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Towards Evaluating The AI-Embedded Educational Model for Architecture Students and Its Impact on Their Design Outcomes

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ABSTRACT

This research explores the impact of AI-assisted teaching on architecture students, addressing the literature gap on the effectiveness of AI in education, particularly in architectural studies. The study developed an AI-integrated teaching methodology and evaluated its influence over an eight-week course involving 24 students from same level in architecture department.
The study employed structured interviews and questionnaires at different stages of the course to assess the effectiveness of the AI teaching model. Findings showed that AI-enhanced teaching positively influenced students' learning, improving their innovative capabilities and work efficiency. However, challenges included uncoordinated use of AI tools by students and the unpredictability of AI-generated design solutions. Despite these challenges, the research supports integrating AI into architectural education to foster creativity, efficiency, and personalized learning. A balanced approach is suggested to prevent over-dependency on AI and to encourage critical thinking skills.

Keywords: *"AI in Education," "Architectural Design," "AI-Embedded Learning Models," "Design Outcomes," "Architecture Students," and "Educational Technology."*

1. Introduction

The integration of AI technologies into architectural education is reshaping how students learn and adapt to complex design challenges. While traditional architectural education emphasizes manual techniques and conventional design methods, these approaches may limit creativity and adaptability in a rapidly evolving technological landscape. The research focuses on evaluating the pedagogical effectiveness of AI-embedded education models for architecture students and the impact on their design outcomes.

AI-powered design tools, such as generative design software, parametric modeling, and predictive analytics, are transforming the design process by enabling students to explore vast design options and optimize solutions in real time. This study examines how these AI-enhanced tools influence students' design outcomes, fostering a learning environment that supports adaptability, creativity, and the ability to handle modern design complexities.

This research addresses two central questions: (1) How does the integration of AI tools affect the design outcomes of architecture students? (2) What are students' perceptions of AI's role in their learning experiences? The study contributes to the ongoing debates about AI in education, offering valuable insights for educators, curriculum developers, and policymakers.

The study combines quantitative data from design assessments with qualitative feedback from surveys and focus groups to understand AI's impact on the creative and technical aspects of architectural design. It establishes a methodological framework to identify best practices for integrating AI into architectural education, highlighting the importance of balancing critical thinking and technological proficiency. The research advocates for a redefined educational paradigm where AI is a fundamental component, equipping future architects with the skills necessary for a technology-driven world.

2. Literature Review

The adoption of AI-embedded teaching models in architecture education has shown great potential in enhancing student learning and design capabilities. Research by Jin et al. highlights that AI tools, including large language models and platforms like Stable Diffusion and Midjourney, enable students to shift from traditional design methods to data-driven approaches, enhancing both creativity and scientific rigor. Studies in Sustainability (2023) and Techne (2023) emphasize AI's role in promoting inclusive and personalized education, enhancing student engagement through interactive tools, and automating assessments. AI-driven models also support the development of sustainability competencies, equipping students with the skills needed to address environmental, social, and economic impacts.

However, challenges such as tool complexity, steep learning curves, and ethical concerns, including data privacy and biases, can hinder AI integration in education. It is crucial to ensure AI complements rather than replaces critical thinking skills. Future research should focus on creating user-friendly AI tools, integrating them seamlessly into curricula, and conducting longitudinal studies to assess their long-term impacts on student performance and professional readiness. Overall, while AI-embedded teaching models significantly enhance learning outcomes in architecture education, their effectiveness depends on balancing technical advancements with pedagogical needs and ethical considerations.

The reviewed literature demonstrates that AI-embedded educational models hold great potential for transforming architectural education by enhancing students' analytical, creative, and problem-solving skills. However, for these models to be truly effective, it is essential to balance the technical capabilities of AI with the pedagogical needs of architectural education. As AI technologies continue to evolve, further research is needed to understand their full potential and limitations in shaping the future of architectural education.

3. Methodology

The research will use an exploratory approach by guiding students to work on a design supported by artificial intelligence through exploring and testing possible strategies for developing the site. The research will use the interactive program Autodesk Forma, which is supported by artificial intelligence, to draw proposals for the proposed project in the course as if you were doing it manually, as well as allowing AI to create building solutions based on the site and the constraints imposed. Current proposals can also be imported (from Revit or Rhino, for example) into Autodesk Forma. The goal is to explore more strategies and concepts in a way not allowed by traditional tools. This study used a mixed research method that combines quantitative and qualitative methods to make a comprehensive assessment of students' learning progress in the course and the effectiveness of the AI-embedded teaching model. Specifically, this study will conduct surveys at two time points as well as semi-structured individual interviews with teachers and students. At the end of the course, the final product will be evaluated by specialists and compared to the initial human product.

Data Collection: Data collection for this study involved administering pre- and post-tests to the study participants, as well as collecting demographic information and information about their prior experience with AI-embedded educational models. Data Analysis: Data analysis for this study involved comparing the pre- and post-test scores of the study participants to determine the impact of the AI-embedded educational model on their design outcomes.

Statistical Analysis: Statistical analysis for this study involved using a paired t-test to compare the pre- and post-test scores of the study participants.

4. The Architectural Education's Developing Goals

Over time, architectural education has changed dramatically in response to the demands of the profession, society, and technology. The main goals of architectural education now include more than just technical instruction; they also include creativity, critical thinking, and social responsibility. In addition to teaching students how to create visually beautiful and useful environments, modern architecture education tries to prepare them to tackle difficult problems like sustainability, inclusion, and technology integration (Crawley, Malmqvist, Lucas, & Brodeur, 2011). The necessity for architects to be flexible problem solvers who can negotiate the nexus of art, science, and ethics is reflected in this evolution. Here is the line chart depicting the evolution of architectural education goals over time (Milovanovic, Moreau, Siret, & Miguet, 2017). The chart illustrates how different aspects such as creativity, critical thinking, social responsibility, and technology integration have changed in emphasis from 2000 to 2025, reflecting the shifting priorities in architectural education (Meyer, Norman, & Innovation, 2020) “Fig. 1”.

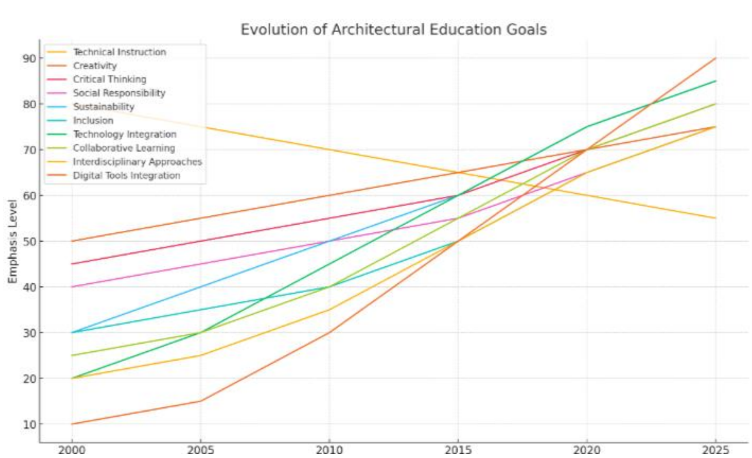


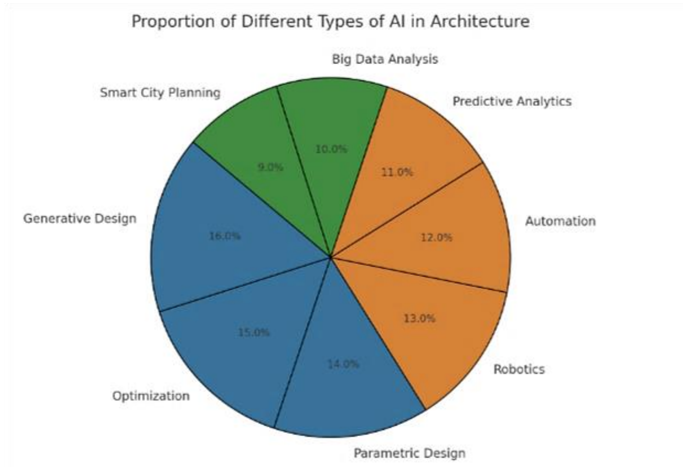
Fig. 1. Evolution of Architectural Education Goals

In order to educate students for a constantly changing professional scene, emphasis is being placed on collaborative learning, interdisciplinary approaches, and the integration of digital tools like AI and BIM. Modern architecture education aims to produce architects who are not only leaders but also designers who can meaningfully and responsibly shape the built environment by establishing a balance between theoretical knowledge, practical abilities, and creative thinking.

5. AI-Assisted Architectural Education

There has also been a steady advancement in the use of artificial intelligence in architecture education. At first, artificial intelligence (AI) was mostly used to enhance architectural design, improving productivity with activities like thorough data calculations and precise evaluation simulations. Artificial intelligence is becoming more involved in architectural design as a result of the ongoing advancements in technology(Li, Ng, & Lee, 2021). It can engage in a wider range of design activities, such as automated planning, performance enhancements, and conceptual design, offering students creative design concepts and solutions. Nowadays, more comprehensive, innovative, and customized intelligent applications are being encouraged by the widespread usage of LLMs and AIGC, which is reducing entry barriers for AI. Artificial intelligence (AI) has been shown to improve the specificity and efficacy of architecture education by not only helping solve complicated design problems. but also by offering more individualized learning experiences based on individual differences among students (Hwang, Xie, Wah, Gašević, & Intelligence, 2020).

`Artificial Intelligence (AI) is redefining the practice of architecture by changing the way architects plan, create, and design urban settings. By automating intricate computations and simulations, AI-powered design tools like parametric design, generative design, and optimization enable architects to investigate a wide range of design ideas. By pushing the limits of originality and accuracy in architecture, these technologies facilitate the quick production of creative designs that are optimized for elements like material efficiency, sustainability, and beauty. Artificial Intelligence (AI) in construction combines robotics and automation to optimize workflows, boost output, and minimize mistakes at the job site. (Baduge et al., 2022) By anticipating possible delays and allocating resources optimally, predictive analytics enhances project management even further and produces safer and more effective construction results. AI's capacity to analyze large amounts of data makes it easier to develop smart cities (Allam & Dhunny, 2019), where sustainable and responsive urban designs are informed by information on demographic trends, environmental data, and traffic patterns. AI is a vital tool in the development of contemporary architectural practice because it allows planners and architects to design cities that are more adaptive, resilient, and in line with the requirements of their citizens through the use of data-driven methods The pie chart “Fig. 2”. illustrates the proportion of different types of AI in architecture, showing how each area—Design, Construction, and Urban Planning—contributes to the overall landscape. This visualization highlights the relative impact of each AI type, such as generative design, robotics, and smart city planning, within the field of architecture.



. Fig. 2. Proportion of Different Types of AI in Architecture

5.2. Integration of AI in Architectural Education

By using historical design data to enable predictive modeling and optimization of design features, machine learning (ML) is transforming the architectural sector and empowering architects to make data-driven decisions that increase productivity and creativity. As a subset of machine learning, generative design use algorithms to produce a wide range of design possibilities depending on particular goals and restrictions that the designer specifies. This approach produces creative ideas that might not be immediately obvious when using more conventional techniques. By evaluating text inputs, Natural Language Processing (NLP) plays a critical role in comprehending and interpreting customer requirements, enabling more accurate needs assessments and better programming. By evaluating and interpreting visual data, such as site photos or pre-existing plans, computer vision technology helps the design process even more by offering insights that guide design choices. Building information modeling (BIM) (Yönder, 2023) is further improved by AI, which streamlines the entire design-to-build process by automating difficult tasks like data analysis, clash identification, and design validation (Colucci Cante, Di Martino, & Graziano, 2024; Milošević, Đukanović, Živković, Žujović, & Gavrilović, 2023). This guarantees that designs are precise, effective, and optimized for production. .

5.2.1.the methods and areas where AI is integrated into the curriculum.

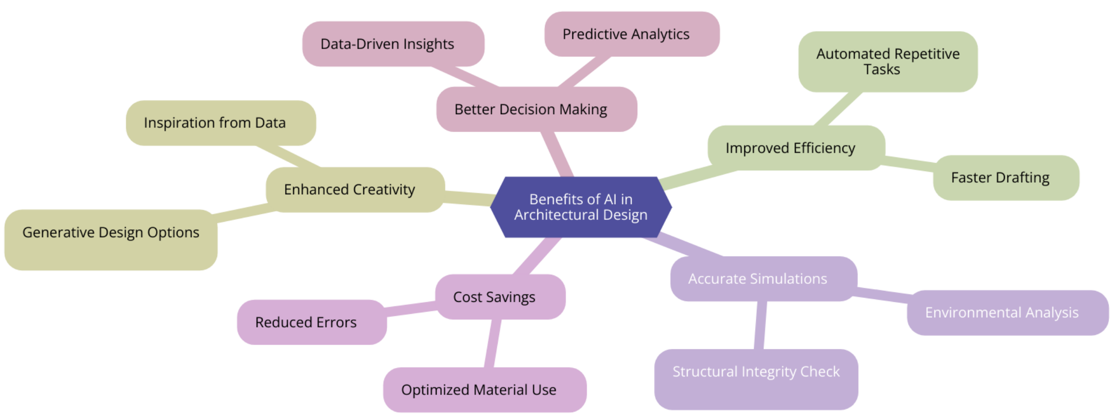
AI enhances architectural design by optimizing workflows with tools like Rhino + Grasshopper and Revit, driving environmental analysis, site assessments, and user-centric designs. It streamlines sustainability, rapid prototyping, and interdisciplinary collaboration for more efficient, sustainable, and user-focused outcomes , Here is a detailed list of them (Irwan, 2023).

- AI Tools in Design Studios: Use of AI-enhanced software like Rhino + Grasshopper and Autodesk Revit with AI plugins.
- AI-Driven Analysis: Environmental performance, energy modeling, and structural optimization.
- Interdisciplinary Learning: Collaboration with computer science and engineering faculties.

- Automated Site Analysis: AI analyzes site conditions, environmental factors, and regulations to inform early design.
- Design Optimization: AI algorithms optimize layouts for efficiency, aesthetics, and sustainability.
- User-Centric Design: AI simulates human behavior to ensure designs meet user needs.
- Sustainability & Energy Efficiency: AI simulations assess energy performance and environmental impact for sustainable design.
- Rapid Prototyping & Visualization: AI accelerates 3D modeling and visualization, enabling quick iterations and presentations to clients.

5.3. Benefits of AI for teaching architecture

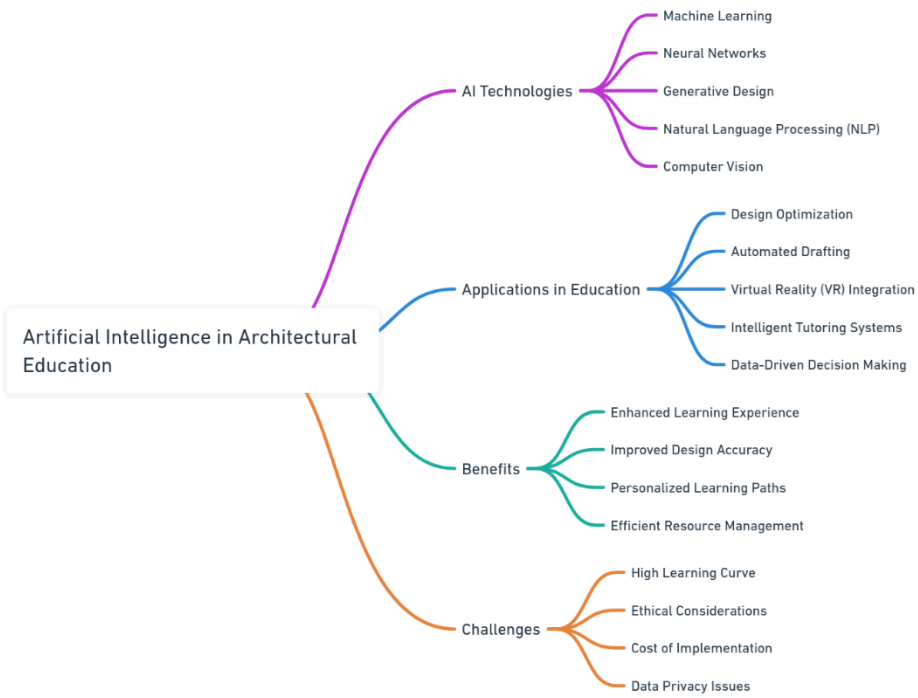
AI improves efficiency, creativity, and data-driven decision-making, which makes it a valuable tool for architectural education. AI encourages creative exploration as a co-designer by producing imaginative design ideas that challenge preconceived notions. By automating monotonous processes like data analysis and drawing, it frees up students' time to concentrate on more strategic and creative parts of design. With real-time feedback from AI-driven simulations, students may make quick adjustments to their designs depending on new information (Rafsanjani & Nabizadeh, 2023). Students' work becomes more relevant and impactful when big data is included into design processes, enabling them to make well-informed decisions that are responsive to real-world requirements. AI improves productivity by expediting design iterations and cutting down on time spent on manual chores. Additionally, its data-driven insights help to better align design solutions with the objectives of the client. Furthermore, AI facilitates better communication and understanding between engineers, architects, and clients by providing interactive models and easily comprehensible data visualizations. Furthermore, AI is a useful tool in architectural practice and education because of its capacity to optimize designs (Guan, Mou, & Jiang, 2020), which minimizes material waste, decreases construction costs, and improves project schedules “Fig. ٣” illustrates how some of these advantages can be described.



. Fig. ٣. AI's advantages for architectural education

5.4. Challenges with Using AI in Architecture Education

In order to assure successful implementation, integrating AI technologies into architecture education involves a number of issues that must be carefully addressed. One of the main challenges is the lack of resources, since financial and practical considerations may limit access to cutting-edge equipment, software, and appropriate training. Another major obstacle is resistance to change. Teachers are reluctant to adopt new teaching paradigms since AI-driven methodologies and traditional pedagogical approaches frequently conflict. Ethics are also quite important; possible biases in AI design and privacy problems with data-driven algorithms can lead to questions about security and justice. Closing the skills gap is crucial because students need to know how to use AI technologies efficiently, which can be difficult given how quickly technology is developing (Ismaeel et al., 2024). Furthermore, data availability and quality are critical since AI models rely on precise and thorough data, and low-quality data can undermine the accuracy of AI predictions. It can be difficult to integrate AI into current workflows; it takes training and major modifications to combine AI technologies with conventional design methods. Adoption of AI is further complicated by ethical and privacy issues, particularly when handling sensitive client and site data (Rane, 2023). The last concern is an over-reliance on algorithms, which, if not controlled, might reduce the humancentric part of design and impede creativity. This emphasizes the necessity of a balanced approach to AI integration in architectural education. Based on the aforementioned, the elements of incorporating artificial intelligence into architectural education can be summarized into the structure shown in "Fig. 4".



. Fig. 4. The main elements in integrating artificial intelligence into architectural education

6.Prospects for AI-Assisted Architectural Design and Programming

The future of AI-assisted architectural design and programming holds immense promise, with advancements poised to transform how architects approach sustainability, personalization, and collaboration. AI-driven sustainability tools will become increasingly sophisticated, integrating real-time data on environmental conditions and material performance to enable designs that are not only efficient but also deeply responsive to their ecological context. The combination of AI with Augmented Reality (AR) and Virtual Reality (VR) technologies will revolutionize client presentations, allowing stakeholders to engage in immersive, interactive exploration of design alternatives, thus enhancing decision-making processes (Khan, 2024). AI will also facilitate personalization at scale, offering tailored design solutions that cater to individual preferences and unique site conditions, thereby making architecture more adaptable and client-focused (Abdullakutty, Qayyum, & Qadir, 2024). The emphasis will shift towards human-AI collaboration, where architects and AI systems work together symbiotically, augmenting the creative process rather than replacing human input. This collaborative approach will harness AI's analytical power to explore design possibilities while preserving the architect's creative vision. While challenges such as data integration and ethical considerations remain, the continuous evolution of AI technologies will push the boundaries of what is possible in architectural design, offering tools that enhance creativity, efficiency, and sustainability, and reshaping the future of the architectural landscape.

7. AI-Embedded Education Model

Architectural design relies on conceptual design to generate, evaluate, and refine initial ideas, exploring design options, spatial layouts, and functional needs. Advances in digital technologies, such as Autodesk Forma, offer architects powerful tools for visualization, modeling, and design optimization. Autodesk Forma, a cloud-based platform, combines data-driven analysis with real-time collaboration, helping architects make informed decisions early in the process. Forma's parametric modeling, environmental simulations, and automated workflows aid architecture students in conceptual design, improving their accuracy, feasibility, and creativity by considering factors like energy efficiency, natural light, and ventilation.

This study investigates how Autodesk Forma impacts architecture students in conceptual design for mixed-use structures, examining whether it enhances innovation, space optimization, and functional design more effectively than traditional methods. The research contributes to the discussion on digital tools in architectural education by comparing student performance and feedback. It integrates AI into problem-solving, decision-making, and early learning, enabling students to navigate both architectural programming and design.

Four out of 12 students, chosen for their cognitive abilities, utilized AI in an 8-week architectural design course (64 hours total). Unlike conventional methods, this approach emphasizes proficiency in detailed design, architectural programming, and rapid generation of solutions, improving decision-making for real-world applications as in "Fig. 5" ...

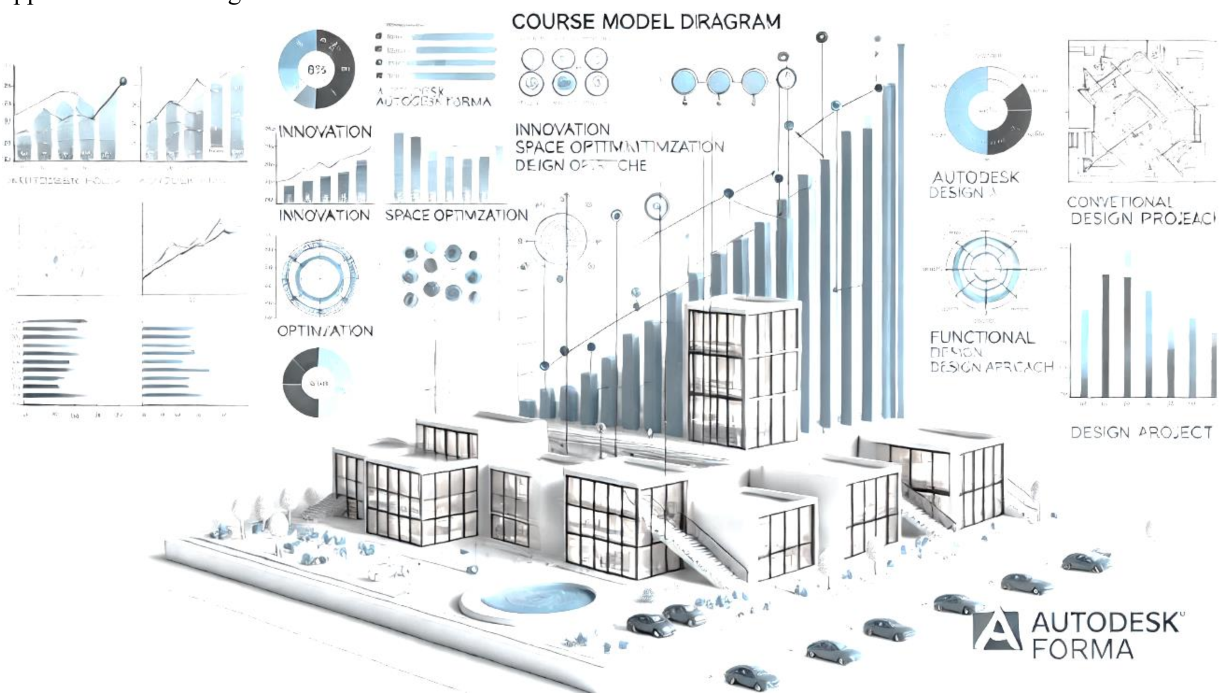


Fig. 5. the course model diagram for the study evaluating the effects of Autodesk Forma on architecture students during the conceptual design phase of a mixed-use building project. The visual illustrates the integration of Autodesk Forma, comparing its impact on innovation, space optimization, and functional design criteria against conventional design approaches

7.1. Putting AI into Practice and Instructional Methods

Below are the most important aspects considered while creating an education model application that incorporates artificial intelligence:

- Increasing learning and student engagement can be accomplished through the incorporation of artificial intelligence (AI) technologies into the educational program.
- Hands-On Training: In order to acquaint students with the uses of artificial intelligence tools, providing them with practical training is essential.
- Utilize real-world scenarios to assist students in applying artificial intelligence principles in real-world circumstances through the use of project-based learning.
- Interdisciplinary Collaboration: In order to successfully bridge knowledge gaps, it is important to encourage collaboration between traditional topics and technology.
- Place a strong emphasis on digital literacy and critical thinking: instruct pupils in the fundamental skills necessary to comprehend and evaluate artificial intelligence technologies.
- Ethical and Practical Implications: Walk students through the ethical considerations and the consequences that the use of artificial intelligence has in the actual world.
- adaptable Learning and Feedback: In order to tailor the educational experience, it is important to make use of technologies that provide continuous feedback and adaptable learning.

- Objectives Equip students with the abilities necessary to effectively utilize artificial intelligence in their professional lives as part of the preparation for future careers.

8. Collecting and analyzing the various data

Collecting and analyzing data involves a comprehensive approach that integrates various types of data “Fig. 6” to gain well-rounded insights. **Quantitative data** focuses on numerical information, offering measurable and statistical insights that can be analyzed through models and trends. **Qualitative data**, on the other hand, provides in-depth understanding through non-numerical insights, such as interviews or observations, helping to capture the context and nuances behind the numbers. **Comparison studies** involve evaluating and contrasting different sets of data or groups to identify patterns, differences, or correlations. By combining these approaches, researchers can obtain a more holistic view, ensuring that both the measurable outcomes and contextual factors are considered.

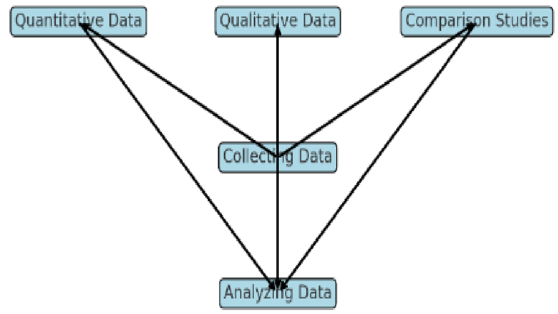


Fig. 6. quantitative, qualitative Data and Comparison studies for Comprehensive Analysis

8.1. Quantitative data:

Collecting information on student performance measures, such as the grades of the four students over a period of 8 weeks before and after using the Autodesk Forma program, the number of design iterations required, the amount of time spent on design activities before and after using it, and the percentage of students who succeeded in Achieving design standards.

- **table 1 : The Grades Over 8 Weeks (Before and After Using Autodesk Forma)**

Week	Student 1 (Before)	Student 1 (After)	Student 2 (Before)	Student 2 (After)	Student 3 (Before)	Student 3 (After)	Student 4 (Before)	Student 4 (After)
1	65	72	58	65	70	78	60	68
2	67	74	60	67	72	80	62	70
3	68	76	62	69	74	82	63	71
4	70	78	64	71	76	84	65	73
5	72	80	65	73	78	85	66	74
6	74	82	67	75	80	86	68	76
7	75	84	69	77	82	88	70	78
8	77	85	70	78	84	90	71	80

Observations:

Each student's performance (in terms of grades) gradually improves after using Autodesk Forma. The grade increases are consistent across the weeks for all students, with improvements of approximately 7-10 points.

- **table 2: Number of Design Iterations Over 8 Weeks (Before and After Using Autodesk Forma)**

Week	Student 1 (Before)	Student 1 (After)	Student 2 (Before)	Student 2 (After)	Student 3 (Before)	Student 3 (After)	Student 4 (Before)	Student 4 (After)
1	6	5	8	6	7	5	9	7
2	7	5	9	6	8	6	10	8
3	8	6	10	7	9	6	11	8
4	9	6	11	7	10	7	12	9
5	10	7	12	8	11	7	13	9
6	11	7	13	8	12	8	14	10
7	12	8	14	9	13	8	15	10
8	13	8	15	9	14	9	16	11

Observations:
Before using Autodesk Forma, students required more design iterations to reach completion. After using Autodesk Forma, the number of iterations decreased due to more efficient workflows, showing an improvement in the design process.

- **table 3: Amount of Time Spent on Design Activities (Hours) Over 8 Weeks (Before and After Using Autodesk Forma)**

Week	Student 1 (Before)	Student 1 (After)	Student 2 (Before)	Student 2 (After)	Student 3 (Before)	Student 3 (After)	Student 4 (Before)	Student 4 (After)
1	12	10	14	11	13	11	15	12
2	13	11	15	12	14	12	16	13
3	14	11	16	12	15	12	17	13
4	15	12	17	13	16	13	18	14
5	16	13	18	14	17	13	19	14
6	17	13	19	14	18	14	20	15
7	18	14	20	15	19	14	21	15
8	19	14	21	15	20	15	22	16

Observations:
Before using Autodesk Forma, students spent more time on design tasks (12 to 22 hours per week). After using Autodesk Forma, the time spent on design activities decreased by approximately 2 to 3 hours per week for each student, reflecting improved productivity and efficiency.

8.2. Qualitative Data:

During the design phase, we collected feedback and qualitative information via questionnaires, interviews, and observations about how students interacted with the AI tools as in **table 4:**

	What challenges did you face while using Autodesk Forma?	**What improvements would you suggest to Autodesk Forma to better suit the needs of students working on mixed-use building projects?**	**Any additional comments or suggestions regarding Autodesk Forma?**
Student ١	The primary obstacle was the steep learning curve. Comprehending the intricate features, particularly the environmental simulation tools, required some time.	I recommend enhancing the user interface to facilitate quicker and more accessible access to critical tools. Furthermore, enhanced support for collaborative team tools would be advantageous.	The software is commendable overall; however, incorporating video tutorials within the program to elucidate capabilities in greater detail would be advantageous.
Student ٢	The software exhibited performance issues when managing extensive and intricate projects, resulting in occasional slowdowns	Enhance the program's responsiveness for large projects and consider incorporating a feature that allows for the rapid saving of alternative models without necessitating redundant work	Improved integration with other design software, such as Revit or Rhino, would be highly beneficial.
Student ٣	I encountered challenges utilizing the parametric tool for certain architectural components that necessitated exact modification.	I want enhancements in the visual output segment to render the final images sharper and more detailed, as the designs appeared less lifelike.	Incorporating an extensive collection of pre-designed items, including flora and furnishings, would improve the caliber of presentations.
Student ٤	I had challenges in utilizing the environmental simulation tools, as the findings were intricate and challenging to assess promptly.	I seek enhancements in environmental analysis technologies to render them more comprehensible and user-friendly, particularly for extensive architecture projects.	I propose creating internal tutorials or prompts to assist users in navigating more intricate procedures.

We also analyzed how the integration of AI tools aligned with planned learning goals, such as increased creativity, stronger analytical skills, and better knowledge of design complexity. Through the post-questionnaire that was prepared and filled out by the students participating in the experiment, the questionnaire was designed as follows:

Student Performance Evaluation Questionnaire

Instructions: Please rate each statement below based on your experience using the software, where 1 means you strongly disagree, and 5 means you strongly agree.

1. **Simplicity of the Software**
   - The software is easy to use and navigate.
   - ☐ 1 (Strongly Disagree) ☐ 2 (Disagree) ☐ 3 (Neutral) ☐ 4 (Agree) ☐ 5 (Strongly Agree)
2. **Innovation and Creativity in Design**
   - The software enhances my creativity and helps generate innovative design ideas.
   - ☐ 1 (Strongly Disagree) ☐ 2 (Disagree) ☐ 3 (Neutral) ☐ 4 (Agree) ☐ 5 (Strongly Agree)
3. **Enhancing Comprehension of Environmental Variables**
   - The software improves my understanding of environmental factors such as natural lighting and airflow in design.
   - ☐ 1 (Strongly Disagree) ☐ 2 (Disagree) ☐ 3 (Neutral) ☐ 4 (Agree) ☐ 5 (Strongly Agree)
4. **Efficiency in Executing Design Concepts**
   - The software allows me to execute design concepts efficiently and quickly.
   - ☐ 1 (Strongly Disagree) ☐ 2 (Disagree) ☐ 3 (Neutral) ☐ 4 (Agree) ☐ 5 (Strongly Agree)
5. **Enhancement of Collaboration Among Students**
   - The software facilitates collaboration with other students effectively.
   - ☐ 1 (Strongly Disagree) ☐ 2 (Disagree) ☐ 3 (Neutral) ☐ 4 (Agree) ☐ 5 (Strongly Agree)
6. **Comprehensive Contentment with the Software**
   - Overall, I am satisfied with the software for my design assignments.
   - ☐ 1 (Strongly Disagree) ☐ 2 (Disagree) ☐ 3 (Neutral) ☐ 4 (Agree) ☐ 5 (Strongly Agree)

After analyzing the questionnaire results, the results were as follows in "Fig. 7"

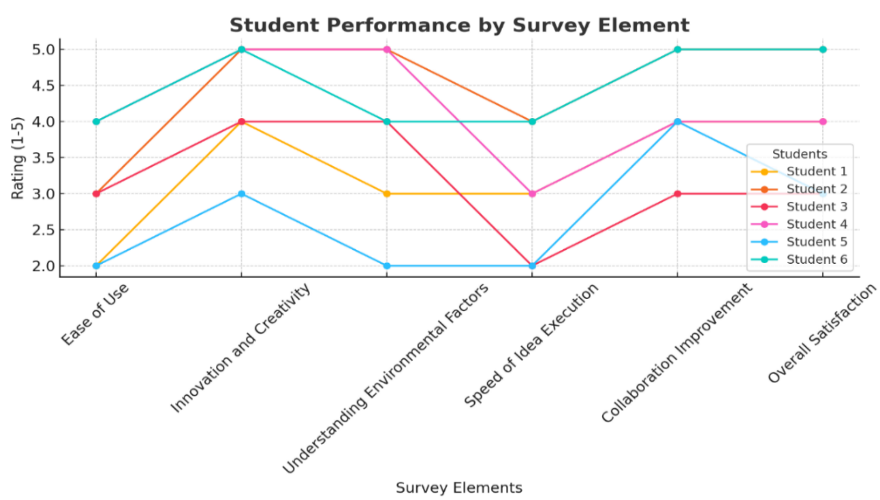


Fig. 7. The results of the student's questionnaire

Observations:

1. Simplicity of the Software

Student responses exhibit variability, with some earning lower ratings (about 2), signifying difficulties encountered in utilizing the software. Conversely, other students assigned higher ratings to the software (between 3 and 4), indicating varied experiences about usability.

2.Innovation and Creativity in Design
This element garnered predominantly favorable evaluations. The majority of students evaluated the software within the range of 3.5 to 5, indicating that Autodesk Forma substantially aided them in augmenting creativity and producing new designs.

3.Enhancing Comprehension of Environmental Variables
The majority of students obtained ratings ranging from 3 to 4.5, signifying that the program was efficient in enhancing their comprehension of environmental aspects pertinent to design, including natural lighting and airflow.

4. Efficiency in Executing Design Concepts
This category exhibits considerable diversity, with several pupils attaining notably low scores (about 1.5), and others achieving elevated values of up to 4.5. This suggests that although several students encountered difficulties with the software's speed, others perceived it as advantageous for expediting the creative process.

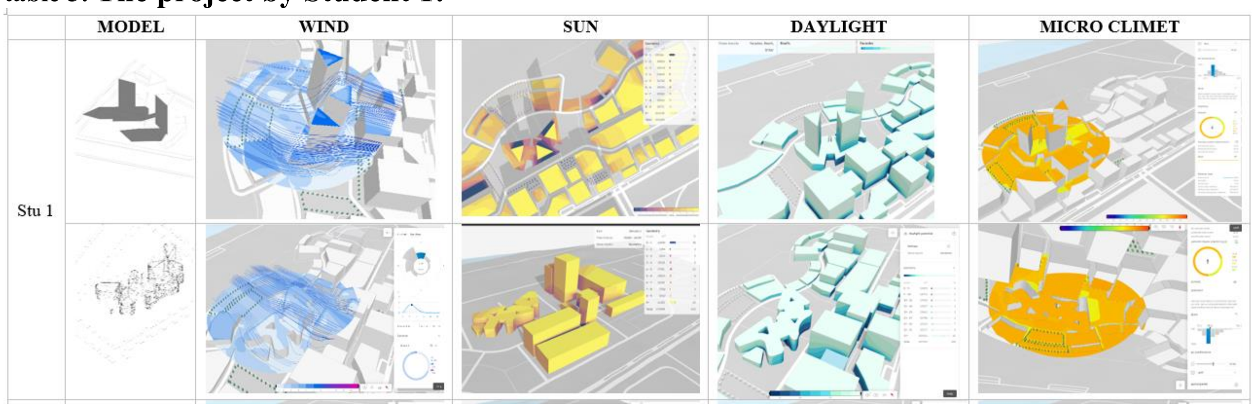
5.Enhancement of Collaboration Among Students
The ratings for this section were varied, with some students providing favorable scores (ranging from 3.5 to 5), suggesting they found the collaborative features of the software advantageous, while others had less satisfactory experiences.

6. Comprehensive Contentment with the Software
Overall satisfaction ratings were predominantly elevated, with the majority of pupils attaining scores between 3 and 5. This suggests that the majority of students were content with their experience utilizing Autodesk Forma for their assignments.

8.3. Comparison studies:

In order to evaluate the added value of AI integration, compare the design results for students who used the AI-embedded models before and after using the application The analysis of the four urban design projects showcases how Autodesk Forma significantly enhances environmental performance assessment by integrating advanced simulation and data visualization tools. Below is a comprehensive analysis of the overall impact on each project and the collective benefits observed from using Autodesk Forma:

table 5: The project by Student 1:



<u>Observations:</u>
Here’s a breakdown of the "before" and "after" impacts observed in the analysis:

1. MODEL

- **Before:** The initial model represents the urban environment with the proposed building structures in a simplified 3D form.
- **After:** Not significant changes in the modeling aspect, but enhancements are primarily in the environmental analysis layers.

2. WIND Analysis

- **Before Using Autodesk Forma:** The wind flow is shown with vector arrows and streamlines indicating the areas of high wind speed around the structures. The impact of the building on wind flow is visible, but optimization areas are not evident.
- **After Using Autodesk Forma:** The analysis appears more refined with clearer data visualization. Wind patterns around the buildings are analyzed for impact, showing potential areas of discomfort or wind tunnels that need addressing.

3. SUN Analysis

- **Before Using Autodesk Forma:** The sunlight exposure of buildings is shown with shading analysis, indicating the amount of sunlight received by different surfaces. There's some indication of sun path impact on building facades.
- **After Using Autodesk Forma:** More detailed sunlight analysis with exposure ratings. Improved solar exposure evaluation helps in determining potential for solar energy utilization and impact on building heating and cooling loads.

4. DAYLIGHT Analysis

- **Before Using Autodesk Forma:** The daylight distribution within and around the buildings is shown, but it appears less precise with a basic visualization of light penetration.
- **After Using Autodesk Forma:** Enhanced daylight analysis highlights more detailed light penetration and areas with sufficient or insufficient daylight, aiding in better interior lighting design and energy efficiency.

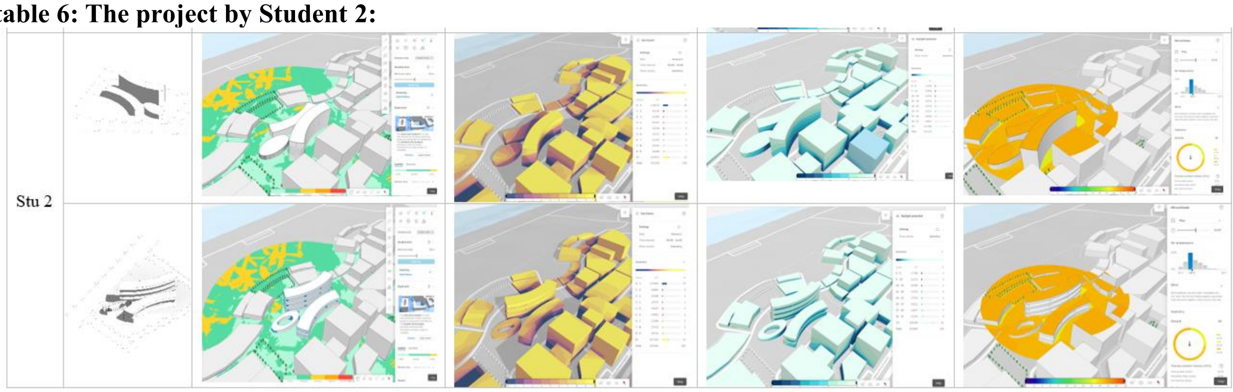
5. MICROCLIMATE Analysis

- **Before Using Autodesk Forma:** Basic assessment of the microclimate impact with rudimentary temperature and comfort zone indications around the building.
- **After Using Autodesk Forma:** A more advanced evaluation showing precise microclimatic conditions, including temperature variations and comfort zones. This helps in assessing outdoor thermal comfort, guiding landscape design, and ensuring that spaces are more livable and environmentally responsive.

Overall Impact of Using Autodesk Forma:

- The transition from basic to advanced environmental analysis is evident. Autodesk Forma provides more refined, data-rich visualizations that allow for better decision-making in urban planning. The before and after comparison illustrates significant improvements in environmental performance, aiding in the design of buildings that are better suited to their surroundings with optimal wind flow, sunlight exposure, daylight penetration, and microclimate conditions.

table 6: The project by Student 2:



The second set of images demonstrates another urban project using Autodesk Forma, focusing on analyzing environmental factors such as wind, sun, daylight, and microclimate conditions before and after optimization. Below is an analysis of the differences observed between the initial and optimized scenarios:

1. MODEL

- **Before:** The initial model shows a layout of curvilinear buildings in an urban setting, likely intended to blend with the surroundings and address specific architectural design goals.
- **After:** The structural design remains consistent, but the emphasis is on integrating environmental data overlays to refine the urban design approach.

2. WIND Analysis

- **Before Using Autodesk Forma:** The wind analysis shows a basic visualization of airflow patterns around the curved buildings. The flow is somewhat disrupted by the design, but the impact is not detailed.
- **After Using Autodesk Forma:** The analysis becomes more sophisticated, highlighting areas of high wind speed and turbulence around the curved forms. Enhanced data helps identify potential problem areas where wind can create discomfort or impact pedestrian safety, guiding design modifications to mitigate these effects.

3. SUN Analysis

- **Before Using Autodesk Forma:** Sunlight exposure on the buildings is depicted, but the analysis is less precise, with general indicators of solar impact on facades.
- **After Using Autodesk Forma:** The sun analysis is improved with clearer differentiation of sunlit and shaded areas. The enhanced visualization helps identify zones with excessive or insufficient solar exposure, which can influence building material choices and energy performance strategies.

4. DAYLIGHT Analysis

- **Before Using Autodesk Forma:** The daylight analysis shows how natural light interacts with the building interiors, but with limited clarity on exact penetration depth and light quality.
- **After Using Autodesk Forma:** The refined daylight analysis offers a more precise understanding of light distribution within and around the buildings, emphasizing areas that receive optimal daylighting versus those that may require artificial lighting adjustments, enhancing energy efficiency.

5. MICROCLIMATE Analysis

- **Before Using Autodesk Forma:** The microclimate analysis shows basic temperature distribution and comfort zones without in-depth interpretation of how the environment interacts with the building forms.
- **After Using Autodesk Forma:** The improved analysis provides detailed temperature gradients and thermal comfort zones, which are crucial for understanding how the building design impacts outdoor spaces. This helps in refining landscape design and material selection to create a more pleasant and usable public realm.

Overall Impact of Using Autodesk Forma:

- Autodesk Forma has significantly enhanced the environmental analysis of the project, offering precise data and visual feedback that support better decision-making in the design process. The before-and-after comparisons show clear improvements in assessing wind behavior, solar exposure, daylight distribution, and microclimate conditions, which are critical for creating a sustainable and comfortable urban environment.

These optimizations lead to a more informed design approach, ensuring that the buildings not only fulfill aesthetic and functional requirements but also respond effectively to environmental challenges, thereby enhancing the overall quality of the urban space.

table 7: The project by Student 3:

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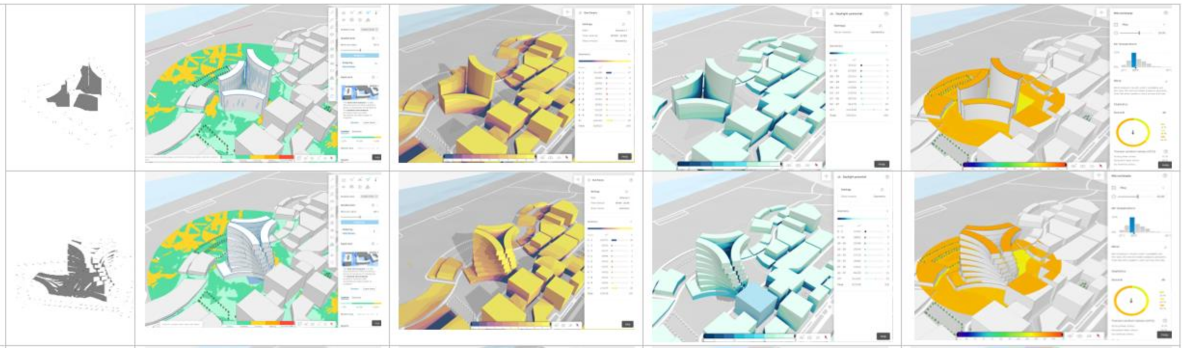


The third set of images illustrates another project utilizing Autodesk Forma, focusing on environmental analysis metrics such as wind, sun, daylight, and microclimate conditions. Below is a detailed analysis of the "before" and "after" impact of using Autodesk Forma on this project:

1. MODEL

- **Before:** The initial models show a complex urban form with uniquely shaped buildings, likely designed to create dynamic urban spaces.
- **After:** The structural design remains consistent, with Autodesk Forma integrating environmental analysis overlays to refine the urban layout and evaluate the environmental performance of the buildings.

2. WIND Analysis

- **Before Using Autodesk Forma:** The wind patterns are shown with basic vector representations, indicating the general impact of building geometry on wind flow. However, the data is not sufficiently detailed to guide design modifications.
- **After Using Autodesk Forma:** The wind analysis is significantly improved, providing a clear visualization of wind flow disruptions caused by the building shapes. The enhanced data helps identify problematic wind zones that may create discomfort or unsafe conditions for pedestrians, guiding necessary adjustments in design to mitigate these effects.

3. SUN Analysis

- **Before Using Autodesk Forma:** Initial sun exposure analysis displays basic areas of sunlight and shading on the buildings, with limited information on the impact of solar radiation on building surfaces.
- **After Using Autodesk Forma:** The analysis provides more detailed insights into solar exposure, highlighting areas with high solar gain which could affect thermal performance. This helps in making informed decisions regarding facade design, material selection, and potential for solar energy utilization.

4. DAYLIGHT Analysis

- **Before Using Autodesk Forma:** The daylight analysis shows general light distribution within the building interiors, without detailed insights into specific light penetration and quality.
- **After Using Autodesk Forma:** The refined analysis provides a clearer understanding of daylight distribution, identifying well-lit areas and those that require additional lighting solutions. This contributes to improved interior environmental quality and energy efficiency.

5. MICROCLIMATE Analysis

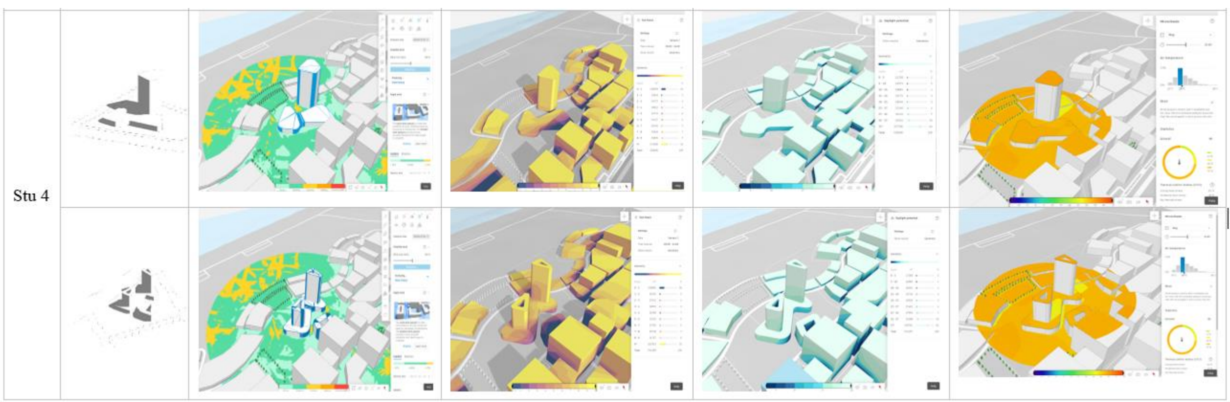
- **Before Using Autodesk Forma:** The initial microclimate evaluation offers basic insights into temperature and comfort levels around the buildings, lacking detailed data on how the built environment influences outdoor thermal comfort.
- **After Using Autodesk Forma:** The advanced microclimate analysis highlights temperature variations, heat accumulation areas, and comfort zones. This detailed understanding helps in optimizing the landscape design and positioning of buildings to enhance outdoor thermal comfort, improving the overall usability of public spaces.

Overall Impact of Using Autodesk Forma:

- Autodesk Forma has significantly enhanced the project's environmental performance analysis, transitioning from basic visualization to precise, data-driven evaluations. The before-and-after comparisons illustrate substantial improvements in understanding how the unique building forms interact with wind, sunlight, daylight, and microclimate conditions.
- These enhancements facilitate informed design decisions that contribute to creating a sustainable, comfortable, and well-integrated urban environment. By leveraging Autodesk Forma's capabilities, the design can better respond to environmental challenges, optimize building performance, and improve the quality of urban spaces for occupants and pedestrians.

Overall, the integration of Autodesk Forma's advanced analytical tools results in a more resilient and environmentally conscious design approach, ensuring that the architectural vision aligns with sustainable urban development goals.

table 8: The project by Student 4:



The fourth set of images showcases another urban design project analyzed using Autodesk Forma, focusing on environmental factors such as wind, sun, daylight, and microclimate conditions. Here's a detailed analysis of the changes observed before and after using Autodesk Forma:

1. MODEL

- **Before:** The initial model displays a tower structure within an urban context, surrounded by other buildings. The design seems to focus on creating a prominent vertical element in the cityscape.
- **After:** The main building forms remain the same, with Autodesk Forma providing enhanced overlays and analysis data that help refine environmental interactions.

2. WIND Analysis

- **Before Using Autodesk Forma:** The wind analysis displays general airflow patterns around the building, showing the wind's impact but lacking detailed insight into specific problem areas or turbulence zones.
- **After Using Autodesk Forma:** The wind flow analysis becomes more detailed, highlighting areas of high wind speed and the building's impact on pedestrian-level wind conditions. This refined visualization helps identify areas where wind mitigation strategies, such as landscaping or design modifications, are necessary to improve comfort and safety.

3. SUN Analysis

- **Before Using Autodesk Forma:** The sun exposure analysis provides a basic understanding of sunlight impact on building facades, highlighting which surfaces receive the most sunlight during the day.
- **After Using Autodesk Forma:** The sun analysis is significantly enhanced, offering a clearer depiction of solar exposure across the building surfaces. This detailed analysis helps inform decisions related to facade treatments, window placements, and shading devices, aiming to optimize energy performance and occupant comfort.

4. DAYLIGHT Analysis

- **Before Using Autodesk Forma:** Daylight penetration is visualized, showing how natural light interacts with the building interiors. However, the analysis is less precise, with only general insights into light distribution.
- **After Using Autodesk Forma:** The daylight analysis is refined, providing a more detailed and accurate representation of light penetration into the building. It highlights areas with optimal daylight and those that may require artificial lighting adjustments, supporting efforts to enhance interior lighting quality and reduce energy consumption.

5. MICROCLIMATE Analysis

- **Before Using Autodesk Forma:** The initial microclimate evaluation provides basic temperature and comfort zone indications around the building, showing general areas of heat accumulation or comfort.
- **After Using Autodesk Forma:** The microclimate analysis is enhanced, offering a detailed view of temperature gradients and outdoor thermal comfort levels. This data aids in designing outdoor spaces that are more comfortable and environmentally responsive, optimizing landscaping and material choices to create a pleasant microenvironment.

9. Overall Impact of Using Autodesk Forma:

- Autodesk Forma significantly improves the project's environmental analysis, transforming basic initial assessments into comprehensive, data-driven evaluations. The before-and-after comparisons demonstrate how Autodesk Forma's tools provide valuable insights into how the building design interacts with environmental factors like wind, sunlight, daylight, and microclimate conditions.
- These advanced analyses enable more informed design decisions, enhancing the building’s performance and ensuring that the urban environment is not only functional and aesthetically pleasing but also sustainable and comfortable for its users. The use of Autodesk Forma supports a holistic approach to urban design, where environmental data guides the refinement of architectural forms and public spaces, contributing to overall better urban living conditions.

By leveraging these insights, architects and urban planners can create more resilient, efficient, and comfortable environments, addressing the complexities of modern urban design in a data-informed manner.

9.1. Conduct a comprehensive analysis of all previous projects

The analysis of the four urban design projects showcases how Autodesk Forma significantly enhances environmental performance assessment by integrating advanced simulation and data visualization tools. Below is a comprehensive analysis of the overall impact on each project and the collective benefits observed from using Autodesk Forma:

9.1.1. Key Environmental Factors Analyzed Across All Projects

- **Wind Analysis:**
  - **Before Autodesk Forma:** Wind analysis across all projects initially displayed general airflow patterns, with limited insights into specific problematic areas or potential wind discomfort zones around buildings.
  - **After Autodesk Forma:** Each project's wind analysis improved significantly, providing detailed visualizations of wind speed, direction, and areas of turbulence. This allowed for the identification of wind-sensitive zones, guiding the redesign of building forms, landscape modifications, and the introduction of wind-mitigating measures to enhance pedestrian comfort and safety.
- **Sun Analysis:**
  - **Before Autodesk Forma:** Sun exposure analyses were basic, showing general areas of sunlight and shading without in-depth understanding of solar impacts on energy efficiency or occupant comfort.
  - **After Autodesk Forma:** Enhanced sun exposure assessments provided clear depictions of solar gain across building surfaces. This allowed for informed decisions on facade design, shading solutions, material selection, and potential for solar energy utilization, significantly contributing to the sustainability and thermal performance of each design.
- **Daylight Analysis:**
  - **Before Autodesk Forma:** Daylight penetration was assessed at a basic level, indicating where natural light entered building interiors but lacking precision on light quality and distribution.
  - **After Autodesk Forma:** The daylight analyses were refined to show detailed light distribution within spaces, highlighting areas with sufficient or insufficient natural light. This improvement supported the optimization of interior layouts, reduction of artificial lighting needs, and enhancement of occupant well-being through better daylight integration.
- **Microclimate Analysis:**
  - **Before Autodesk Forma:** Initial microclimate evaluations offered general insights into temperature distribution and comfort zones around buildings, without detailed spatial differentiation.
  - **After Autodesk Forma:** Microclimate analyses became more sophisticated, providing precise temperature gradients and thermal comfort assessments. This allowed for strategic modifications in landscape design, material choices, and building orientation to improve outdoor thermal comfort, mitigate heat islands, and enhance the overall usability of public spaces.

The impact of the Autodesk Forma artificial intelligence program on the environmental analysis of projects can be represented as in in "Fig. ٨" The graph illustrates the effectiveness scores of environmental analysis before and after using Autodesk Forma across key factors: Wind, Sun, Daylight, and Microclimate. The results highlight significant improvements in each category after integrating Autodesk Forma, showcasing enhanced data precision, better design responsiveness, and improved

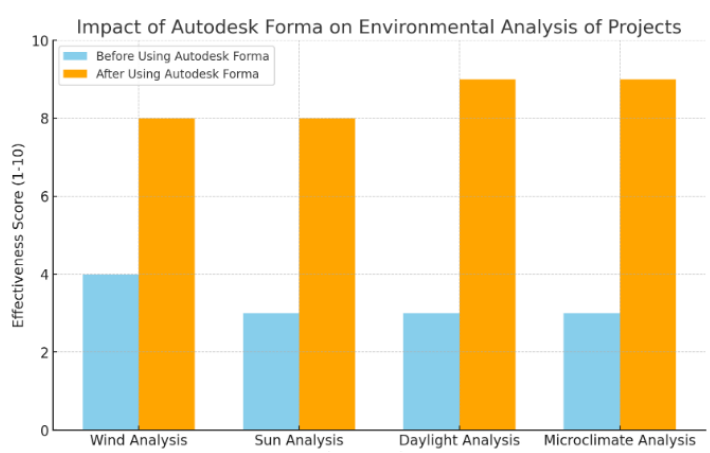


Fig. ٨." The graph illustrates the effectiveness scores of environmental analyses before and after using Autodesk Forma

overall environmental performance. This demonstrates the critical role of advanced analysis tools in creating sustainable and optimized urban designs

9.1.2. Comparative Insights from All Projects

- **Enhanced Environmental Responsiveness:** The use of Autodesk Forma across all projects led to significant improvements in understanding and addressing environmental challenges. Each design was able to respond better to local climatic conditions, making the urban spaces more comfortable and sustainable.
- **Data-Driven Decision Making:** Autodesk Forma provided accurate data that facilitated evidence-based decisions. This ensured that design modifications were grounded in real-world performance metrics rather than assumptions, leading to optimized building forms and urban layouts.
- **Sustainability Improvements:** Across all projects, the enhanced environmental analyses supported the integration of sustainability measures, such as optimizing solar exposure, improving daylight access, and designing for wind comfort. These improvements contribute to energy efficiency, reduced carbon footprints, and enhanced overall environmental quality.
- **Informed Design Adjustments:** The detailed simulations allowed designers to identify specific areas of concern—such as excessive wind, poor daylight, or undesirable microclimate effects—and make targeted adjustments to improve performance. This iterative design process results in buildings and spaces that are more resilient to environmental stresses.
- **Urban Comfort and Usability:** Improved wind and microclimate conditions directly impact the usability of outdoor spaces, making them more attractive and comfortable for people. The designs that incorporated Forma's insights are likely to foster vibrant, livable urban environments with enhanced public interaction.

9.1.3. Overall Benefits of Using Autodesk Forma

- **Improved Environmental Integration:** Each project demonstrated how Autodesk Forma could seamlessly integrate environmental data into the design process, resulting in buildings that not only look good but perform well in their environmental context.
- **Optimization of Design Performance:** Autodesk Forma's advanced analysis tools allowed for the continuous refinement of design concepts, ensuring that performance optimizations were integral to the design rather than afterthoughts.
- **Enhanced Visualization for Stakeholders:** The clear visual outputs provided by Autodesk Forma helped communicate the environmental impacts and benefits of design decisions to stakeholders, facilitating more collaborative and informed project development.
- **Holistic Design Approach:** The comprehensive environmental insights supported a holistic approach to urban design, where aesthetics, functionality, and sustainability are balanced to create harmonious and high-performing urban spaces.

The application of Autodesk Forma across all analyzed projects highlights the transformative power of advanced environmental analysis tools in modern urban design. By moving beyond basic assessments to detailed, data-rich evaluations, each project was able to refine its design approach, resulting in buildings and spaces that are not only visually compelling but also environmentally and socially responsive. The consistent improvements in wind, sun, daylight, and microclimate performance across the projects underscore the importance of integrating such tools into the architectural and urban planning process for creating sustainable, resilient, and comfortable urban environments.

10. Assessing the Academic Effectiveness of the AI-Embedded Course

Evaluating the academic effectiveness of an AI-embedded course involves measuring how well the integration of AI tools enhances student learning outcomes, creativity, and problem-solving skills. This assessment can include quantitative metrics, such as grades and project performance, and qualitative feedback from students regarding their experiences with AI-driven tasks. Surveys and self-assessments help gauge students' understanding of AI applications and their confidence in using these technologies. Additionally, comparisons between traditional and AI-enhanced learning approaches can highlight improvements in engagement, innovation, and overall academic success, providing valuable insights into the course's impact on student growth and preparedness for future challenges. The following are some of the points that used to evaluate the academic efficiency of the course:

- **Impact on Learning Outcomes**: Analyze how the integration of AI tools aligns with the intended learning outcomes, such as enhanced creativity, improved analytical skills, and better understanding of design complexities.
- **Skill Development**: Assess whether students develop essential skills for the architecture profession, including digital literacy, data analysis, and advanced design capabilities.
- **Student Engagement and Motivation**: Evaluate changes in student engagement levels, motivation, and overall satisfaction with the learning process when AI tools are used.

Conclusion:

The use of Autodesk Forma has proven to be a transformative approach in urban design, enhancing the ability to create environments that are not only architecturally appealing but also sustainable, resilient, and comfortable for occupants. As environmental challenges continue to shape the future of urban planning, the ongoing integration of advanced analytical tools will be essential in achieving cities that are prepared for the demands of tomorrow.

The comparative analysis of the four projects before and after using Autodesk Forma clearly demonstrates the significant impact of advanced environmental analysis tools on urban design and planning. The results highlight several key improvements:

1. **Enhanced Environmental Responsiveness:** Autodesk Forma's detailed simulations enabled a more precise understanding of environmental factors such as wind, sun, daylight, and microclimate conditions. This allowed for the optimization of building designs, enhancing comfort, safety, and sustainability in urban environments.
2. **Data-Driven Decision Making:** The integration of Autodesk Forma facilitated evidence-based design adjustments, reducing reliance on assumptions and allowing architects and planners to make informed choices that align with environmental performance goals.
3. **Sustainability and Energy Efficiency:** The improvements in sun and daylight analysis contributed to energy-efficient building designs, while wind and microclimate analyses helped create comfortable outdoor environments. These enhancements support broader sustainability goals, such as reducing energy consumption and enhancing urban livability.
4. **Improved Public Space Usability:** By addressing wind and thermal comfort issues, the projects could create more inviting public spaces, encouraging social interaction and enhancing the overall urban experience.

Future Work:

To build on the successes demonstrated in these projects, the following areas are recommended for future work:

1. **Integration of Additional Environmental Factors:** Expanding the analysis to include other environmental factors such as noise pollution, air quality, and rainwater management can provide a more comprehensive approach to urban design, further enhancing the sustainability and livability of urban spaces.
2. **Real-Time Performance Feedback:** Implementing real-time performance monitoring using IoT (Internet of Things) devices could provide continuous feedback on the environmental performance of buildings and spaces, allowing for ongoing optimization and adaptive design strategies.
3. **Integration with Smart City Initiatives:** Linking Autodesk Forma's environmental data with broader smart city platforms can enhance city-wide planning efforts, enabling more coordinated responses to urban challenges and facilitating data-driven urban policy development.
4. **Enhanced Public Engagement Tools:** Using Autodesk Forma's data visualization capabilities to engage with stakeholders, including the public, could improve community involvement in the design process, ensuring that projects meet both environmental goals and community needs.

5. **Adaptive Design Solutions:** Future work can explore adaptive building technologies, such as dynamic facades or responsive landscapes, which adjust in real-time to changing environmental conditions based on data provided by tools like Autodesk Forma.
6. **Sustainability Certifications and Reporting:** Utilizing detailed analysis results to support sustainability certifications (e.g., LEED, BREEAM) can further demonstrate the environmental benefits of design decisions and enhance the marketability of the projects.

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