Design Education Forum of Southern Africa

Vulindlela – making new pathways

17th DEFSA conference – 21|22 September 2023

AI, Alexander, and architecture

Hermie Delport, University of Cape Town

Abstract

This research reflects on the future of artificial intelligence (AI) technologies and Pattern Theory in architectural and design education and how it may inform the design process, projects, assessments, and research in this space. We are increasingly bombarded by new technologies and an abundance of information. The rapid evolvement of AI has created many uncertainties. Might AI take away our jobs? Will AI kill creativity? How will we know who has produced the work? How do we as educators and students make sense of these technologies and use it (or not) in our education and practice? Can we possibly discover through AI new tools and possibilities and ways of working that contribute positively to what we do?

This paper explores student experience, reflections, and perceptions on the use of AI in a third-year history-and-theory of architecture course. Students were required to use AI word and image generators as part of an assignment that focused on the book *A pattern language* by Christopher Alexander. The students unpacked the 253 patterns in *A pattern language* through AI word and image generators and critiqued the results in comparison to their own hands-on analysis developed through physical models and hand-drawings.

Alexander's book *A pattern language* is a seminal architectural text and has, since its publication in 1977, not only influenced architectural education, but also inspired the use of pattern methodologies in computer programming. When invited to speak at a computer software conference, Alexander (1996, para. 74) envisioned a world where "computers (could) play a fundamental role in making the world – and above all the built structure of the world – alive, humane, ecologically profound, and with a deep living structure". Alexander's idea and methodology of patterns and pattern languages have also been applied in many other disciplines.

This paper also introduces Pattern Theory (Leitner 2015) as an extension of Alexander's work and comments on its potential for developing new ways of working in architectural education, practice, and research that could balance human and machine intelligence and that might result in more humane, ecologically profound, and living structures, as envisioned by Alexander.

Keywords: Architectural education, artificial intelligence, Christopher Alexander, Pattern Theory.

A is for…

Alpha. We are at the alpha-phase of artificial intelligence (AI). And we are at the beginning of a rapidly changing, sometimes highly confusing, and simultaneously very exciting time in the world.

© Copyright 2023 Design Education Forum of Southern Africa (www.defsa.org.za)

As if the recent and rapid pivot online in response to the COVID-19 pandemic was not enough, we now have generative AI tools that update and exponentially multiply on a minute-by-minute basis. How do we stay abreast, never mind ahead? The result of this research is probably already outdated when seen as part of an AI-timeline, but I will amble forward.

AI is criticised for not understanding the human condition (Gillani et al. 2023), for not displaying emotional awareness, intelligence, or subjectivity, and for having a limited perception of context with no ethical or moral considerations (Ray 2023). In response, this paper aims to be human. Lest we get perturbed by the assertions made by people like Dickinson that:

> Artificial intelligence (AI) might just eliminate architecture as a career for those who are not versed in the things that only humans can do: synthesise, channel, invent, craft. Beyond imitation. By its new nature, architecture could be becoming inhuman (2020, para. 1).

There has already been much debate about the use of AI in education. Whether we should allow it, even encourage it, or outright ban and police it. As Gillani et al. (2023, p. 99) puts it, the "political, pedagogic, and practical implications" of AI still requires a lot of discussion. I support the position that AI should be viewed as a tool, that it is with us to stay, and that we need to find ways to ethically introduce AI into our own and our students' practice, ways that "could actually help prepare students for the real world" (Abrahams 2023, para. 13).

This research reflects on the future of AI technologies and Pattern Theory in architectural and design education and how it may inform the design process, projects, assessments, and research in this space. The link between Christopher Alexander and computer technology is also foregrounded. The paper is structured through a series of A-sections. The section, Approach, gives an overview of the research process and methodology. The next section provides context on AI, technology, and architecture. Three sections follow with background on Christopher Alexander. These are Alexander and *A pattern language*, Alexander and the language of computers, and Alexander, Leitner and Pattern Theory. The following section, Assignment 1, outlines the student assignment on which this paper is based. The section Analysis and appraisal discusses the student reflections, and the section Ahead we go beta is waiting, concludes the paper.

Approach

In the beginning of 2023, I had to develop a history-and-theory semester course for third-year architectural students in a Bachelor of Architecture degree. The broad aim of the course curriculum is to "foster knowledge and a critical perspective of current practice and theory in architecture and urbanism" (Delport 2023). At the time, the world was abuzz about AI, specifically fuelled by the release of ChatGPT in November 2022, and the world is still abuzz. I wanted to include AI in the history-and-theory course, taking the approach of exposing students to AI tools and having them reflect on the responsible use thereof to encourage critical engagement. I had been following the development of AI and the possible applications in architectural (and other) education and was cognisant of Ceylan's (2021, p. 101) sentiment that we need "a fundamental understanding [...] that considers AI as a basic and natural element of architectural education".

The aim of this paper is to explore students' experiences, reflections, and perceptions on the use of AI generative tools in a third-year history-and-theory course in a Bachelor of Architecture degree. Students were required to use AI word and image generators as part of an assignment that focused on the patterns in *A pattern language* (Alexander 1977). The goal is to initiate discussion and further

research about the role of AI in design education with Pattern Theory (Leitner 2015) as a developmental and interpretive lens, with a reminder of role and relevance of Christopher Alexander.

Design-based research and Pattern Theory were considered for the development of the history-and-theory course and for this research. Design-based research is fundamental to the architectural design process (and those of other design disciplines). Design-based research resonates with an explorative approach to educational practices and innovations in real contexts, emphasising iterative refinement and the potential for theory development (Anderson & Shattuck 2012). Pattern Theory was adopted as an underpinning lens. Pattern Theory builds on the seminal work, *A pattern language* (Alexander 1977) a seminal architectural text has, since its publication, not only influenced architectural education, but also inspired the use of pattern methodologies in many other disciplines, including computer programming.

AI, technology, and architecture

Architects explain their thoughts, process, and designs through representation. Representation usually takes the form of drawings or models. Architecture students are encouraged to learn representation by using hands-on methods, with pen or pencil on paper and models made of cardboard. Educators have serious debates about where in the design process the appropriate or beneficial time is to introduce 'the computer'. Pallasmaa (2017) argues that the hand is not merely a tool but a source of embodied knowledge. Most educators support this view and believe that hands-on exploration through sketches and drawings is an essential as part of the conceptual stage of the design process.

Technology for representation has mostly benefitted the production or documentation stage of the design process; this is after the conceptual stage. Draughting technologies enabled more precise documentation, starting with the drawing board and the invention of blueprints and photostat machines. Towards the end of the last century computer technologies revolutionised production speed through 2D CAD, which started basically as an online drawing board.

Since then, computer technology has evolved rapidly, and AI technologies have been with us for a while. AI already assists the research process by working through huge amounts of data, AI tests form development through software that produces variables, including parametric architecture, Grashopper, etc., AI is inherent in building information modelling (BIM) that assists in collaboration, application, and analysis of energy, systems, services, and the construction of these, and in the presentation of ideas, through software such as Lumion, etc. (Ceylan 2021).

The use of AI technologies to design and develop a building from start to finish with full documentation is still somewhere in the future. The complexity of architectural design is not yet grasped by AI, specifically at the conceptual and design development stages of the process. There have been attempts to codify the design process, amongst these through "deep neural network(s) [...] that extracts design into essential building blocks" (As, Pal & Basu 2018, p 1), but we are not there yet.

Generative AI images developed from text prompts may provide provocative visuals, but developing well-informed conceptual ideas has up to now not been the strength of 'the computer'. AI building images consciously and unconsciously plagiarise, for example, buildings that all look like Zaha Hadid designs, and reflect inherent bias or stereotyping prompted with words such as 'African' or 'European' (Maganga 2023) and typically does not consider physics, structure (Kudless 2022) or spatial realities. These images are not directly translatable into buildings but may provide inspiration.

© Copyright 2023 Design Education Forum of Southern Africa (www.defsa.org.za)

Alexander and *A pattern language*

A pattern language was developed and written by Christopher Alexander and several colleagues. It was first published in 1977 and proposed a fundamentally new approach to architectural design, based on the concept of patterns. The patterns in *A pattern language* were based on observations of (perceived) successful architectural and urban spaces, as well as on more abstract concepts from disciplines such as psychology and sociology. The patterns represent an attempt to capture the essence of what makes places feel alive. The authors argued that by understanding and implementing these patterns, anyone would be able to identify and solve design problems in their own contexts. Alexander's intent was to democratise design, making the process accessible to all, not just professionals in the field.

The book set out 253 distinct patterns, each representing a common solution to a repeating design problem. The patterns include a description of a particular problem, the context in which it arises, and a solution, illustrated with diagrams and photographs. For example, Pattern #159, LIGHT ON TWO SIDES OF EVERY ROOM, identifies the problem that rooms with light on only one side create a harsh and unwelcoming environment (Alexander 1977, p. 746). The solution, therefore, is to design rooms where there is light coming from at least two sides. One of the key ideas of the book is that the 253 patterns are all interconnected and that together it forms a 'pattern language'. This 'pattern language' can be used to generate designs that respond to contexts.

Of course, *A pattern language* is not without its share of critique. Many architects view *A pattern language* as too prescriptive, including "deterministic and authoritarian" (Bhatt 2019) or as naïve and romantically irrelevant (Mehaffy 2022). Alexander's own work, including the four-volume *Nature of order*, has however developed the pattern methodology further and others have also taken the work forward, such as Salingaros with his book *A theory of architecture* (n.d.).

Alexander and the language of computers

The pattern structure set out in *A pattern language* was instrumental in the development of computer program languages, and Alexander was a revered and respected figure in computer circles (Coplien 1996). The evolution of object-oriented programming (ibid), which shares conceptual similarity with Alexander's idea of patterns, aligned with the application of the pattern language concept to software design. Alexander already wrote a computer program as early as the early 1960s (Matt 2021, par 3) and is directly credited with having influenced technology for the development of Wikipedia and games such as Sim City (Mehaffy 2022). Alexander criticised the separation of math and computers from human creativity and believed that "a designer could only successfully solve [...] problem(s) by combining his creativity with the analytic and computational power of machines" (Matt 2021, par 3).

When invited to speak at a computer software conference, Alexander shared his vision of a world where "computers (could) play a fundamental role in making the world – and above all the built structure of the world – alive, humane, ecologically profound, and with a deep living structure" (Alexander 1996). Alexander, at this stage, was somewhat despondent since *A pattern language* had not had the impact on the built environment, he had hoped it would. He saw in the software engineers' potential allies that would be able to translate spatial knowledge patterns into programming that could enable the design buildings.

As pointed out earlier, we are not at a point yet where AI has the capacity to design buildings (it can produce images of buildings, and test and develop some formal resolutions) because of the complexity of the informants on design in the built environment, but I suspect that we will soon be there. And we

can only hope that this capacity will answer Alexander's vision of the creation of buildings and spaces that support human "well-being, our health, and even our capacity to survive" (Mehaffy 2022).

Alexander, Leitner and Pattern Theory

Pattern Theory, proposed by Helmut Leitner in 2015, takes the pattern concept beyond architecture. Leitner expanded this framework into a generalised theory that could be applied across various domains. Within Pattern Theory, the concepts of 'centre' and 'wholeness' are significant to understand. Both concepts originate with Alexander and do take books to unpack, starting with *A timeless way of building* that preceded *A pattern language*. Leitner explains Pattern Theory as the examination of the intrinsic relationships between elements within a living system (defined through 15 fundamental properties as developed by Alexander in *Nature of order).*

Here, the concept of centre is something that "has a meaning and a reason to exist" and "activities and exchange" (Leitner 2015, p. 29) both in the concrete and the abstract. Centres cannot exist without the whole and exist also because of the whole. Wholeness emphasises the idea of coherence in systems that transcend the sum of individual parts (centres) (Leitner 2015, p. 30).

Through wholeness, patterns emerge "by describing recurring solutions to problems" (Leitner 2015, p. 141). The patterns underpin the existence and development of the whole as well as the centres, while at the same time, the whole and the centres describe the development of the patterns. Leitner (2015, p. 141) defines a 'pattern' as "the solution to a problem in a design or application context. Patterns are shared as completed methodical descriptions intended for practical use by experts and non-experts" (Leitner 2015, p. 148).

Leitner (2015, p. 66) explains that patterns are very useful for designers. As abstracted solutions, the application of patterns can "increase [...] efficiency and save [...] many hours of work". Patterns are subjectively developed as generic "solutions to problems in context" (Leitner 2015, p. 67) and are dependent on the developer and the definition of the system it is a part of. Patterns occur as part of human culture and also as part of nature.

Leitner (2015, pp. 66-70) stipulates that a pattern description should have the following essential elements: pattern name, context, initial situation, problem, and the solution (to the problem). In addition, a pattern should refer to related patterns that form part of the system or pattern language in which the pattern exists and should include an explanation that indicates the reasoning with examples.

Assignment 1

The course assessment that forms the basis for the discussion of this paper was the first assignment in a first-semester architectural history-and-theory course for third-year students in a bachelor's degree. This assignment was introduced to students at the end of February 2023. In order to get a sense of whether students were already using AI tools, they were polled to indicate their use and exposure to ChatGPT at the time and their perception of whether they should be 'allowed' to use ChatGPT and similar AI tools in their academic output. I was under the impression that most of them would already actively be using ChatGPT and that they would support the use of AI tools in their academic output. I certainly had already been testing ChatGPT and was thinking about how to incorporate it into my teaching practice and I found it a hot topic in conversations I was having with academics and non-academics alike.

© Copyright 2023 Design Education Forum of Southern Africa (www.defsa.org.za)

It was surprising to learn that of the 68 respondents in the poll. Only three had been using ChatGPT actively, two used it occasionally, nine used it only once or twice, 30 had heard of it but never used it, and 24 had never even heard of it. In other words, 35% of the respondents had never even heard of it. Also, surprisingly, 14 of the students (20%) thought they should not be allowed to use it in their work, while only 19 (28%) thought they should use it in their work and the rest were non-committal or wanted to know more before deciding.

Students had approximately three weeks to complete this assignment. They had to work in groups of three or four (30 groups) to explore the socio-geometric patterns of *A pattern language*. The assignment highlighted the interconnectedness of the patterns and encouraged students to consider the potential of both AI and pattern methodologies in their architectural practice. Students had to use AI generative tools, ChatGPT and an image generator and had to reflect on these.

The assignment had several distinct parts. Groups each had to select two patterns from *A pattern language*. Then they posed predefined questions to the AI generative text tool, ChatGPT. The questions investigated the principles of their selected patterns, as set out in *A pattern language*, and the local contextual applicability of the patterns. Students then evaluated the relevance and accuracy of the ChatGPT answers through group discussions and had to correct any answers that were not satisfactory (if any).

Next, they had to find two on-campus spaces that aligned with their chosen patterns. These spaces were documented through their own hands-on processes using photographs, diagrams, and physical models. They drafted narratives explaining the resonance between their chosen campus spaces and patterns.

They then used ChatGPT to create a prompt for an AI image generator that had to produce an image that reflected the essence of their patterns. They used the prompts to develop AI images and then had to adapt the prompt for several iterations to find suitable images. Most students used the very accessible DALL-E and some used Midjourney or Stable Diffusion. They had to evaluate the effectiveness of the images.

Lastly, the students wrote a reflective piece that touched on the current and contextual applicability of the socio-geometric patterns as well as the benefits and/or limitations of the AI tools used. The following section, ‘analysis and appraisal’, unpacks the student reflections.

Analysis and appraisal

Student reflections on their use of AI in Assignment 1 focused on four main aspects. These are information accuracy and the completeness of factual generated AI text; the applicability and relevance of interpretive questions put to ChatGPT; the effectiveness of ChatGPT generated image-prompts; and the effectiveness of their hands-on exploration (models and drawings) versus that of the images created by the AI image generator. The sub-headings below address each of the four aspects and the section concludes with general observations that emerged.

Information accuracy and “completeness” of factual generated AI text

There was general agreement (all groups) that ChatGPT was inconsistent in terms of accuracy and completeness of information. Although students used the same basic prompts (provided to them in the assignment) to generate answers about their two patterns, most found that in some instances ChatGPT provided fairly accurate and complete responses, while in other instances there were omissions of important information or downright inaccuracies. The following statements express the

sentiments, saying that the information was “accurate and summarised really well, although it was incomplete” (Group 15), “complete to an extent” (Group 11), and “points were omitted” (Group 2).

Applicability and relevance of interpretive questions

Again, there was general agreement (all groups) that ChatGPT was inconsistent. When ChatGPT had to find local contexts in which the patterns could be applied and write about the relevance of the patterns in contemporary South Africa, it could sometimes provide substantiated answers but at other times was off the mark.

According to students, if “the prompt is asked the exact way the brief suggests, the answer we receive is completely inaccurate” (Group 14) and “the example given doesn’t adhere to [...] the pattern and is a poor example” (Group 16). ChatGPT also sometimes “neglects [...] the social aspect” (Group 21) but at times “the response made an appropriate [...] reference” (Group 12). ChatGPT had to interpret the patterns for the South African context and Group 14 found, after adapting the prompts, that “AI demonstrates a full understanding of South African culture [...] heritage [...] economic context [...] poverty rates (and) climatic conditions”.

Effectiveness of ChatGPT-generated image prompts

The images generated with the ChatGPT-created prompts was almost in no instances satisfactory although a few groups said that the “sketches generated relate to the pattern” (Group 1). The alignment might also be related to the concrete or abstract nature of the specific pattern. One group reported that ChatGPT explained to them how a prompt should be written, rather than writing the prompt for them. It was clear from the images generated by the ChatGPT-created prompts that ChatGPT was not able to interpret the conceptual pattern information into a prompt for an image. Group 2 reported that the “images are graphically interesting but the link to (the pattern) is unclear”.

Comparison between the effectiveness of hands-on exploration vs an image generator

Students said that the AI image-generators provided value in terms of time (it is quick), but one group commented that you may spend so much time and energy on developing a useful prompt that making a hand drawing might be quicker. Other positives were that the image generator is a cost-effective way of generating many options. Most groups shared the sentiment that the images “often lacks human touch” (Group 21) and that image bias occurs because of the databases that are referenced.

Groups generally felt that their hands-on explorations were more effective than the AI-generated images. Specific comments of relevance here are that “handwritten and built models still have a better chance of being relatable and understood by humans” (Group 21), that one “can never devalue the power of hand drawings and model making” (Group 16) and that “hand-drawn allows exploration and findings on another level” (Group 22). The dominant feeling about the image generator is echoed in the comments of Group 1, who says that “accuracy, understanding, and meaning fall short” and “space and what it consists of do not carry meaning”.

General observations

Students were surprised by the introduction of AI generative tools in their history-and-theory course but found both ChatGPT and the AI image generators an exciting experience and want to continue using it. They expressed this opinion in written form in the assignment as well as in verbal interactions in class.

© Copyright 2023 Design Education Forum of Southern Africa (www.defsa.org.za)

Students thought that AI text generators, such as ChatGPT, could allow them to see information from a different perspective. ChatGPT also proves to be valuable for summaries and the generation of information, although accuracy and consistency are often lacked. Students saw ChatGPT as a "potential to aid critical thinking" (Group 18) and a "valuable tool in the triangulation of knowledge" (Group 18) but on the other hand it has "no intuition" (Group 21).

The findings about accuracy and completeness of information were not surprising and resonate with comments in the media during March 2023 (the time of the assignment), that ChatGPT "sometimes provide nonsensical or inaccurate responses" (Marr 2023 par 3) and that "it still makes mistakes" (Metz & Collins 2023, par 10).

General observations for AI image generators were that, going forward, the ideal would be to combine AI and hand drawings and models. Group 5 motivated this as they saw the "process more or less the same". However, Group 16 said that in terms of the design process it would be problematic if one relied on "using AI image(s) [...] as design solutions rather than deep critical evaluation of what the bigger picture architects attempt in resolving, socially and economically".

Some students realised that the image-prompts had to be more descriptive of the image rather than of the concepts of the pattern and subsequently their own generated prompts provided better image results than the ChatGPT generated prompts. Prompt-engineering, for both AI text and image generators has since grown into a science by itself, with entire platforms dedicated to it and huge salaries being paid (Popli 2023).

Ahead we go… beta is waiting

This paper explored the students' experience, reflections, and perceptions on the use of AI generative tools in a third-year history-and-theory course for a Bachelor of Architecture degree. What was surprising was that the students found their own hands-on explorations so valuable in comparison to the AI-generated images. I would be lying if I did not say that this is what I hoped they would conclude. Although AI image (and text) generators will continue to develop, and improved prompts will produce better results, I believe that the hand as a thinking tool (Pallasmaa 2017) will continue to play an important role and that AI generators are simply a new set of the tools we will be using.

Moving forward, we need to view AI text and image generators as additional tools in our process, whether it is the process of answering an assignment or project, developing a course, curriculum, or future research. Conceptualising our (design) process and the tools we use through the lens of Pattern Theory and with an understanding of the values of Alexander, we could develop *A pattern language* that can guide us in this process.

References

Abrahams, A 2023, 'How to use ChatGPT as a learning tool', APA, viewed 18 June 2023, <https://www.apa.org/monitor/2023/06/chatgpt-learning-tool>.

Alexander, C 1977, *'A pattern language'*, New York, Oxford University Press.

Alexander, C 1996, 'The origins of Pattern Theory, the future of the theory, and the generation of a living world'*, Keynote Speech to the 1996 OOPSLA Convention*, viewed 20 March 2023, <https://www.patternlanguage.com/archive/ieee.html>.

Anderson, T & Shattuck, J 2012, 'Design-based research: a decade of progress in education research?', vol. 41, no. 1, *Educational Researcher*, <https://doi.org/10.3102/0013189X11428813>.

As, I Pal, S & Basu, P 2018, 'Artificial intelligence in architecture: generating conceptual design via deep learning', *International Journal of Architectural Computing,* vol. 16, no. 4, <https://journals.sagepub.com/doi/10.1177/1478077118800982>.

Bhatt, R 2019, 'Christopher Alexander's pattern language: an alternative exploration of space making practices', *Journal of Architecture,* vol. 15, no. 6, pp. 711-729, <https://www.researchgate.net/publication/239794953_Christopher_Alexander's_pattern_language_An_alternative_exploration_of_space-making_practices>.

Ceylan, S 2021, 'Artificial intelligence in architecture: an educational perspective', *Proceedings of the 13th International Conference on Computer Supported Education* (CSEDU), vol. 1, pp. 100-107, viewed 20 January 2023 <https://www.scitepress.org/Papers/2021/104445/104445.pdf>.

Coplien, J 1996, 'Introduction to keynote speech', *Proceedings of 1996 OOPSLA Convention*, viewed *20* March 2023, <https://www.patternlanguage.com/archive/ieee.html>.

Dawes, M & Ostwald, M 2017, 'Christopher Alexander's 'A pattern language': analysing, mapping and classifying the critical response', *City, Territory and Architecture*, vol. 17, viewed 22 February 2023, <https://cityterritoryarchitecture.springeropen.com/articles/10.1186/s40410-017-0073-1>.

Delport, H 2023, *HATA V Course guide*, University of Cape Town School of Architecture Planning and Geomatics.

Dickenson, D 2022, 'Is good architecture synonymous with beauty?', *Arch Daily,* viewed 20 February *2023*, <https://www.archdaily.com/989288/is-good-architecture-synonymous-with-beauty>.

Gillani, N, Rebecca, E, Catherine, C & Finkel, K 2023, 'Unpacking the "black box" of AI in education', *Educational Technology & Society*, vol. 26, no. 1, <https://www.jstor.org/stable/10.2307/48707970>.

Kudless, A 2023, 'Diffused narratives'*, Journal* Feed #2, *Gradient*, viewed 22 February 2023, <https://gradient-journal.net/articles/diffused-narratives>.

Leitner, H 2015, *Pattern Theory,* CreateSpace, South Carolina.

Maganga, M 2023, 'The AI image generator: the limits of the algorithm and human biases', *ArchDaily*, viewed 15 February 2023, <https://www.archdaily.com/992012/the-ai-image-generator-the-limits-of-the-algorithm-and-human-biases>.

Marr, B 2023, 'The top 10 limitations of ChatGPT', *Forbes*, viewed 20 March 2023, <https://www.forbes.com/sites/bernardmarr/2023/03/03/the-top-10-limitations-of-chatgpt/?sh=21ba57798f35>.

Matt, T 2021, 'On Christopher Alexander', *Urbit*, viewed 12 February 2023, <https://urbit.org/blog/on-christopher-alexander>.

Mehaffy, M 2022, 'Why Christopher Alexander still matters', *Planetizen*, viewed 12 February 2023, <https://www.planetizen.com/features/116600-why-christopher-alexander-still-matters>.

Metz, C & Collings, K 2023, '10 ways GPT-4 is impressive but still flawed', *New York Times,* viewed 20 June 2023, <https://www.nytimes.com/2023/03/14/technology/openai-new-gpt4.html>

Popli, N 2023, 'The AI job that pays up to $335K – and you don't need a computer engineering background', *Time Magazine*, viewed 25 April 2023, <https://time.com/6272103/ai-prompt-engineer-job/>.

Ray, P 2023, 'ChatGPT: a comprehensive review on background, applications, key challenges, bias, ethics, limitations and future scope', *Internet of Things and Cyber-Physical Systems*, viewed 1 June 2023, <https://www.sciencedirect.com/science/article/pii/S266734522300024X>.

Pallasmaa, J 2017, 'Embodied and existential wisdom in architecture: the thinking hand', *Body & Society,* vol. 23, no. 1, 6 Jan., pp. 96-111, https://doi.org/10.1177/1357034X1668144.

Salingaros, N n.d., 'A theory of architecture', *Patterns*, viewed 26 April 2023, <https://patterns.architexturez.net/doc/az-cf-172872#off-canvas>.