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ARTIFICIAL INTELLIGENCE AS A RESEARCH TOOL FOR CONSTRUCTING UNDERSTANDING OF COMPLEX SYSTEMS: A CASE STUDY OF THE EDUCATIONAL ECOSYSTEM

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ABSTRACT
Understanding that the products, spaces and services we design are part of a complex system is crucial for successful decision-making. The challenge to propose sustainable, adaptable, and responsible design solutions requires designers to have holistic comprehension of the system they are intervening. By analysing the relationships between its components and the internal and external factors that impact the system, designers can develop strategies to address both immediate needs and long-term implications.
The objective of this research is to explore the integration of Artificial Intelligence (AI) as a tool to facilitate the understanding of complex systems and inform decision-making in design practice. AI's capacity to process vast amounts of data, identify patterns, and simulate scenarios across different levels of abstraction allows students to comprehend system's dynamics and optimise their design proposals.
The paper discusses a project implemented in an interior design course, with the educational ecosystem selected as a case study due to its inherent complexity, societal impact, and potential for transformation. The gigamapping technique was used as an inquiry and visualisation tool. AI aided students to cluster and classify the gathered information, identify relationships and critical nodes, forecast potential outcomes and simulate emergent behaviours within the system. As a result, students not only gained a deeper understanding of the educational ecosystem, but also enhanced their digital literacy, systems thinking, problem-solving, and creativity. By challenging the status quo, they were empowered to explore new possibilities and envision potential futures for the educational landscape.

Keywords: Complex systems, AI as a research tool, educational ecosystem, Gigamapping

1 INTRODUCTION
We live in "the Systems Age" [1]. In this view, the world is seen as structured wholes composed of interconnected nodes. Objects, events, and our experiences of them are not isolated but a part of larger, complex systems that exhibit emergent properties and behaviours [2]. Understanding that the products, spaces and services we design are embedded within such complex system is crucial for successful decision-making. If we fail to grasp the nature of systems and their behaviour, we risk repeating the same non-solutions all over again [3]. According to Ackoff, our failures stem not from providing incorrect solutions to the right problems, but from addressing the wrong problems altogether [1]. This misalignment sustains cycles of inefficiency and highlights the importance of systems thinking in addressing the complexities of the interconnected world. Systems thinking is defined as "a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects" [4].
The concept of systems is inherent in design theory and practice [5]. The challenge to propose sustainable, adaptable, and responsible design solutions requires designers to have holistic comprehension of the system they are intervening. By analysing the relationships between its components and the internal and external factors that impact the system, designers can develop strategies to address both immediate needs and long-term implications.
Design education is essential for preparing future designers to deal with complexity. It should train them to perceive the world systematically and develop a mindset that focuses on uncovering and understanding the relationships between objects rather than the objects themselves.

Systems oriented design – a methodological approach rooted in design practice, aims to aid the designer to build their own interpretation and implementation of systems thinking. This is a pragmatic approach integrating systems thinking, design thinking, reflection in action and design, developed as a way to teach design students how to design for the unexpected, for change and with time in mind [6].

2 COMPLEX SYSTEMS MAPPING

To comprehend and articulate objective reality – comprising objects, processes, and phenomena – we construct models. These models simplify the complexities of real-world entities, enabling us to analyse and study them more effectively. Systems mapping is an established method to build an understanding of the system's behaviour [7]. It involves the creation of a visual model of the system under study composed of networks, nodes and edges. Nodes, which represent key entities within the system, are typically represented as boxes, connected by lines that illustrate the causal relationships and dependencies between the nodes. This visual representation enables designers to test and refine their assumptions, beliefs, and comprehension of the system. By organising ideas in a structured manner, they can more effectively orientate themselves, synthesise information, and uncover connections, resulting in enhanced clarity of the system. Through this process emerges a deeper understanding not only of the individual entities but also of the nature and dynamics of their relationships and interactions. Additionally, systems maps serve as a tool for communicating the implicit mental models held by different individuals. They foster discussions, help draw meaningful insights and support the development of targeted interventions. By extrapolating from assumptions to implications, systems mapping provides a structured pathway for exploring complex systems and driving informed decision-making.

For the purpose of this research gigamapping was selected as a tool to address the complexity of the system, which will be intervened [8]. "A Gigamap is a very extensive map that includes large amount of information, across different scales and categories" [9]. The Gigamap is a multi-layered, detailed visualisation tool that usually integrates various types of maps into a single comprehensive overview. It functions as a "desktop" for organising and contextualising thoughts and ideas, emphasising the relationships and connections between different elements [10]. This approach allows for both a holistic view of the analysed system and the ability to zoom in on specific details for deeper understanding. Central to gigamapping is the continuous process of sense-making [10], which makes it an ideal tool "for research through design" [8].

3 THE EDUCATIONAL ECOSYSTEM

The educational ecosystem, which is defined as a network of people, educational resources, pedagogical tools and abiotic components interacting to seamlessly work together [11] is a compelling area of interest for designers. There is an urgent need to reimagine the spatial design of educational environments, which in their majority feature traditional layouts with segregated classrooms and auditoriums supporting lecture-based learning and reinforcing the hierarchical relationships between educators and learners. This outdated model fails to align with the demands of 21st-century education, which prioritises student-centred, skill-oriented, and technology-enabled approaches. Modern education emphasises collaboration, personalisation, and the integration of innovative tools, necessitating a shift toward flexible, inclusive, and interactive learning spaces that foster creativity, critical thinking, and equitable engagement among all participants.

To propose innovative and disruptive solutions for the redesign of educational spaces, designers must first develop a comprehensive and holistic understanding of the entire educational ecosystem. This involves examining the pedagogical, social, technological, and cultural dimensions that shape the learning environment. By considering the context in which learning takes place and identifying systemic challenges and opportunities, designers can develop solutions that respond to the environmental fluctuations, withstand emerging threats, and align with the current and evolving needs of the new generations of learners.

3.1 The project

Based on its inherent complexity, societal impact and potential for transformation, the educational ecosystem was selected as a topic to be explored by interior design students at the University of Monterrey within the studio class Institutional spaces. The main objective of the design project was to conceptualise the educational space for the future. The journey began with the task of exploring the educational system in depth, aiming to build the holistic understanding necessary to develop design solution, which can act as change-makers.

When the project was first introduced in the 2024 spring semester, several key observations were made regarding students' performance. It was noted that students struggled with knowing how to approach the research, and the majority of them were feeling overwhelmed by the complexity of the task. Their research lacked sufficient depth, resulting in incomplete analyses that overlooked critical components of the educational ecosystem. Most importantly, students failed to understand the abstract concept of relationships, preventing them from identifying how different elements within the system interact and influence one another. This last challenge is particularly crucial for developing a systems thinking mindset, which is essential for addressing complex problems. Without a clear grasp of these relationships, students were not able to determine areas in which to develop their design interventions and this led to rather fragmented and superficial solutions.

3.2 Role of AI in the research

In the second iteration of the project in the 2024 autumn semester, AI was introduced as a tool to facilitate the process. In the previous semester, students created very simple maps based on their existing knowledge, drawing primarily from their personal experiences as stakeholders within the educational system, which resulted in quite incomplete and biased system representations (Figure 1). The AI-driven research approach enabled students to move beyond their subjective perspectives and gain a more nuanced understanding of the ecosystem's complexity. They were not only able to accurately identify the components of the educational ecosystem, but also to define its boundaries and uncover the external and internal factors that influence its development.

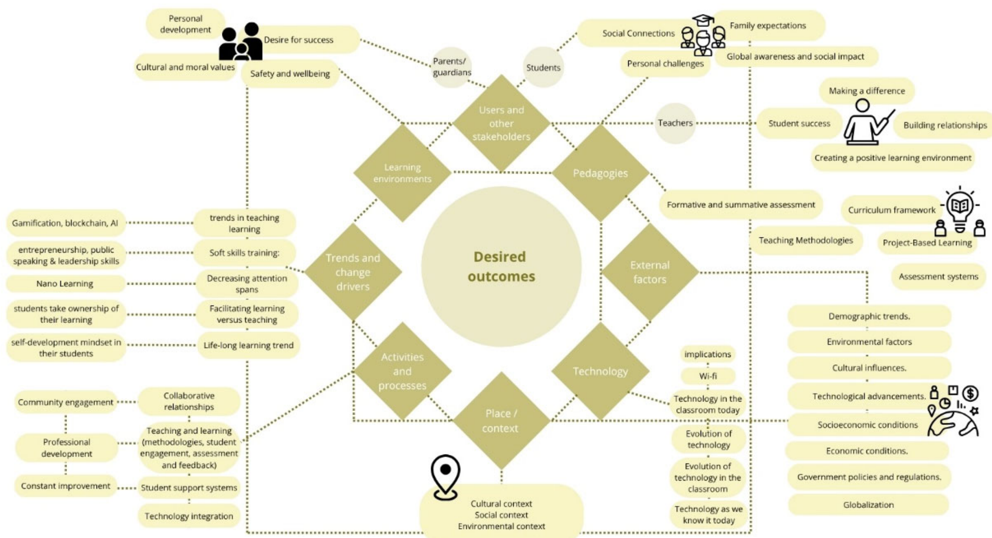

Figure 1. Map of the educational system, showing incomplete and biased system representation

The second important AI-driven insight was to comprehend that the educational ecosystem is not static, but evolves in response to technological advancements, societal needs, economic fluctuations and environmental shifts. Understanding how the educational ecosystem interacts dynamically with its environment is crucial for making predictions about emergent behaviours and making informed decisions that can accommodate new paradigms and adapt to future changes.

The third critical role of AI in the research process was to recognise relationships and patterns within the system that are not immediately apparent. By identifying the causal connections between system components, students were able to move beyond surface-level issues and address the root causes of systemic challenges. AI enabled them to zoom in and out, analysing both the micro and macro levels of the system. This broader perspective allowed students to see beyond individual interactions and recognise system-wide patterns, leading to a deeper understanding of the complexities within the educational ecosystem.

Lastly, AI was used to generate future scenarios and explore the potential effects on the system. By simulating various "what-if" situations, valuable insights were gained on how adjustments in one area could ripple across the entire ecosystem. This encouraged students to experiment and reframe the goals of their design interventions.

4 METHODOLOGY AND AI-DRIVEN OUTCOMES

The mapping process unfolded as a dialogue with OpenAI's ChatGPT. Figure 2 represents the phases of the process. The inquiry phase followed a cyclical pattern of prompt generation, response evaluation, and prompt refinement. Students started by drafting the key components of the educational ecosystem – users, pedagogies, technology, and learning environments. Prompts such as *"List all the stakeholders in the educational ecosystem and describe their goals and challenges"* aided them to identify relevant actors and organise the information into a coherent framework. Based on the received output prompts were continuously refined – expanded for deeper exploration or narrowed to focus on a particular aspect. Through this ongoing interaction with AI, students were guided to consider multiple dimensions of the ecosystem, including:

- Stakeholders: Goals, motivations, values, expectations, and behaviours of each stakeholder.
- Pedagogies: Curriculum frameworks, teaching methodologies, assessment systems, etc.
- Technology: Role of digital infrastructure, educational technology tools, building technology, etc.
- Activities and processes: How the system is functioning, which are the organisational processes, when, where and how the activities are performed.
- Learning environment: Physical environment (campus infrastructure, classroom setup, learning spaces design, etc.), spatial factors affecting the educational experience and the digital/virtual environments which are crucial part of modern educational ecosystem.
- External factors: Which are the external factors having impact on the educational system through imposing demands, putting constraints and providing opportunities?
- Place/context: Cultural, social and environmental context in which the educational ecosystem exists considering the local and global perspective.
- Trends and change drivers: Which are the key drivers and trends having impact on the educational system and shape its environment? How they affect the educational ecosystem and its components (both in a positive and negative aspect), and anticipate future trends and potential disruptors in education, such as emerging technologies, changes in skills demands, and shifts in educational delivery methods.

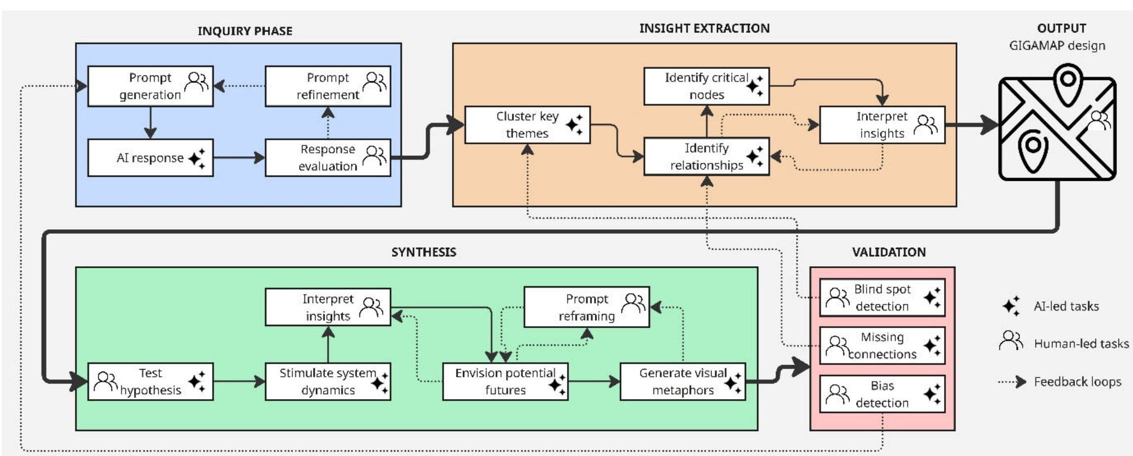

Figure 2. Diagram of the AI-assisted system mapping workflow

After each round, students were encouraged to reflect on how AI had expanded their perspective. As a result, a more diverse and inclusive system representation was created, enabling a higher-level understanding of the educational system.

In the second phase, students clustered key themes and uncovered the underlying structure of the system to define key trends, identify drivers of change, and recognise systemic limitations. This process cultivated their ability to look at the big picture and fostered their conceptual and systemic thinking. As a next step, students shifted their focus to exploring the relationships between the various components of the educational system. This required them to move from viewing these components as isolated elements to understanding them as interconnected parts of a broader, dynamic ecosystem. To achieve this, they had to think more holistically, clustering themes and identifying patterns that revealed how different elements interacted and influenced one another. Students examined how changes in one part of the system, such as shifts in policy, advancements in technology, or evolving societal expectations impact other areas. They analysed the nature of these relationships, determining whether they were competitive or collaborative. They also assessed the level of influence each component had over others, identifying which elements acted as key factors of change and which were more reactive. As more relationships were identified, the Gigamap grew increasingly complex, reflecting the intricate web of interdependencies that define the educational ecosystem (Figure 3).

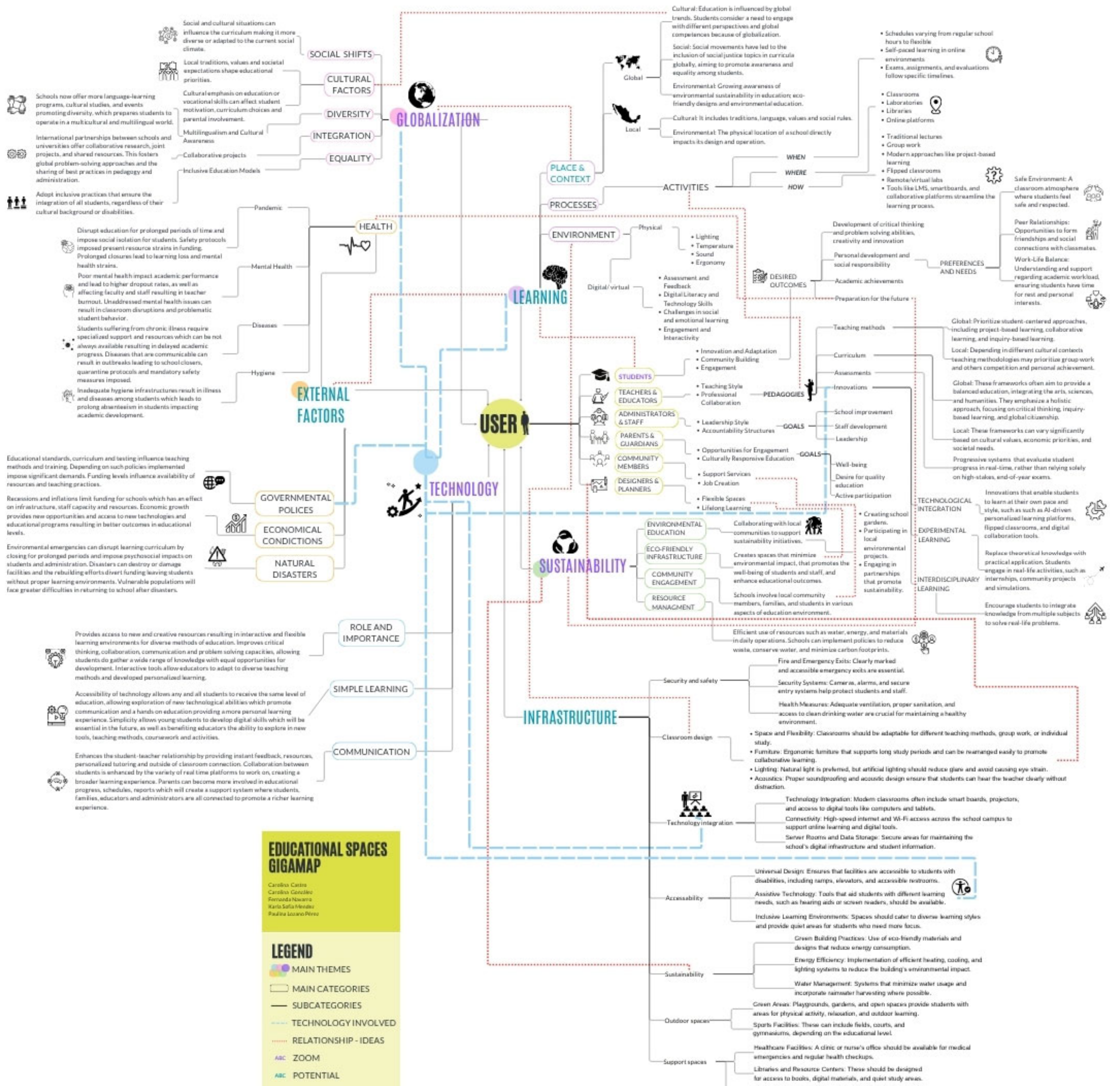

Figure 3. Gigamap of the educational ecosystem, developed with the integration of AI-generated insights

This more complex representation led to a deeper understanding of the system, preparing students for the analysis of the Gigamap, which is considered as the most "demanding" stage of the process [12]. It became easier to identify areas requiring further research – those with the greatest potential for meaningful system intervention. This enhanced clarity not only streamlined the research process but also provided a solid foundation for the conceptualisation and creative problem-solving phase. Students could reflect on the potential consequences, both immediate and long-term, and envision design ideas that support the future needs of the learners. This process developed their ability to find patterns, synthesise complex information, and think critically about systemic challenges.

In the synthesis phase, students tested hypotheses and explored system's dynamics to envision potential future scenarios. Among the hypotheses generated were hybrid learning becoming the dominant educational model; environmental crisis giving rise to extreme learning environments; the growing necessity for nature-immersive learning experiences; and the increasing prioritisation of mental health in education. Students prompted AI to envision potential futures and to generate visual metaphors that represent them. Thus, analytical thinking was bridged with creative exploration, enabling students to construct complex, interconnected narratives that reflected possible evolutions of system. The validation phase focused on detecting blind spots, missing connections and biases within the Gigamap. Students were encouraged to engage in critical reflection and assess whether the map was both conceptually robust and contextually relevant.

5 CONCLUSIONS

The integration of AI as a tool to facilitate the understanding of complex systems and inform decision-making bridged the gap between traditional systems thinking techniques and advanced digital technologies, offering a novel methodology for enhancing both the comprehension and application of complex systems analysis in design practice. AI's capacity to process vast amounts of data, identify patterns, and simulate scenarios across different levels of abstraction allowed students to comprehend the dynamics of the system and optimise their design proposals. Furthermore, the use of AI encouraged students to embrace the uncertainty and complexity inherent in systems rather than be discouraged by them. By modeling and analysing a complex system, their perspective was shifted from a reductionist approach to a holistic, systems-oriented mindset. As a result, students not only gained a deeper understanding of the educational ecosystem, but also enhanced their digital literacy, systems thinking, problem-solving, and creativity. By challenging the status quo, they were empowered to explore new possibilities and envision potential futures for the educational ecosystem.

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