



Co-designing with the Machine: Learning Through Co-designing with Artificial Intelligence Agents

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Abstract. This study presents a course designed to introduce design students to generative design and machine learning tools. This course takes a unique perspective on AI, encouraging students to envision artificial agents as active contributors to the design process rather than mere tools. In this way, students can use AI and become developers, designers, and creators of new models and processes. With this approach, students acquire a deep understanding of AI and improve their practical skills to leverage it as a creative tool effectively. The course offers two formats: a traditional classroom and an intensive workshop. Both formats cover four key stages: an introduction to machine learning concepts and coding principles, project conceptualization, development, and evaluation. Students work closely with researchers at each stage to refine models, understand technical implications, and reflect on their experiences. The projects from this course exemplify the immense creative potential of AI in diverse design contexts. By integrating AI into education with a design-based approach, the co-design model accentuates the importance of collaboration and teamwork, showing the synergy between various functions and skills. Furthermore, it underlines the importance of user-centered design and collaborative mindset to address current and future challenges in the field.

Keywords: Artificial Intelligence · co-designing process · generative design

1 Introduction

Integrating artificial intelligence agents (AI agents) into the design process has revolutionized how we approach creative problem-solving and innovation [1]. In recent years, there has been a growing interest in exploring the potential of AI agents to enhance the design process across various domains [2] due to its potential to analyze vast amounts of data, generate concepts, provide recommendations, generate image and text-based outputs, and assist in decision-making. However, artificial intelligence operates differently from humans as it is designed to make decisions without humans' emotional and cognitive limitations. While Artificial Intelligence (AI) can mimic specific human abilities in various tasks and may exhibit creativity in certain contexts, it is essential to

note that the machines themselves lack conscious experience of the creative process [3]. Nevertheless, combining human creativity with AI introduces a realm of unexplored possibilities, potentially leading to remarkable breakthroughs across diverse domains. This research presents the concept of Co-Designing with the machine. An approach that involves creative machine learning agents as co-designing partners and stakeholders in the development of creative design projects. A course based on this approach was designed and implemented within the Systems Planning Laboratory of Chiba University in Japan, with the goal of familiarizing design students with generative design and machine learning tools, focusing on collaborative design projects that allowed students, faculty, and researchers to explore the possibilities of integrating machine learning agents as co-working partners. The Co-Designing with the Machine course offers a unique perspective on AI, encouraging students to view artificial agents as active contributors to the design process rather than mere instruments. This perspective empowers students to use AI and actively participate in its development, design, and creation of innovative models and processes. By adopting this approach, students can deeply understand AI and enhance their practical skills to use it as a valuable creative tool. Finally, we aim to shed light on the current state of the art, identify the main challenges of design education with artificial agents, highlight possible future directions, and contribute to the existing body of knowledge by providing an overview of exploratory applications of the use of AI agents in the design domain.

2 Co-designing with Artificial Intelligence Agents

Co-creation can be defined as a collective expression of creativity experienced and enacted collaboratively by a group of individuals. On the other hand, co-design refers to a collaborative creative process that is applied throughout the entire design process [4]. The Co-design term, also known as participatory design or collaborative design, entails actively engaging stakeholders, such as users, clients, community members, and experts, in the design process. It recognizes that the collective intelligence and collaborative efforts of a diverse group can lead to more innovative and inclusive outcomes [5]. The term co-designing with the machine, for this study, refers to a collaborative approach where human designers and artificial intelligence agents work together through the design process. In this collaborative framework, human designers and AI models interact throughout various stages of the design process, from idea generation to evaluation and refinement. The perspective of co-designing with artificial intelligence agents incorporates aspects of the distributed creativity framework, where creativity is viewed as a collective and dynamic phenomenon that involves the interaction and collaboration of multiple actors, individuals, artifacts, and environments, with each contributing unique elements to the creative process [6]. In the same way that creative collaborations between humans play an important role in solving complex problems [7], these dynamics not only serve to complement and enrich the projects with different points of view but also to productively manage the tensions, conflicts, and disagreements that might arise through collaborative work [8]. The Co-designing with the machine approach recognizes the capabilities of AI systems, while acknowledging the indispensable role of human creativity, intuition, and critical thinking in the design process.

The use of AI technologies during design the process does not undermine the fundamental principles of Design Thinking, which are user-centered, abductive reasoning and iterative processes [9]. In contrast, AI allows us to overcome some limitations of design procedures with solutions that have the potential to become even more user-centric, addressing the specific needs of each individual with great precision. In addition, AI enables enhanced creativity and facilitates continuous updates through learning iterations, enriching the entire lifecycle of a product [1]. And although there is a great body of evidence on how accurate the results of these models can be in terms of recognition and image generation [10–12], one of the big questions regarding the incorporation of artificial agents in the design world has been the discussion on creativity, and whether or not intelligent models or agents are really capable of producing creative responses. According to the model proposed by Csikszentmihalyi in 1988, a model of creativity [13] is proposed that requires 3 interrelated elements: (1) an accepted domain of current knowledge; (2) an individual who alters a component of the domain to produce something new; and (3) a field of experts who ultimately decide whether or not the novelty will be accepted in the existing domain. Indicating that the individual is not an independent and unique component in the creative process and requires other elements, also arguments that creativity is socially founded [14]. Following that premise about the fundamentals of creativity, the concept of creativity 4.0 emerges as an evolution of the understanding of creativity in the context of Industry 4.0, which refers to the integration of intelligent digital technologies in different industrial processes [15]. The concept of creativity 4.0 mainly implies a change in the way creativity is harnessed in this modern technology-driven era and emphasizes the fusion of traditional creative thinking with digital tools, artificial intelligence and automation to improve problem solving, innovation and productivity. This concept has been addressed by different authors discussing the impact of technology on creativity and innovation [3, 16, 17]. Based on this premise, a model under the name of Creativity 4.0 was introduced by the author Daniel Gruner and Csikszentmihalyi in 2018 [3]. This specific model proposes a framework that addresses how artificial intelligence affects the social structure of the creative practice by adding AI as an additional element to the three basic components mentioned above in the previous creativity model (Fig. 1). In this model, the individual accesses existing information in the current knowledge domain and generates something original where a group of experts will judge whether the contribution made by the individual is considered new and can be transferred to the existing domain. In this way by incorporating artificial intelligence that is programmed to adapt to the information it finds in the domain, it has the capability of adding and altering possibilities for new permutations. Consequently, it has an indirect influence on all the interconnected elements [3]. Concluding that the integration of artificial intelligence agents into the design process offers immense potential for enhancing creativity, efficiency, and collaboration.

Nevertheless, we can find a different approach to the concept of creativity 4.0 from other authors such as Paul Atkinson and Richie Barker who discuss that the previous model does not show all the possibilities in which artificial intelligence can be incorporated in the creative process [16] and propose an adaptation in which the element of AI plays an important role in the filtering process and the gatekeeping of information, as well as including the importance of generative systems. This suggests that in addition

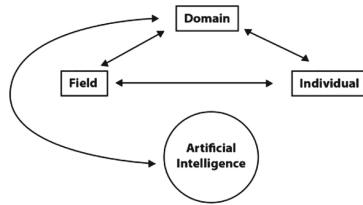


Fig. 1. Creativity 4.0 model (Daniel T. Gruner and Mihaly Csikszentmihalyi)

to operating within the social structure of the creative process, the user plays a role not only as a content creator but also as a selector or modifier of the material generated by artificial intelligence. An alternative approach to the concept of creativity 4.0 has been proposed by Carmen Bruno and Marita Canina who suggest a conceptual framework that helps us to understand how the digital transition is impacting the human condition on 3 levels, cognitive, individual, and social, where creativity is seen as a transversal human skill in all these levels of the human being [17]. Despite the different positions regarding the concept of creativity 4.0, all of them consider the significant impact of artificial intelligence in the creative process, therefore, by examining some academic projects, this paper aims to provide valuable insights into the current landscape of AI in the design process. We will explore diverse applications, methodologies, and frameworks used in designing with AI agents, as well as identify potential areas for future research and development.

3 Co-Designing with the Machine Course

In the context of academic design projects, the integration of AI agents in a creative task requires a deep understanding of the specific domain and, in addition, to take full advantage of AI, it is necessary to possess technology knowledge and skills. Addressing the lack of knowledge in this area, a novel course was organized to familiarize design students with generative design and machine learning tools. The design course, with a focus on co-design projects, was open to students of different levels and backgrounds. It was conducted in four distinct stages, starting with an introduction to the concepts of machine learning and the principles of co-design. Following stages involved students in the conceptualization, development, and evaluation of projects, benefiting from close collaboration with professors and researchers to improve models and gain knowledge of their technical application. By employing an interdisciplinary approach, students had the opportunity to explore innovative techniques and creative methodologies, increasing their proficiency in technical areas and improving their problem-solving skills. The co-design framework underscored the importance of collaboration and teamwork, exemplifying how diverse roles and skill sets can effectively collaborate. The course emphasized the importance of a user-centered design approach and the benefits of collaborative problem solving. The course has been conducted in two different formats. The first format consists of a seven-session class spread over one quarter, with three annual iterations beginning in 2021 and concluding in 2023. The second format consists of an intensive 5–7 session workshop, delivered in collaboration with various

institutions on five separate occasions. In conjunction with student work, professors, and researchers focused on developing models and tools to facilitate the process, such as sets of models and pre-trained data sets, as well as Jupyter notebooks that explain step-by-step the concepts and processes needed to develop the models or adapt models previously developed by other course members in the desired direction. In this way, the course works in an iterative way since some outstanding students are reintegrated in the next iteration to take another role in the development process of the project, as leaders or researchers. In this way, despite not providing continuity to the same project directly, it provides continuity to the development of some agents and tools and reinforces the learning not only of the basic principles of machine learning but also of the co-design process. As previously described, the course is divided into four parts (Fig. 2), the first part aims to provide theoretical foundations of machine learning, as well as basic concepts related to the design process.

The second phase focuses on the conceptualization of the project, based on research and analysis of the needs derived from a specific problem chosen collectively by the students. During this phase, the teams are composed of members of different academic levels, including undergraduate and graduate students, as well as students of various nationalities. This diversity is intended to assign different roles to each student: some assume the role of experienced researchers, mainly graduate students, while others concentrate on the development and production aspects. Once the problem has been selected, the teams explore how to integrate a particular agent or artificial model chosen into specific stages of the design process, with particular emphasis on the conceptualization, production and testing phases. During the third phase, the teams engage in the development of the project, focusing on the design and technological aspects. This involves iterative methods in which the artificial agent or artificial intelligence model undergoes continuous training and development, adjusting and optimizing based on data and feedback. Throughout this phase, students work closely with professors and researchers to improve the models and gain knowledge about the decision-making process and technical implementation. Lastly, during the fourth phase, the project undergoes its final evaluation. Students showcase their work, presenting the co-design process and the successful integration of the artificial intelligence model into their design. Alongside the project presentation, this stage involves reflection and discussion sessions where students can openly share their experiences, challenges, and valuable lessons gained. Furthermore, they engage in conversations about the possibilities and constraints of incorporating artificial intelligence technology into design processes.

The design process typically encompasses key stages: research, conceptualization, prototyping, development, implementation, and evaluation. At each of these stages, AI agents can effectively intervene by leveraging advanced data analytics, generative models, and adaptive learning techniques. The following scholarly projects report ways in which AI agents can intervene at different stages of design, offering valuable insights and enhancing collaboration between human designers and intelligent machines. By examining prototypes and case studies, we shed light on how AI-driven interventions have the capacity to expand the way we teach the design process in academia by fostering a new era of interdisciplinary collaboration.

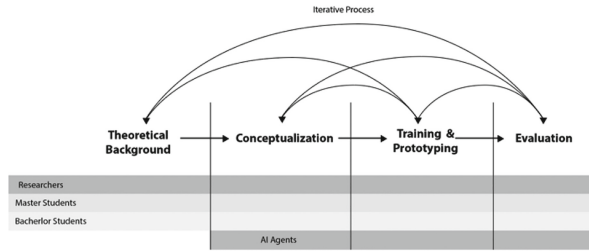


Fig. 2. Iterative process followed during the Co-designing with the machine course at Chiba University, Japan. Participants with different backgrounds (Researchers, MA and BA students) collaborate with artificial intelligence agents during the design process to develop their academic projects.

3.1 Conceptualizing a Product with Generative Adversarial Networks/Lamp Project

During the first iteration of the course, the students focused on designing lighting and ceiling lights. Under the concept of sea creatures, students decided to employ two generative models based on generative adversarial networks (GAN): one for generating ceiling light shapes and the other for generating deep-sea creature shapes. By intervening the neural networks of these models, the students successfully created an agent capable of proposing conceptual sketches for lamp base shapes, as well as suggesting colors and possible illuminations for each proposed shape. Once the images of these shapes and illuminations were generated, the students chose a set of images as a conceptual foundation and then worked collaboratively to develop three-dimensional representations for each selected image from their individual perspectives (Fig. 3). In this project, the students took on the role of sense making and directors on the proposals that the model provided in order to interpret it following their own criteria. This exercise fostered engaging discussions and debates among the students, considering the co-design approach they employed throughout the process. Ultimately, the students concluded by exploring the potential extension of this methodology and its agent to other realms of product design, such as furniture design. In this project, IA models or agents were involved during the conceptualization process.



Fig. 3. Example of a result generated by the GAN model and three different interpretations generated by three different students.

3.2 Using AI Agents to Evaluate the Visual Impact on the Users/Data Viz Project

This Project centers on data visualization and involves the active participation of end-users in the co-design process. To achieve this, the students trained a CNN Convolutional Neural Network for facial emotion recognition, utilizing their own faces as the dataset. Additionally, they incorporated a graphical particle generation model, which could be controlled by a Generative Pre-trained Transformer, adapted to make decisions based on the detected facial parameters. The outcome of this project is an agent capable of generating graphical representations that reflect the estimated emotions on the user's face (Fig. 4). This agent was applied in a specific context where the team explored its potential use not only as a decorative element for homes but also as a tool for prompting reflection on how excessive use of devices like cell phones can negatively impact our emotional well-being. During this project, the students examined the possibility of integrating this process and the resulting agent into cross-cultural settings where people often struggle to communicate or understand others' emotional states. This integration could foster not only co-creative processes but also facilitate cross-cultural communication, presenting exciting opportunities for enhancing emotional understanding and expression. In this project, AI models or agents intervened during the prototyping process and generation of visual elements as well as in the evaluation of human reactions to further feed the loop.

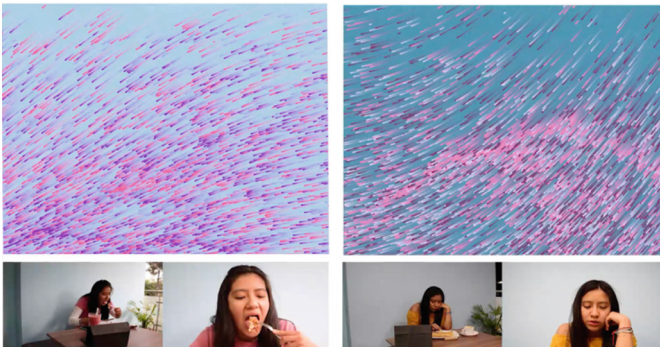


Fig. 4. Visualization test of the emotional impact of eating while using a cell phone

3.3 Agents Capable of Questioning You for Reflection Purposes/Question Generator Project

This project involves exploring tools built on commercially available Generative Pre-trained Transformers. At that stage, these tools could respond to user queries and commands but may not delve into the user's specific needs or attributes extensively. In this context, the students aimed to create an agent that encourages users to contemplate the prompts, questions, or commands they submit. Instead of providing a definitive or straightforward answer, the agent responds with related questions tailored to the user's

profile or concerns. The project resulted in an experience termed as the “question generator” (Fig. 5) with a focus on the agent’s inability to generate answers, thus inviting users to engage in introspection and thoughtful reflection. In this project the AI models or agents intervened during the prototyping and information generation process, as well as in the evaluation of the user’s answers in order to continue the interaction loop.

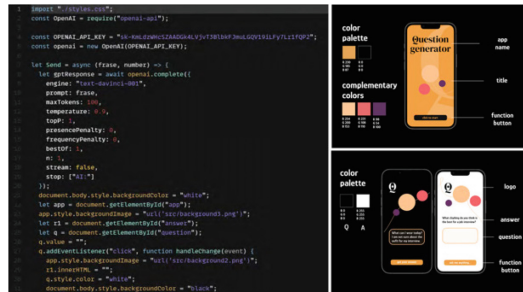


Fig. 5. Design Project focused on addressing your queries with other reflective questions using commercially available Generative Pre-trained Transformers.

3.4 Finding Bias in the Available Models/Barbie Doll Project

This project emerged from a collaborative intensive workshop involving students from the Data Design master’s degree from Elisava Barcelona School of Design and Engineering and Design students from System Planning Laboratory in Chiba University. It revolves around training an agent using a generative model of images through diffusion. The agent was trained using two primary datasets—one comprising images of Barbie dolls and the other featuring indigenous groups from Southeast Asia. Throughout the process, the students were required to manually tag each image by providing a specific ‘caption.’ Employing the reverse prompting technique to automatically generate corresponding captions for all pictures was not feasible due to the majority of images being unrecognizable and not matching those present in the original Stable Diffusion database. This aspect of the process underscored the models’ deficiency in certain representations within their datasets and showcased how the model was unable to accurately identify the chosen images, leading to a significant lack of representation for these ethnic groups. After this unexpected finding, the outcome was a remarkable agent capable of generating dolls with indigenous characteristics (Fig. 6), reflecting the insights gained from examining the design of mass-produced commercial products and their potential impact on the perception and personal value of individuals from diverse socio-cultural and demographic backgrounds. The project sheds light on how such products can influence the perspectives and values of people in different cultural contexts. In this project, AI models or agents were involved during the research, conceptualization, prototyping, and image generation process.



Fig. 6. A sample of a dataset image selected by the students and the image of a doll with indigenous characteristics resulted from the generation process.

3.5 Artificial Agent to Envision Future Scenarios According to Human Interactions on Real Time/AI Sneak Peak in Your Future

In this project, students explored the potential of generating visual stimuli to envision possible futures related to specific user profiles and their needs. They also examined how such stimuli could impact the perspectives individuals have on others. For this purpose, the students created a diffusion-based image generation model that utilized speech recognition as input. This model translated real time conversations between two unknown individuals into images depicting a potential future for them as a couple. The result was an interactive experience where the proposed agent actively participated in the conversation, generating scenarios where compatible couples reacted positively to the stimuli, while incompatible ones responded uncomfortably and negatively (Fig. 7). The students concluded by discussing the potential application of the agent in a different context, moving away from the couple aspect, and focusing on generating images during the creative brainstorming process. In this project, AI models or agents intervened during the prototyping process, through the analysis of user profiles, voice recognition and image generation.

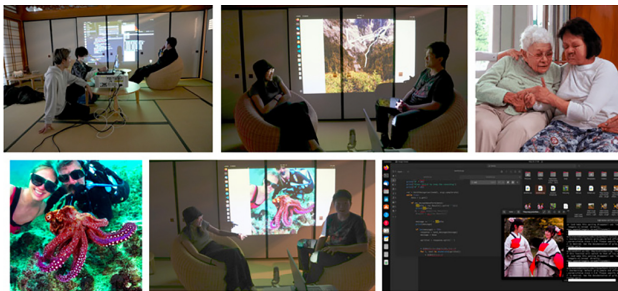


Fig. 7. Images generated based on real-time conversations showing the possible futures of participants if they engage in a relationship. Images were projected during the conversations.

3.6 Real-Time Co-designing with Artificial Gents/Shadow Master Project

The remarkable project resulting from the fourth iteration of the course focuses on exploring new ways of interacting with generative artificial agents. Taking advantage of lighting and shadow identification, the project generates illustrations in a playful process of co-creation (Fig. 8). Users, even without prior knowledge of the generative process, can participate by “playing” with their bodies to create graphic representations of animals based on shadows. Its importance lies in its potential for designing visual communication experiences in cross-cultural environments and enabling visual representation of intricate concepts for children or people with disabilities. The implications of the project open the door to fostering inclusive and innovative visual communication approaches in culturally and demographically diverse contexts. In this project, AI models or agents intervened during the delivering design stage, through the analysis of user image input (shadow image) followed by image generation (final output).



Fig. 8. Generative Design project based on real-time human interaction. Users can participate by “playing” with their bodies to create graphic representations of animals based on shadows.

4 Discussions and Limitations

Throughout the implementation of the course, areas for improvement were identified through participant observation and evaluation. One significant aspect involved evaluating the achievement of the course’s achievement in terms of co-creation or co-design. The question was raised about to whether the machine’s involvement in projects could be compared to a human participant in a traditional co-design process. The machine’s ability to understand project context and make meaningful contributions, essentially becoming an integral part of the design team, was considered. The outcomes of these projects can be seen as the result of a co-creation process facilitated by the participation of the machine’s participation. On the previously presented projects, students discovered that artificial agents were limited to specific roles, such as shape detection, image representation, and human emotion estimation. They believed that these contributions would not have been possible without the involvement of the machine. These findings demonstrate how artificial intelligence can be seamlessly integrated into the creative process, not just as a tool, but as a creative partner with specialized expertise in specific domains. Another significant observation made during the “Co-Designing with the

Machine” course was the uncertainty among participants regarding integrating intelligent agents into their design process. This uncertainty did not solely arise from technical limitations, but also from a desire to explore AI beyond predetermined recommendations or outputs dictated by architecture or pre-existing models. Allowing students to focus on context selection during project development, including training models based on datasets they collected or composed, resulted in increased acceptance, satisfaction, and understanding of machine learning concepts. Finally, one notable limitation in the current application of AI’s current application to creative processes is the widespread lack of technical knowledge among creative practitioners, including designers and design students. While courses like this one can provide a high-level understanding of machine learning and artificial intelligence principles, there is still a gap exists in fundamental knowledge for these disciplines, such as programming and statistics. It could be argued that designers may not need this knowledge to engage in a co-design or co-creation process with an intelligent agent. However, it becomes indispensable when designers are responsible for designing and developing agents for specific project roles.

5 Conclusions

In conclusion, incorporating artificial intelligence agents into the design process of academic projects has been a transformative educational experience. This course highlights the potential of integrating AI into educational practices and demonstrates a multi-disciplinary approach capable of providing a highly stimulating and dynamic learning scenario. By engaging with AI models as members of a team and entrusting certain decisions to algorithms, students have harnessed the potential of collaborative AI to enhance their creative abilities. In addition, the course has enabled students to master the art of creating a problem-solving loop to train AI models, allowing these agents to actively participate in the design process. This paradigm shift goes beyond mere iteration; designers must now understand the entire loop and learn to seamlessly integrate AI agents as indispensable team collaborators. Consequently, this design-led educational experience unfolds as an intricate nested process, in which students not only learn the entire design process, but also acquire the skills to train and engage other agents on the team. Furthermore, this course also emphasizes the importance of the culture of collaboration and co-design. The projects conducted by this co-design model represent how different roles and skills can work together in an efficient and productive way. Adopting this perspective opens new horizons for designers, enriching their abilities to navigate an evolving landscape of human-machine collaborative design experience and amplifying the potential for groundbreaking design innovations. Finally, it is our hope that these examples will inspire further exploration, discussion, and innovation in this exciting and rapidly evolving field.

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