Enhancing Industrial Design Creativity through Artificial Intelligence: Insights from a study on human-machine co-creation

Potenciando la Creatividad en Diseño Industrial a través de la Inteligencia Artificial: Estudio sobre la cocreación hombre-máquina

Ignacio López-Forniés, Laura Asión-Suñer
ignlopez@uniar.es, lauraasion@unizar.es

Departamento de Ingeniería de Diseño y Fabricación
Universidad de Zaragoza
Zaragoza, España

Abstract- The present work analyses artificial intelligence (AI) in industrial design creativity. It emphasizes creativity as a key driver of innovation, supporting collaborative and multidisciplinary approaches such as co-creation and co-design, along with AI. Additionally, AI tools generate images from text. This highlights the interaction between designers and AI in product conceptualization. A sample of 80 students in industrial design engineering is analysed. This analysis highlights the benefits and challenges of this human-machine co-creation and concluding with future development options.

Keywords: Creative process, Artificial Intelligence, Generative models.

Resumen- El presente trabajo analiza la inteligencia artificial (IA) en la creatividad del diseño industrial. Hace hincapié en la creatividad como motor clave de la innovación, apoyando enfoques colaborativos y multidisciplinares como la cocreación y el codiseño, junto con la IA. Además, las herramientas de IA generan imágenes a partir de texto. Esto pone de relieve la interacción entre los diseñadores y la IA en la conceptualización de productos. Se toma una muestra de 80 estudiantes de ingeniería de diseño industrial. El análisis manifiesta los pros y contras de la cocreación hombre-máquina, concluyendo con opciones de desarrollo futuro.

Palabras clave: Proceso creativo, Inteligencia Artificial, Modelos generativos.

1. INTRODUCTION

In industrial design and product development, it is critical for students to understand that the creative process enables differentiation and innovation in products and services through novel and design-adapted solutions, creating value for consumers and users. Creativity is considered a key driver of innovation as it allows overcoming current limitations and finding creative design approaches.

Classic creative processes are complemented by collaborative and multidisciplinary approaches such as co-creation and co-design, involving different actors with diverse skills and perspectives. These adapted approaches are based on the idea that creativity arises from the interaction among various actors, including designers, users, engineers, marketing experts, among others (Sanders & Stappers, 2008). Artificial intelligence (AI) emerges as an innovative actor, a valuable tool for the creative process by providing new perspectives and possibilities. Thus, the human-machine co-creation process can combine human expertise with AI data processing and analysis capabilities. Machines can enhance our cognitive strengths, embody human capabilities, and expand our physical capacities. The human-machine co-creation system can also be used to train young people (Woo, 2020).

AI is undergoing a similar evolution to other technologies. It is transitioning from being a research topic and a tool for a privileged few to becoming increasingly accessible and widely used in different fields and applications (Moore, 2019). As increasingly sophisticated applications are developed and AI capabilities improve, its adoption is expected to continue increasing. It will become an essential tool in various areas of life and business.

Currently, a highly beneficial application is the use of AI as an assistant or co-pilot in creative steps, where AI helps with open-mindedness, originality, flexible thinking, productivity, attention to detail, and openness to change - classic indicators of personal creativity (Frith et al., 2021). By using generative AI from text to image, as used in this work, the designer is assisted with a wide range of tools to generate unique images. As a result, the designer creates sketches of product idea ideas, builds virtual models and prototypes, or creates immersive environments. The evolution of AI will continue to gain popularity and reshape the design industry.

2. CONTEXT & DESCRIPTION

Artificial intelligence can be a powerful tool to support and enhance creative processes while maintaining human thinking as a fundamental element for generating original ideas and creating truly innovative works (Zylinska, 2020). Its effectiveness and efficiency have been demonstrated in areas such as design, illustration, music, and writing.

The use of traditional creative methods, techniques, and tools increase human creativity. Technological advancements enable the introduction of new digital tools to support and enhance classical tools. This facilitates co-creation between designers and artificial intelligence as an emerging field in design and technology (Carter & Nielsen, 2017). Access to co-creation

DOI: 10.26754/CINAIC.2023.0103

between designers and AI challenges conventional ideas about the creative process and creativity's nature and structure. Designers explore creative techniques and forms of expression that would not be possible without technology.

In the last decade, there has been an increase in the development of AI tools for visual creativity, enabling designers to work on exploring different variations and forms of idea visualization. This work analyses the human-machine co-creation process and present a series of results that define the benefits and difficulties, allowing for the establishment of new challenges in this emerging form of co-creation.

A. AI-generated creative stimuli

In the creative process, stimuli can be classified into two categories: sensory and informational. We use visual and auditory stimuli in the sensory category. However, they may also be olfactory, tactile, and gustatory, although these methods are more challenging to use.

Informational stimuli vary in format and medium. Verbal stimulation involves words, phrases, slogans, metaphors, and concepts. Visuals include static and moving images, shapes and silhouettes, textures, patterns, and colours. Voices, conversations, sounds, melodies, tones, rhythms, songs, etc., are auditory. Performances, dramatizations, experiments, representations, and simulations (testing artifacts and prototypes) are the factual. Finally, combined formats present multiple stimuli at once, such as diagrams and illustrations, infographics (data and images), videos, etc. Creative thinking can be enhanced by any stimulus that provides complex information beyond sensory stimulation, either through the amount of information or the combination of different types of stimuli. (Kim et al., 2021). In the future, it is expected that senses, such as touch, smell, balance and proprioception, will be integrated into the creation of stimuli.

Advancements in AI-assisted collaborative work systems, thanks to the increasing popularity of Natural Language Processing (NLP) based interfaces, are leading to applications in which AI acts as an expert and informed participant, providing combinatory visual stimuli to facilitate the creative process of participants. AI systems can be trained to generate images or texts that fit a specific style or theme. For example, designers can use AI tools, such as image recommendation systems, to find visual inspiration and patterns in a relevant image database, see table 1.

Table 1

IA Uses in Design Creative Process

Application	Description
Visual trend analysis	Massive analysis of visual data to identify trends in product design.
Design generation	Generation of proposals according to preferences
Simulations, models and virtual prototypes	Creation of virtual representations and evaluation of the different designs and their effectiveness.
Design customisation	Customisation to suit user needs and preferences
Design automation	Automating certain parts of the design process to improve efficiency and reduce costs

Additionally, designers can also use text generation tools to produce detailed descriptions of products and their functionality. This can help visualize the product and discover new solutions.

B. Generative image tools based on text or images

Designers in this experience have used text-based generative tools, which are free to use and can be accessed directly on the web without the need for social media. These tools use an AI engine, based on a machine learning model to generate high-quality digital images from natural language descriptions. Their interface is based on *prompts*, which are commands or text definitions of what designers want to achieve. Having complete control over the output. The build process is iterative, development is incremental, and definitions can be refined as we see results. Depending on the application, you can use *out painting* to add elements to the scene, or *in painting* to modify them. In the co-creation exercise some tools as can be seen in the table 2 are used by the students.

Table 2

Examples of image AI generative tools

Tool	Q	P	D
Stable Diffusion *	V	N	stablediffusionweb.com
Blue Willow	V	N	Discord (social network)
Midjourney *	V	Y	Discord (social network)
Dall·E 2 *	V	Y	openai.com/dall-e-2
Lexica	H	N	lexica.art/
PlayGround AI	H	N	playgroundai.com/
Leonardo AI	H	N	leonardo.ai/
Mage Space	M/H	N	mage.space/
Bing Image Creator	M/H	N	bing.com/create
Scribble Diffusion	M	N	scribblediffusion.com/
Pic Finder	M	N	picfinder.ai/
Images AI	M	N	images.ai/
DeepDream	M	Y	deepdreamgenerator.com/
Artbreeder *	M	Y	deepdreamgenerator.com/
Starryai	M	Y	starryai.com/

* Tool used by students, Quality (Q), Payment (P) yes(Y) or no (N), Domain (D), Very high (V), High (H) and Medium (M)

C. Design exercise. Creative process and exercise steps

A classic design conceptualization exercise has been carried out, involving the introduction of novel functionality into an everyday and simple object. 84 second-year students in the Industrial Design and Product Development Engineering degree participated in the exercise, resulting in 80 complete and valid outcomes. The results section shows the analysis to observe the differences in influence caused by visual stimuli. The exercise lasts for 60 minutes with additional 10 minutes for delivery preparation. A time allocation recommendation is made, which the students can follow or not. At the beginning of the exercise, the objective, the stimuli, the tools, the steps to follow, and the evaluation method are explained. The stimuli are visual and are generated with text-image AI tools based on

a series of prompts that they write and re-write in two phases of the exercise.

A simplified model condenses the creative process in Problem, Ideation, and Solution. This model initially focuses on the Problem that explores all the initial possibilities. During the ideation phase, multiple ideas and alternative images are generated thanks to AI tools. Subsequently, filtering, selection, and prioritization of all ideas occur, leading to combinations and growth of ideas. For the Solution, the ideas evolve and adapt to the specifications of the problem. Evaluating ideas or concepts is developed to validate the solution in an iterative way. In each iteration, it is possible to return to generate more complex and detailed ideas. Table 3 illustrates the exercise steps.

Table 3.

Steps in the conceptualisation exercise

Step	Description	Results
1	Choose an everyday object and introduce a novel function	Object+Function
2	Quickly and descriptively hand-sketch of the desired object	Representation of mental image
3	Select keywords and conduct initial searches in a text-to-image AI tool	Iterative process
4	Choose the best images or create new sketches if changes to the initial ones are desired	Collection of images
5	Refine the search until finding the desired or valid results	Descriptions as text and images
6	Select the final image and provide a description	Final image and descriptive text

The first step is to define the objective of the problem. An everyday object is chosen for the exercise, a familiar product that we interact with every day. The function is defined based on the user's knowledge, keeping it simple, choosing functions that solve everyday needs, such as dispensing toothpaste onto a toothbrush, measuring physical variables in household objects such as temperature, humidity, among others. Secondly, a mental image is created and visualised through sketches and initial drawings. Based on this mental image, the designer identifies a set of words and phrases that will be used to interact with the machine in the third step.

In the fourth step, initial searches are carried out and the first results are obtained. These results are usually not very precise or similar to the initial drawings. For this reason, it is necessary to refine the searches and create more precise prompts that better describe the intended idea. A more detailed description is therefore required. The fifth step is to check the changes made in the description to achieve the desired result. After these corrections, we may find variations that closely match our original idea. It is also possible that during this process the images offered will make us reconsider the initial idea and allow us to create a new mental image, finding interesting alternatives that evolve until we are satisfied.

The final step is to arrive at the final image and give a more detailed and comprehensive description. At this point there are a large number of generated images that have served as

iterations and stimuli to redefine the prompts. Figure 1 shows the first idea for a dumbbell that counts repetitions and the AI images generated; the final idea includes a digital device to control the training.

Figure 1. Sketches, AI images and design with final changes.

D. Assessment

By assessing the effect of the stimuli generated, we will be able to determine to what extent the final design has been affected. An analysis of the relationship between five variables and one indicator is performed for the assessment.

The variable *Originality* (O) refers to the novelty of the proposal, whether the combination of the everyday object and the function already exists or not. This has been checked through Google, Bing and ChatGPT searches, as text and as image. Extreme values correspond to its existence or non-existence on the market, while intermediate values correspond to the existence of similar things.

The variable *Flexibility* (F) refers to the ability to vary thinking and the ability to open up new options and alternatives. In this case, it is assessed in terms of the number of alternatives tried in the prompts given to the machine, which can be increased by the feedback of the stimuli generated by the images.

Productivity (P) is a variable measured by the number of ideas generated. In this case, it is measured by the number of requests made, regardless of whether they differ much or little from those already made.

The *Detail* (D) variable is measured by the precision of the idea definition. In this case, it is measured by the definition of the search entries. A higher level of detail also provides more precise answers to what is desired.

Changes (C) is measured by the variation from the original idea. It represents the number of changes, modifications or improvements made to the final design as a result of exposure to visual stimuli. The maximum change occurs when the initial idea has been completely transformed and even the function has been improved.

The *Evaluation* (Ev) indicator averages the above variables and represents the degree of resolution of the proposed problem. It is assessed using a specific rubric.

Each variable can have five values: Null N (0), Low L (2.5), Medium M (5), High H (7.5) and Excellent E (10).

3. Results

The results for each variable and level are analysed as in Table 4 (Number of students scoring at a given level for each variable, and also in percentages). The results are generally satisfactory. All variables and the indicator exceed 30% at a high level. As a result of the Evaluation indicator, 58% of students achieved a high level. Originality has an excellent result 30% and 38% high. Flexibility has a low result of 38%, a medium result of 24%, and a high result of 33%, which is balanced downward. The Productivity variable, 70% of the results are between high and medium, while in the Detail

variable, 59% are high and 13% are excellent. The Change variable is fairly balanced, with 38% being high, 25% being medium, and 28% being low. In interpreting these results, it can be seen that originality is quite high, as free thinking is proposed as the starting point, without restrictions or limitations. Flexibility, which is a strong indicator of creativity and has a high influence on novelty, is low, indicating that the stimuli did not lead to alternative thinking, but rather to the development of thinking, detail, and productivity.

This exercise is designed to refine the original idea, to make changes, and to improve it. Change variable distributions are centered on high, medium, and low values, with 30% (null and low levels) not achieving the expected changes and 70% (medium, high, and very high levels) exceeding them.

Table 4

Results of the Conceptualisation Exercises (number and %)

	Ev	O	F	P	D	C
N	0	0	1	1	0	2
	0%	0%	1,25%	1,2%	0%	2,5%
L	3	10	30	2	26	22
	3,7%	12,5%	37,5%	1,2%	32,5%	27,5%
M	19	15	19	28	24	20
	23,7%	18,7%	23,7%	35%	23,7%	25%
H	47	31	26	29	26	30
	58,7%	38,7%	32,5%	36,2%	32,5%	37,5%
E	11	24	4	5	3	6
	13,7%	30%	5%	6,2%	3,7%	7,5%

Nil (N), Low (L), Medium (M), High (H) and Excellent (E)

Using AI in the creative process. Pros and Cons

Pros: In *simple* applied creativity exercises or design problems, students usually stick to their first ideas, but the AI tool gives them new results, making changes and suggestions. Digital tools are *attractive* to students, writing or drawing by hand is an unattractive task, using these AI tools on computers, laptops, tablets or mobile devices puts them in their familiar environment. *High quality* images that match the description If the stimuli are effective, they will lead to a more accurate and detailed description, returning stunning, high-quality images. Create *multiple variations* with tools that can generate up to four images for a single prompt. AI can help designers create multiple variations once it has recognised a pattern and the input is accurate. *Ideation in different environments*, whether the designer is in an industry or not, AI can enhance the ideation process to create new ideas, the original idea can be modified through interaction. *Combined stimuli*, using different AI systems, can be an interesting way to explore new solutions and generate creative ideas.

Cons: *Freedom of choice* can create a creative block, since designers are used to a design brief with specifications and constraints find it difficult to embark on open-ended projects. Generating images from descriptions is a very *complex task,* sometimes images do not match the description and there are limitations to creating images that match the description. AI is *not always a help*, the creative process is still the responsibility of human designers and creators, and while technology can be a useful tool to work on creativity, it is not a valid solution in all cases. *Additional work,* if the image generation tool for generating ideas and design suggestions does not produce the desired results, it may be necessary to combine it with other creative approaches and tools.

4. Conclusions

Artificial Intelligence supports inductive thinking, for the novice designer who does not yet have enough experience and knowledge, AI helps him to complete his mental images. AI can perform creative tasks, always under the guidance of the designer (Zylinska, 2020). The function of imagination and mental imagery allows us to ask powerful questions to get the most out of AI tools. It is important to note that these tools vary in the accuracy and quality of the descriptions generated, and that timely user learning, parameter tuning or model training may be required to achieve optimal results.

The search is repeated if the results are not valid and new entries are generated, including more complete and detailed phrases. However, there are some interesting elements that cannot be ignored and should be exploited despite initial failure. Just as in serendipity the prepared mind can create random situations, so the distracted mind will not discriminate the good from the jumble of information. The learner will pass one image after another as if watching a Tik-Tok.

AI tools can be trivialised, as happened with graphic design tools in the 1980s and the idea that anyone could be a graphic designer. Knowing and using the tool does not qualify designers, it does not make them competent, they need training and a critical sense. The generation of images can be the basis for applying creative techniques such as inversion, deconstruction, combination and rearrangement of elements to create a more original and differentiated image, but created by the designer himself.

Acknowledgements

As part of the Recovery, Transformation and Resilience Plan of the Ministry of Higher Education, funded by the European Union's Next Generation programme, this research has been conducted as part of the UNIDIGITAL IASAC project.

References

Carter, S., & Nielsen, M. (2017). Using artificial intelligence to augment human intelligence. Distill, 2(12), e9.

Kim, J., Maher, M. Lou, & Siddiqui, S. (2021). Collaborative Ideation Partner: Design Ideation in Human-AI Co-creativity. CHIRA, 123–130.

Moore, A. (2019). When AI becomes an everyday technology. Harvard Business Review, 7.

Frith, E., Elbich, D. B., Christensen, A. P., Rosenberg, M. D., Chen, Q., Kane, M. J., ... & Beaty, R. E. (2021). Intelligence and creativity share a common cognitive and neural basis. Journal of Experimental Psychology: General, 150(4), 609.

Elizabeth B.-N. Sanders & Pieter Jan Stappers (2008) Co-creation and the new landscapes of design, CoDesign, 4:1, 5-18, DOI: 10.1080/15710880701875068

Woo, W. L. (2020). Future trends in I&M: Human-machine co-creation in the rise of AI. IEEE Instrumentation & Measurement Magazine, 23(2), 71–73.

Zylinska, J. (2020). AI art: machine visions and warped dreams. Open Humanities Press