia softwares in Architecture
 Introduction to Machine Learning and Algorithms in Architecture

Semester 2:Computer-Aided Design (CAD)
 Programming for Architects

Semester 3: Introduction to 3d software
Introduction to BIM tools

Semester 4: Introduction to advanced 3D softwares including LAAM (Landscape Architecture and Urbanism)
Introduction to parametric design software

Semester 5: Introduction to AVR and VR in Architecture in Design, construction & building performance
Programming in GIS

VI. Appendices

1. <https://forms.gle/18z8tAoP75X4sDeX8>

Responses Link: <https://bit.ly/42r1mbf>

2. <https://forms.gle/mDoQyhmnRtkkwDr6>

Responses Link: <https://bit.ly/42ODXQA>

VII. Bibliography & References:

- McKinsey & Company. "Notes from the AI frontier: Tackling Europe's gap in digital and AI." McKinsey & Company, 2019
- Gartner. "Magic Quadrant for Cloud Infrastructure as a Service, Worldwide." Gartner, 2018
- McCarthy, John, Marvin L. Minsky, Nathaniel Rochester, and Claude E. Shannon. "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence." *AI Magazine*, vol. 27, no. 4, Winter 2006, pp. 12-14
- Hammad, Ahmad, Samer F. Al Nsairat, and Mohammad Al-Asmarat. "The integration of building information modeling in architectural education." *Journal of Engineering, Design and Technology*, vol. 18, no. 6, 2020, pp. 1586-1601.
- Su, Y. W., Pan, W., Wang, C. H., & Lee, J. H. "The impact of BIM education on architectural students' learning performance and critical thinking." *Sustainability*, vol. 11, no. 22, 2019, p. 6427.
- Chaszar, A. "AI and Architecture: Opportunities, Challenges, and the Future." *Buildings*, vol. 10, no. 6, 2020, p. 106
- Groninger, R. "AI in architecture education: Opportunities and challenges." *Advances in Computer Science and Ubiquitous Computing*, edited by S. A. Elshater et al., 2020.
- Computing, pp. 165-175, Springer, 2020, doi: 10.1007/978-981-15-7872-7_16
- LeCun, Yann, Yoshua Bengio, and Geoffrey Hinton. "Deep Learning." *Nature*, vol. 521, no. 7553, 2015, pp. 436-444,
- Salama, A. M. "Artificial intelligence and the built environment: An exploration." *ArchNet-IJAR*, vol. 13, no. 1, 2019, pp. 115-128
- Eastman, C., Teicholz, P., Sacks, R., and Liston, K. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*. John Wiley & Sons, 2011.
- Grau, David, Stefan Merk, and Michael Shamiyeh. *Artificial Intelligence for Architects: Accelerating Innovation in Design and Construction*. Birkhäuser, 2021.
- Kolarevic, Branko. *Architecture in the Digital Age: Design and Manufacturing*. Spon Press, 2008.
- Oz Karamanli, Duygu, Burcu Akinci, and Yogesh Patil. "Artificial intelligence in architecture, engineering, and construction: An overview." *Journal of Computing in Civil Engineering*, vol. 33, no. 6, Nov. 2019, article no. 04019039.
- Figueroa, Pedro, and Leandro Aouad. "Designing with Machines: An Automated Approach for Generating Architectural Designs." *arXiv preprint arXiv:2106.04639* (2021)
- Eastman, Chuck, Paul Teicholz, Rafael Sacks, and Kathleen Liston. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors*. 2nd ed., John Wiley & Sons, 2011.
- Succar, Bilal. "Building Information Modelling Framework: A Research and Delivery Foundation for Industry Stakeholders." *Automation in Construction*, vol. 18, no. 3, Apr. 2009, pp. 357-375.
- Chuang, T. Y., Li, Y. T., and Liu, Y. T. "A Study on Digital Marketing Strategy and Application for Construction Engineering Companies." *Journal of Cleaner Production*, vol. 291, 2021, article 125935.
- El-Diraby, Tamer, Nagwa M. El-Gohary, and Osama Moselhi. "Smart-Contract-Enabled Construction Contracts: A BIM-Based Solution." *Journal of Computing in Civil Engineering*, vol. 35, no. 2, 2021, article 04020067.
- Sanguinetti, Paolo et al. "Comparing user experience in 3D BIM models: The impact of interactivity and realism on perceived usefulness and satisfaction." *Automation in Construction*, vol. 113, 2020, p. 103130.
- Azhar, S., Khalfan, M., Maqsood, T., and Moussa, M. "Building information modelling (BIM): A new paradigm for visual interactive modelling and simulation for construction projects." *Virtual and Physical Prototyping*, vol. 7, no. 1, 2012, pp. 21-34.
- Watts, Andrew. "Artificial Intelligence in Architecture: Towards a New Future." *ArchDaily*, 21 June 2017
- Liu, Y., Guo, C., and Zhang, L. "AI for architectural design: A review." *Journal of Intelligent & Fuzzy Systems*, vol. 39, no. 4, 2020, pp. 5533-5544
- Ghaemi, S., Moradian, S., & Rafiee, M. Y. "Artificial intelligence for architectural design: A review and future directions." *Automation in Construction*, vol. 120, 2021, 103468.
- Whiting, Sarah, and Andrew Whiting. "Exploring the Integration of Artificial Intelligence into Architectural Education." *International Journal of Architectural Research: ArchNet-IJAR*, vol. 14, no. 3, 2020, pp. 27-38.
- Bezerra, R.A.F., et al. "The Impact of Artificial Intelligence on the Architectural Curriculum: A Literature Review." *Journal of Information Technology in Construction*, vol. 25, 2020, pp. 122-139.
- Kaushik, A. K., Rengarajan, S. T., and Kaushik, A. S. "Artificial Intelligence and its Implications for Architectural Education." *Journal of Engineering Education Transformations*, vol. 33, no. 1, 2020, pp. 43-49.
- Karimi, Lida, Mohammed Arif Alshawi, and Sarah M. Al-Gahtani. "Artificial Intelligence and the Future of Architectural Education: A Survey Study." *Frontiers of Architectural Research*, vol. 9, no. 3, September 2020, pp. 464-478

7.1 Website links

1. <https://gtnr.it/40JXyQt3>
2. <https://www.techtarget.com/searchenterpriseai/definition/AI-Artificial-Intelligence>
3. <https://bizop.media/article/how-artificial-intelligence-is-improving-the-architectural-process/>
4. <https://biblus.accasoftware.com/en/8-possible-applications-of-ai-in-architecture/>
5. <https://www.simplilearn.com/ai-architect-article>
6. <https://www.quora.com/For-an-architecture-student-how-will-it-be-beneficial-to-learn-artificial-intelligence-for-a-recent-smart-building-design>
7. <https://www.scitepress.org/Papers/2021/104445/104445.pdf>
8. <https://ieeexplore.ieee.org/document/9069875>
9. <https://www.tandfonline.com/doi/abs/10.1080/095281300409829>
10. <https://www.hindawi.com/journals/complexity/2021/8812542/>
11. <https://blog.dormakaba.com/7-ways-artificial-intelligence-is-revolutionizing-architecture/>
12. <https://excelize.com/blog/journey-of-bim-in-the-indian-aeco-industry>
13. <https://thinkproject.com/blog/5-ways-aeco-is-changing-2021/>
14. <https://www.marsbim.com/blog/bim-in-aeco-architecture-engineering-construction-operations/>
15. <https://catalog.gatech.edu/programs/architecture-bs/#requirements-text>
16. <https://bit.ly/44eiZfp>
17. <https://d2k0ddhflgrk1i.cloudfront.net/TUDeft/Onderwijs/Opleidingen/Bachelor/Bouwkunde/3.Onderwijsprogramma/Blokken/schema%20BSc%20Bouwkunde%20met%20namen%20250821.pdf>
18. <https://arch.ethz.ch/en/studium/studienangebot/bachelor-architektur/bsc-studien-stundenplan.html>
19. <https://www.sydney.edu.au/courses/courses/uc/bachelor-of-design-in-architecture.html>
20. <https://sis.manipal.edu/Syllabus/MSAP/B.Arch%202014%20Scheme.pdf>
21. [https://www.amity.edu/gurugram/naac/1.1.3%20employability%20courses%20documents/1.1.3%20syllabus%20for%20employability%20courses/asap%20\(syllabus-%20employability\)/b%20arch%20\(syllabus\)%202018.pdf](https://www.amity.edu/gurugram/naac/1.1.3%20employability%20courses%20documents/1.1.3%20syllabus%20for%20employability%20courses/asap%20(syllabus-%20employability)/b%20arch%20(syllabus)%202018.pdf)

