# Artificial intelligence in architectural education - green campus development research

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ABSTRACT: The rapid advancement of artificial intelligence (AI) technologies has introduced new possibilities and challenges in design education. This article explores the need for changes and adaptations in the teaching process of design as AI-related technologies, based on image generation, transform the creative process and offer novel opportunities. In a research-by-design studio in an architectural faculty in Poland, students who utilised AI tools achieved more innovative and pioneering results than those designed with traditional tools. Based on these results, three alternative methods of working with AI tools were identified. In the semi-traditional approach, AI-generated images served for inspirational purposes solely. In the hybrid system, students integrated fragments of these images into their own urban decisions. Finally, in the hybrid-interactive approach, students used the higher-order loops in computer-human interaction to achieve more site-specific results. The research underscores the vast potential of AI integration, using image generation models in reshaping architectural design methodologies based on best practice.

Keywords: Artificial intelligence, architectural education, new technologies, new educational needs, professional training, technological change, university campus

## INTRODUCTION

Technological advancements influence the landscape of education research [1-3]. The dynamic synergy between artificial intelligence (AI) and the realm of architectural design is precipitating a transformative revolution in the field. AI's revolutionary influence on architectural design becomes strikingly evident when cutting-edge AI models, such as DALL-E, Stable Diffusion and Midjourney are integrated. These models serve as catalysts for pushing the boundaries of conventional design, emancipating architects from traditional constraints. They increasingly often lead to unconventional architectural solutions that redefine the essence of architectural design practice [4]. The influence of AI extends well beyond the traditional architectural design boundaries, infiltrating various domains, such as greenery design, heritage management and cultural heritage preservation [5-7].

The growing accessibility of these models poses new challenges to architectural education [8-10]. The research-by-design studio in the Faculty of Architecture at Gdańsk University of Technology (FA-GUT), Gdańsk, Poland, became an opportunity to delve into these challenges. The aim was to perform an educational experiment focused on developing hybrid pedagogical methodologies, seamlessly blending conventional teaching practices with cutting-edge AI technology.

In parallel with integrating AI into architectural education, a thought-provoking dialogue has emerged, focusing on the intricate interplay between human creativity and AI-driven solutions. The expected outcome was to introduce the first steps towards building a holistic educational ecosystem and to equip students with the tools they need to harness AI's potential without compromising their professional skills [11][12].

The integration of AI into the architectural and engineering workforce becomes visible in the evolving landscape of architectural pedagogy. This newly introduced path in the architectural education system catalyses proficiency, adaptability and career development in an era of rapid change. Nowadays, AI takes the central role in upskilling and reskilling, effectively preparing the next generation for the dynamic and ever-evolving architectural world [13][14].

This article intends to explore AI's dynamic and evolving role within architectural design education. It seeks to shed light on the transformative potential of AI while simultaneously addressing ethical considerations. The aim is to enrich the ongoing discourse on AI's role in architecture, providing a forward-looking perspective on its profound implications and the future directions it will likely take.

METHOD

To examine the effects of introducing AI into the architectural design course, the research design employed a distinct two-year experimental framework. The process involved Master students who declared their willingness to participate in the research-oriented architectural and urban design studio. Working on the same design topic, in the academic year 2021/2022, the first group of students worked in a traditional way, that is, without the support of AI tools, while in the academic year 2022/2023, another group of students were encouraged to use selected AI tools. In both groups of students, the educational experiment began with developing the brief for a design project. This initial phase involved presentations, discussions and literature studies. During this phase, it became evident that both groups of students had an equal level of preparedness to tackle the design topic and possessed similar technical skills. This first phase revealed that the level of students' preparedness to undertake the design topic and their technical skills were the same. In the inaugural year, they served as a critical baseline devoid of AI tools, which formed the benchmark against which the subsequent year was infused with AI integration. This methodological design permitted an evaluation of AI's impact (Figure 1).

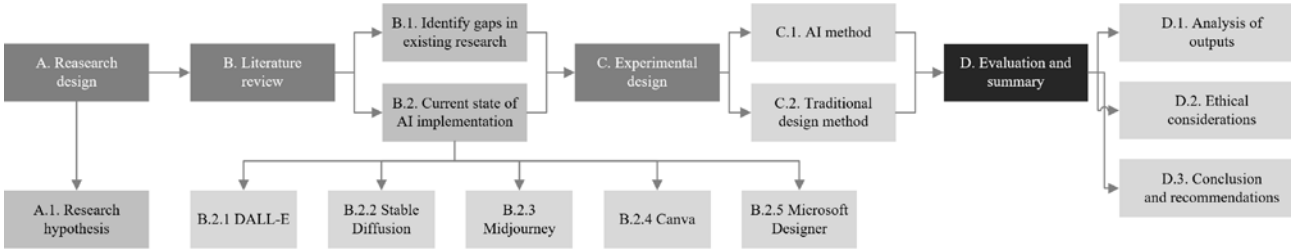


Figure 1: Research method.

Data gathering involved multiple aspects, such as evaluating design results, measuring creativity and assessing productivity. Clear criteria and methods for evaluating design outcomes were defined to ensure objectivity [15]. Ethical concerns were at the core of the research design. Beyond technical matters, this aspect involved addressing possible biases in AI algorithms and considering the broader societal impacts of AI integration in architectural design practices. Conclusions and recommendations summarised the process for best practices in involving AI tools in the design process.

RESULTS

Implementing the designed research methodology has generated comprehensive insights into the process of integration of AI tools within architectural design. In the first stage of the educational experiment, students developed concepts according to the traditional approach method (Figure 2). The process from the initial concept to the final design project included many iterative loops, which spanned the results obtained at the given concept development phase, with the retrospective return to sketching and working on models. Finally, the design concepts were translated into integrated projects and presented as plans, sections and visualisations. This method, based on the constant iterative procedure of discovery and re-interpretations, is well established in the architectural education environment and often referred to as research by design [16].

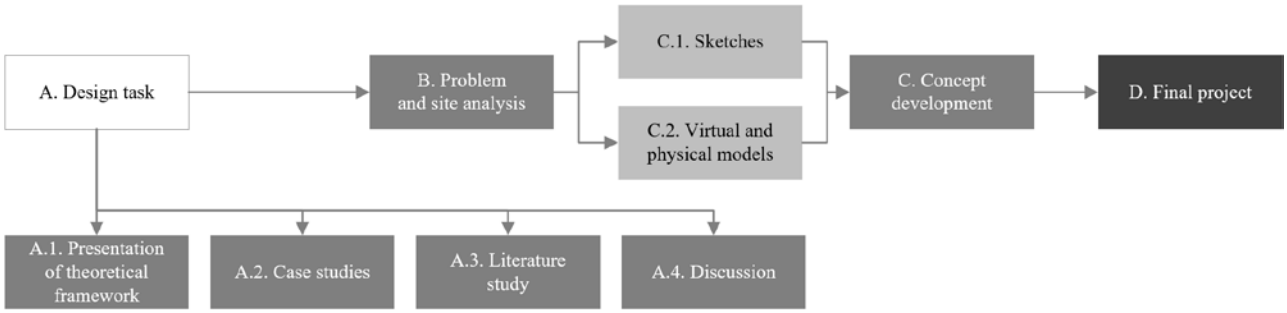


Figure 2: Traditional approach to the design process.

The whole process, along with the final results, was evaluated. Observations from the process of concept development and achieved results were taken as a reference for the second stage of the experiment that took place in the subsequent academic year 2022/2023. In the second year of the experiment, the first phase was the same - literature studies and presentations led to the formation of a project brief. As the second step, however, instead of working with sketches, students initiated the image generation procedure by using prompts engaging with the chosen AI-powered design tools, such as Canva AI, Microsoft Designer, Midjourney by Discord, DALL-E and Stable Diffusion (Figure 3 below).

All these tools use artificial intelligence to create graphic designs and images. To generate images that satisfied expectations and preconceived assumptions, students had to learn how to communicate with an AI bot using prompts. Prompts used as natural language commands were associated with the general concepts of the GUT campus transformation: green campus,

green campus on a hill, terrace green buildings, biophilic-design, topographic architecture, green public spaces, university spaces, spaces for education, climate neutral campus, but also included more detailed communicates, such as axial stairs with public spaces leading to the building on a hill, brick architecture, climate neutral university building, digital laboratory or doctoral school.

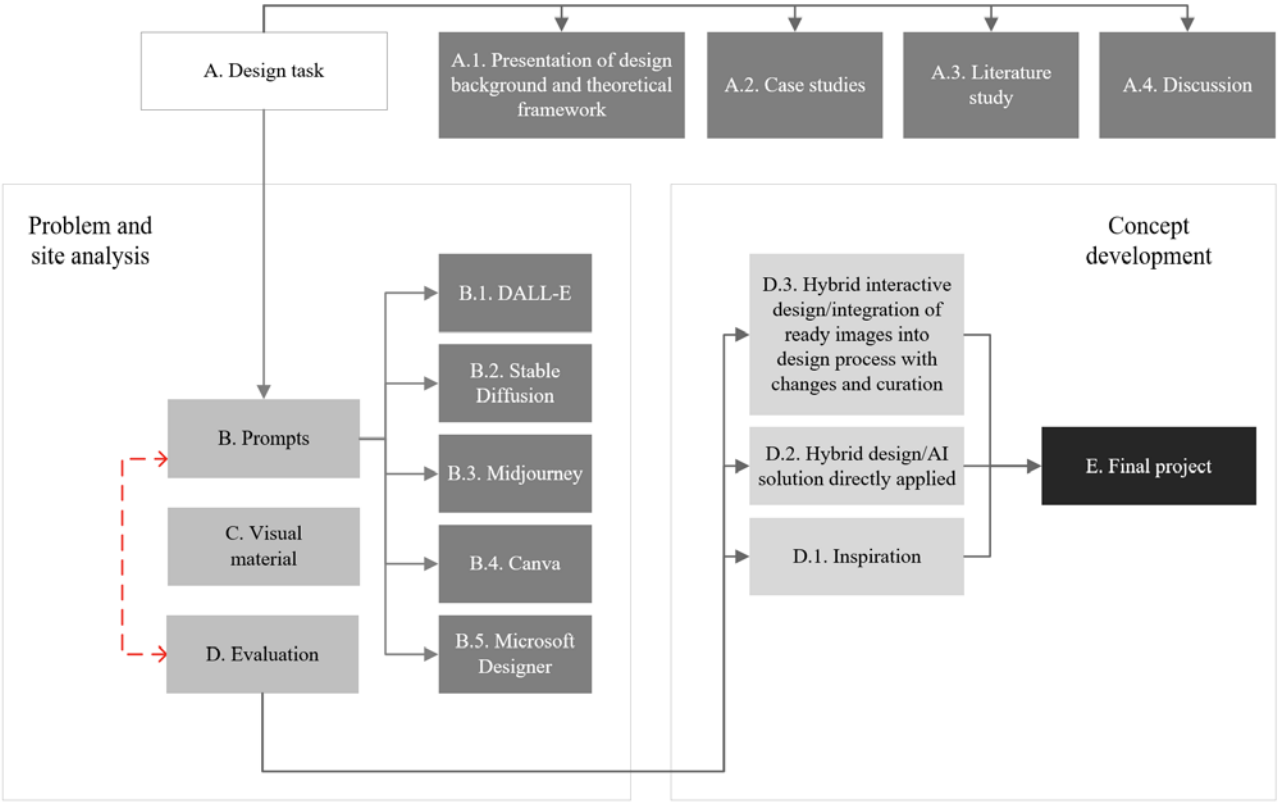


Figure 3: Approach to the design process supported by AI tools.

After obtaining the desired level of images, students undertook the second stage of the design process, in which they experimented with how to use the acquired visual material. In general, three alternative operating methods with the visual data were observed. In the first group, AI images were solely used as inspiration. In this group, which consisted of two students out of 16 taking part in this educational experiment, the students used images for inspiration purposes, in addition to the comparative studies of campus transformation processes worldwide. The new AI-generated images enriched the students' understanding and imagination of campus transformation directions and practices in the same way as other visual material obtained from the architectural offices' Web sites or Internet platforms. After studying the visual material, students made their own decisions and worked on their projects without further references to AI images. Despite using AI tools in the first phase, this process resembled the traditional approach.

In the second group, which consisted of the majority of students (14 out of 16), the architectural and urban proposals were developed as a process of smooth integration of concepts developed by the students with images generated by AI applications. However, in this group, two alternative and distinctive methods of operating with the visual data were observed. The first approach, which could be depicted as a hybrid, was based on halting the process of AI image generation (prompt-image-evaluation loops) at a point where images were evaluated as suitable for a given urban and topographical scenario. Following this path, students integrated fragments of these images into their own urban decisions or built their architectural and urban concepts by adjusting fragments of the site-plan layout to the AI images. However, some students undertook another method based on a closer human-computer interaction and continued experimentations with AI bots at the whole stage of concept development. In this approach, the higher-order loops were identified. Students returned to the graphics generation phase, providing bots with new, more specific commands or, in some cases, 3D mass models of the terrain with the proposed urban layout. This method of designing based on the constant interaction process with the AI bots can be depicted as a hybrid interactive design.

According to the internal Faculty regulations the evaluation of the results comprised the examination of the different stages of the design process and a final project. The final projects were evaluated according to: conceptual clarity and creativity; functionality and space planning; site integration; aesthetics and architectural expression; implementation of sustainable design strategies; cultural and contextual relevance. Central to the findings is a comparative evaluation of diverse design outcomes in reference to the methodology adopted by students. The traditional design method, that is, the one not supported by the AI tools, served as a reference. A cornerstone of the educational experiment's efficacy is the possibility of delineating three distinct approaches of AI integration to the design task - pure transcription of AI-generated images into a design project (hybrid method), higher-order loops focused on achieving more specific AI-generated results (hybrid interactive method) and the semi-traditional design approach where AI images serve as

an additional source of inspiration. These pathways were cardinal compass points for rigorous comparative analysis of each approach on design quality, creativity and efficiency.

The study revealed that working with AI tools was more effective in terms of the fast generation of visual materials that supported the narrative about the characteristics of space students intended to achieve. Even at the first stages of the design experiment, students could explain the leading motivations and the effects they aimed to achieve, supporting their narratives with AI-generated images (Figure 4).

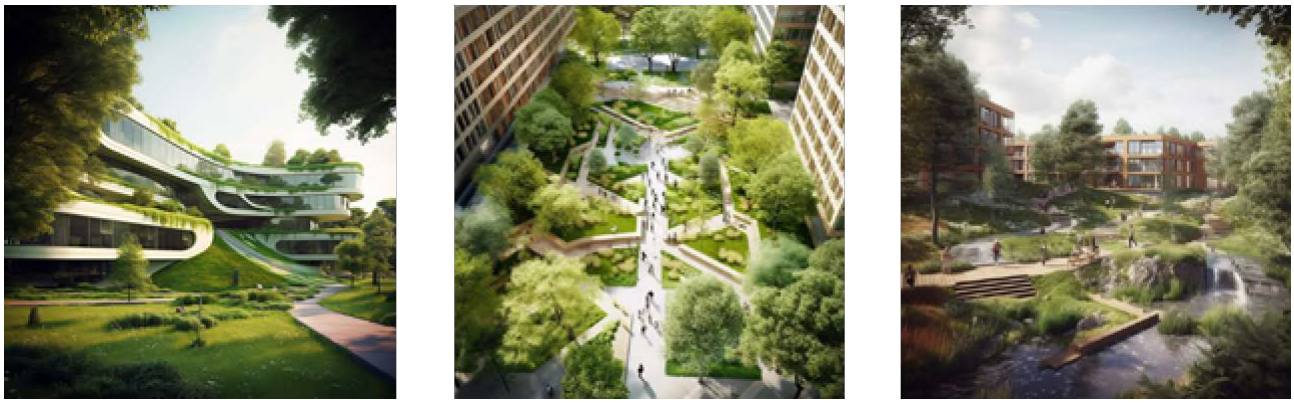

Figure 4: Generative AI images created during classes.

AI tools allowed for the fast production of mood boards and the development of many variant solutions, which was particularly important in the initial design phases. Generated images, in many cases, opened new paths of thinking on possible solutions, stimulated students' imagination and fostered creativity. In comparison, students who worked without AI tools could share the visual material only in the second half of the design process. Since the conceptual development of the design was time consuming, the students who took the traditional path needed more time to develop visual material that could effectively support their concept ideas. Moreover, working with AI tools at the subsequent design stages by using verification loops, notably by introducing 3D models into AI-powered software, brought about high-quality site-specific results. It was observed, however, that few students had considerable problems with the *stabilisation* of their concepts being led by still new, easy-to-generate images. Interestingly, working with AI-powered tools opened a discussion, supported by bot-generated images, on the possible directions of campus transformation. The new images inspired students to transcend conventional notions of university buildings, encouraging them to explore regenerative architecture inspired by nature, which integrates into and sustains local ecosystems. Comparing the results from the first and the second year of the experiment when students applied AI-tools, the second year brought more out-of-the-box results that have already been taken as a reference for further campus transformations.

Generally, the experiment revealed AI-powered new paths toward more efficient architectural and urban design, posing at the same time a question of how to adapt architectural education to the emerging AI tools. Observations of the process allow for the identification of challenges to the long-lasting architectural paradigms. For instance, Le Corbusier's *plan as a generator for architecture* became challenged by the process of conceptualisation that could be depicted as an *image as a generator for architecture*, where images become the starting point for concept development [17]. Additionally, the process of AI-supported design includes an important phase, which could be identified as *design by prompting*. Similarly, the research-by-prompting paradigm emerges as a compelling theme, reshaping the traditional research-by-design approach. All these observations pose new questions to the content of architectural curricula, particularly, in the context of students' ability to adapt easily to AI tools that in many aspects facilitate the design process.

## DISCUSSION

Implementing the research approach presented in this article provides a structured framework for examining the effectiveness of AI tools in architectural design. The findings and observations derived from the research process stimulate pertinent discussions that shed light on various aspects of AI integration within the architectural realm. One fundamental facet of the debate revolves around evaluating the diverse impacts of AI adoption. Assessing its influence on the design process requires a nuanced approach. A key consideration is how AI influences project workflows and design methodologies. Ethical considerations emerge as a pivotal dimension of further studies. It contemplates the ethical implications of AI integration, emphasising responsible AI usage, mitigating potential biases and the imperative of transparency. Moreover, in the context of junior architects, integrating AI tools necessitates a balance between facilitating their inclusion in design work and ensuring a comprehensive learning experience. Directly injecting AI into the design process may risk a gradual erosion of fundamental skills previously, traditionally considered essential in shaping an architect, i.e. the ability to draw, sketch and create physical models. Striking the proper equilibrium demands thoughtful navigation between technology and foundational skills.

Another noteworthy discourse is AI's potential to engender a shift towards a more humanistic approach in the design process. The time saved by AI's handling routine tasks offers architects an opportunity for deeper contemplation and

creativity. However, the discussion must also encompass introducing new tools that reshape the design process, redistributing the weight of various tasks and introducing new dynamics that warrant adaptation. One challenging area is the evaluation of AI-generated solutions. Determining their alignment with project goals, technical feasibility, and compliance with design plans requires new methodologies. This raises the question of how deeply architects should be involved in AI-driven processes. Striking a balance between human ingenuity and AI's capabilities becomes crucial.

Furthermore, the discussion delves into process loops and altering design methodologies. It explores whether AI serves as a source of inspiration or a mechanism for direct integration, raising questions about the viability of hybrid approaches. The discussion on AI's role also includes considering copyright and intellectual property concerns, as AI-generated content blurs traditional authorship lines. In light of the research findings, a suggested approach is to strike a harmonious balance between AI and subsequent human intervention. This balance allows for the maximisation of AI's capabilities while preserving essential architectural skills. To harness the efficiency AI offers, it is pivotal to meticulously adapt AI tools to align with the architect's workflow. However, this adaptation must uphold the importance of nurturing creative thinking and critical design skills.

The research design outlined in this article sets the stage for robust discussions concerning the integration of AI in architectural design. The findings underscore the transformative potential of AI tools while emphasising the need for careful consideration in their implementation. Balancing the advantages of AI with the preservation of core architectural skills emerges as a critical focal point for fostering innovation within the architectural practice. The locus of assessment has moved towards the student's procedural efforts. Historically, the procedural trajectory of design endeavours has been assessed through the prism of sketches and physical prototypes, meticulously catalogued at sequential intervals. In this procedural continuum, the main channel of communication was the semiotics of visual messages. The emergence of innovative artificial intelligence tools has changed the way conceptual work works. In this case, the verb occupies an important place in the pantheon of the design process. Innovative assessment methods require formulation that depends on a conscious understanding of the operational mechanics that characterise iterative loops.

## CONCLUSIONS

In summary, this research unveiled AI tools' impact on architectural design. As AI's transformative role was explored, it became increasingly clear that integrating AI in architecture is not just a technological leap but a profound shift in how architects approach design. The study heralds AI-generated images as novel catalysts for creative imagination, fundamentally altering the trajectory of architectural creativity and redefining the early phases of design. The comprehensive evaluation of design outcomes achieved by integrating AI tools within the design process illuminates the potential and multifaceted considerations associated with AI in architecture. These insights may contribute to steering architectural practice and education that will likely very soon include the effective merging of human ingenuity and AI-driven senses within architectural discourse.

By pushing the boundaries of creativity, sustainability and efficiency, AI tools offer architects a powerful tool to reimagine architectural design possibilities. It showed a dualistic perspective - a realm where AI enhanced efficiency while introducing considerations tied to creativity and evaluation. As the architectural horizon evolved, architects had to harness AI's capabilities judiciously, adapt methodologies, and navigate the changing interplay between human ingenuity and technological innovation. However, the path forward presented its challenges, and among them is an evaluation of AI's impact on the work. Complex considerations encompassing authorship, ethics and intellectual property complicated the evaluation landscape.

A recommendation emerged: a recalibration of the evaluation model. By pivoting from a result-centric appraisal to a competency-based evaluation, architects could foster a comprehensive assessment of skills and capabilities beyond the narrow lens of outcomes. The evolving landscape diminished the longstanding significance of traditional modelling and craftsmanship. As AI-modelled design processes, other modalities took precedence. The imperative emerged for architects to adapt skill sets, ushering in an era of harmonious AI collaboration.

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