Design Thinking Meets Academic Research: Science Communication for Design Communities Using Analogies and Illustrations

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Abstract. Science communication is recognized as an increasingly relevant field within society because it allows for the communication of research results to non-specialized audiences, nurturing scientific literacy among citizens. In this landscape, the field of Design, especially design thinking, has been making valuable contributions by enhancing communication across various academic disciplines, making research findings more accessible to the wider public. The question is whether design can help to communicate academic design research within its own community, reaching out to design educators, students, and practitioners? Our paper explores this question through the description of an example in which two hallmarks of designerly ways of thinking - analogies and visual representation - are applied to communicate a scientific argument arising from academic design research. The selected example revolves around the concept of design research categories. Consequently, a secondary objective of our paper is to investigate the use of analogies and illustrations a means to elucidate the distinctions and subtleties among various categories of research in the field of design. The process itself allowed the authors to reflect not only on the utility of such tools to develop a new way of communication, but also to assist the work of multidisciplinary teams in communicating science.

Keywords: Science Communication · Analogies · Digital illustrations · Academic Design Research

1 Science Communication and Design

In today's world, science communication has never been more important, and it is crucial for it to be effective. As the science communication community becomes more professionalized, the focus has shifted from the quantity of communication to the quality of

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communication, with connecting with the audience in a meaningful way as a central quality indicator [1]. Design can play a crucial role in achieving this goal, and academic institutions like universities have a unique opportunity to rise to the challenge by bringing together a diverse group of stakeholders in collaborative design processes to communicate science. This includes scientists, designers, practitioners, evaluators, and other actors.

Design thinking, an iterative and creative problem-solving approach, has been recognized by the science communication community as an effective framework to structure these complex processes [2–4]. Despite its potential, bringing these different mindsets together can be a challenge. Therefore, more research is needed to identify the best ways to integrate design thinking into science communication efforts and to develop effective strategies for collaboration among diverse stakeholders.

In many respects, design thinking is the opposite of scientific thinking. While scientists analyze facts to identify patterns and insights, designers generate new patterns and concepts to address facts and possibilities. This fundamental difference in approach distinguishes the two disciplines. However, by combining science thinking and design thinking, a more effective source of advice can be created. Although valuable in their own right, the merging of these approaches balances skeptical inquiry with imaginative application. This balance results in a more comprehensive problem-solving method that is superior to using either approach in isolation [5].

There is a growing interest in applying design approaches, such as speculative design and design thinking tools like storytelling, to science communication and public engagement with science, as evidenced by recent research [6, 7]. However, this work takes a different perspective, focusing on how the Design discipline can aid its own communication with academic and non-academic design audiences. As design is both a practice and an academic field, how can academic research findings in design be disseminated beyond traditional academic communication formats? Given that design provides numerous tools for promoting communication and public engagement, this research explores these questions by exploring a specific example.

1.1 Science, Design, Analogies and Visual Representation

Analogies have always been essential for communicating scientific ideas in a way that makes them more accessible. For example, the "plum pudding" analogy has been widely used in textbooks to explain the atomic theory proposed by Thomson in 1904. Even though the analogy may not fully capture the technical aspects of Thomson's atomic model, it offers a vivid image accessible to the general public, making it so popular that it has been adopted by scholarly literature [8].

Analogies are now considered part of scientific language. Their purpose is to transfer knowledge from a known reality, the source, to an unknown one, the target. Analogies are an effective learning instrument because they allow learners to connect what they already know with scientific concepts or theories, making them both cognitively and affectively involved. As such, analogies are not just linguistic embellishments, but a powerful resource for thought processes and conceptual understanding. When learners seek to make sense of abstract, intangible phenomena, they can draw from embodied experiences and look to concrete entities to serve as cognitive representatives [9, 10].

In the field of design, analogies are not only a communication resource but also a promoter of lateral thinking. They foster new inferences and offer new, insightful perspectives for problem-solving. In this context, the potential for creativity increases with the distance between the two domains being compared [11]. Combining these two lines of thought, how can design use analogies to promote the dissemination of its own academic research results amongst design communities?

Art, imagery and visual language in general are also becoming favored media for conveying science to the public. By making visible what cannot be captured by explicit words, pictorial representation allows to engage the public, by reaching emotions beyond cognition, and creating a more interactive and conscious communication. Additionally, visual communication can be especially valuable during conceptual and early stages of a research project, helping to generate new ideas and thoughts [12].

In the field of design thinking, visualization plays a crucial role in facilitating communication, idea sharing, and building a shared understanding among project team members. This helps accelerate the iterative process of generating and experimenting with ideas by allowing team members to easily build on each other's ideas and recall previous discussions. Images are processed more efficiently by the human brain than verbal or textual information, making it an effective tool for facilitating idea elicitation and synthesis, fostering involvement and engagement, and integrating different perspectives [13]. Additionally, pictorial elements are closely related to creativity through its ability to foster visual reasoning. Reasoning is defined as going beyond the provided information, and visual reasoning is a cognitive process that involves using visualization to identify patterns, draw conclusions, and generate new insights.

Numerous authors start from the principle, and have demonstrated in various studies, that visual thinking and the graphic representations it encompasses play a central role in creative design thinking [14, 15]. Observing drawings and other images helps the designer to activate, perceive and process information stored in memory and to relate them to other information [16].

Analogies and imagery are frequently interconnected through visual analogies during the creative process. While they may be identified without the use of imagery, in creative exploration, analogies are often generated through the manipulation and transformation of images. Typically, a designer will consider one display and create an image of another display that is recognized as analogous to the first. The designer will then use these images to think through the problem to solve, working to bring the two images into close enough alignment to enable the mapping and transfer of ideas between the original display, or source, and the new one, the target [17]. By integrating visual elements both as a means to communicate science and as a tool within the design thinking process, the question arises: How can the utilization of visualization promote the dissemination of academic research results within design communities?

In synthesis, the work presented here was motivated by the following questions: How can analogies be effectively applied to enhance the communication of academic research findings amongst design communities? How can images contribute to elucidate these analogies, adding an extra layer of instruction and making scientific information more accessible to these communities? To address these questions, we explore an example centered around concepts resulting from previous academic design research conducted

by the first, fourth, and fifth authors, as previously published [18, 19]. This work pertains to the distinction between various categories of research in design and their role in consolidating design as an academic field. To validate the use of analogies and aid in the development of digital images, we invited the third author, a science communication specialist, and the second author, a graphic designer, to join our multidisciplinary team. Our collaborative effort followed a three-step approach, which will be elaborated upon in the next section. As this description will show, analogies and imagery have also proven to be invaluable in facilitating communication within the multidisciplinary team itself.

2 Exploring an Example

In this section, we delve into the realm of science communication through the lens of design thinking techniques, with a particular focus on reaching out to design communities. Our aim is to explore how academic design research can be effectively communicated within its own community. In Sect. 2.1, we present a scientific design argument derived from previous research [18, 19], adhering to the conventional academic standards of textual and visual language, just as it was originally published in academic journals. This approach allows us to lay the foundation and establish a baseline for our investigation. While the concepts presented in this section do not constitute the core of this work, they must be explained so the following sections can be understood. In Sect. 2.2, the same argument is explained by using an analogy. Embracing the ingenuity of design thinking, we uncover the remarkable potential of analogies to communicate complex ideas in a relatable and more engaging manner. Building upon this newfound insight, in Sect. 2.3, we take our exploration a step further by complementing the analogy with compelling digital illustrations. By synergizing the strength of visual representation with the richness of analogical thinking, we aim to unlock an unparalleled realm of effective science communication.

2.1 The Dual Role of Design Projects in Academic Research in Design: Communicating the Argument

Although multiple authors [20–23] have made significant contributions in recent years, the methodological framework of academic design research remains unclear. The lack of clarity is not solely attributed to the plethora of terminology and conflicting definitions but also due to the ongoing debate regarding the inclusion of design projects within doctoral research and whether they should adhere to the academic standards of more established academic disciplines. Following the publication of previous academic works, the argument presented here deals with the following question: What is the relative place of the design project and academic research in design, namely in terms of doctoral research? In response to this question, based on earlier research by Frayling, etc. [20–23], a 4-category design research model was proposed [18, 19], as shown in Fig. 1. The model includes the following categories: research ABOUT design, research THROUGH design, research FROM design and research FOR design. Research ABOUT design does not involve any kind of design project conducted by the doctoral student as design author during the investigation or in the past.

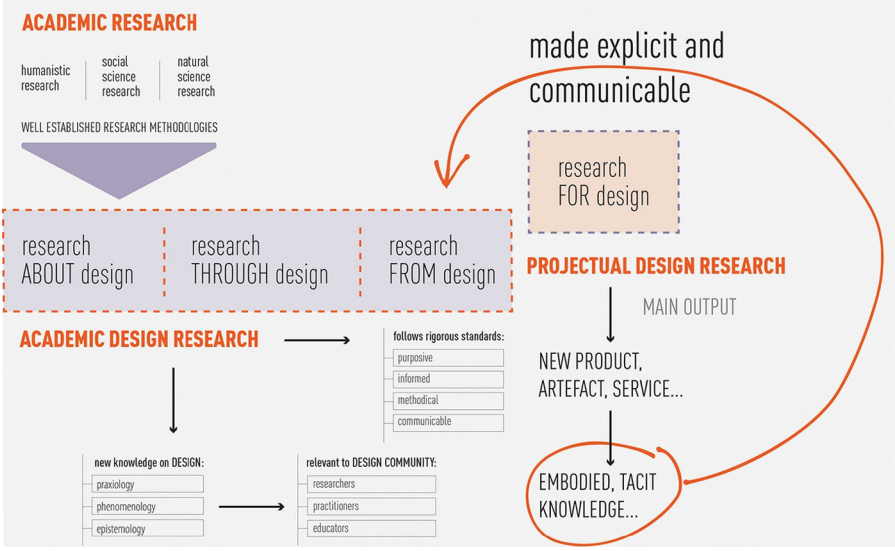

Fig. 1. The 4-category design research model [17]

On the other hand, and outside academic realm, is research FOR design which is the same as professional practice research. This type of research produces outcomes assuming the form of a product, service or process. In this type of research, new implicit knowledge will necessarily be produced, but probably without consideration (or necessity) for academic standards adherence. Also, it is rather improbable that such implicit knowledge would be translated to a communicable and explicit form. In this model, this research category is not considered academically acceptable, meaning that a design project per se, even if more complex, is not acceptable as design doctoral research.

Academic research involving design practice from the doctoral student, includes research THROUGH design and research FROM design and is the topic requiring further clarification, regarding the relative place of the design project and academic research in design, namely in terms of doctoral research. That distinction is the main scope of the ongoing discussion. The presented argument is that the difference between research THROUGH design and research FROM design lies in the time and context in which that reflection takes place. Research THROUH design explicitly refers to doctoral research incorporating a design project performed by the doctoral candidate during the doctoral program. Differently, research FROM design category refers to research that results from the diachronic study of the doctoral student own relevant and professionally validated design activity. In both categories, design projects assume a central role. However, they differ on the place where the design project is developed and, on the time, when the author's reflection and analysis occur. While research THROUGH design involves design projects developed inside universities, whereas author's reflection, research project and design project, all occur in parallel, at the same place and within the same period of time. In research FROM design, on the contrary, the studied design project(s) belong to the researcher's past professional activity, developed outside the academy. The author's

reflection and analysis are diachronic because it only happens after the output of the studied project(s) have been validated by the market. Thus, research FROM design arises from implicit knowledge previously produced by means of research FOR design, later made explicit and communicable for academic purposes.

2.2 Using an Analogy to Communicate the Design Project Duality Argument

The authors' intention was to find an appropriated analogy that could provide a helpful visual image of this intermediate perspective where a design project *per se* is not considered acceptable academic research, but at the same time it is certainly a fruitful source of knowledge to be explored. The authors wanted an image where both positions could reach a compromise, but not in an ambivalent way, where one cannot clearly distinguish the differences between one position and the other. To illustrate the clear understanding resulting from this investigation, the required comparison should emphasize duality. At this point, the dual nature of light behavior emerged almost immediately as a possible analogy. The most interesting feature of the wave/particle question is that it behaves like a particle or a wave depending on the experimental setup. This duality of behavior is what makes the question so intriguing and challenging to understand [24].

This is exactly what constitutes the argument presented at Sect. 2.1 about the role design projects play in design research: depending on the type of experiment conceived, meaning the research methodological approach, we can observe two very distinct and dichotomic roles of the design project. By forcing the analogy a bit we can even identify 'corpuscular' or 'wave-like' characteristics depending precisely on the ontological, epistemological and methodological assumptions considered when conceiving a doctoral research project.

Modern theories about light, and the consequent debate whether light is better described as a wave or as a particle, date back to 17th century. Due to Isaac Newton's studies about optics, the corpuscular theory of light was widely accepted until the 18th century. The scenario changed when Thomas Young carried out the pivotal double-slit experiment around 1800. Young took light and shone it through two very narrow slits, very close together. If light was made of particles, the particles should pass straight through the slits and produce two slight stripes on the screen, approximately the same size as the slits. On the other hand, if light is a wave, then the two waves emerging from the two slits will interfere with each other and produce a pattern of many stripes, not just two. The experiment results showed the interference pattern with many stripes proving that light behaves like a wave. But the case reopened in the early years of the 20th century especially due to Albert Einstein theory of photoelectric effect, which refers to the ejection of electrons from a metal surface when light is shone on that surface at certain wavelengths. Even if ejected electrons are not visible, this effect is verified by the fact that the plate acquires a positive charge due to the loss of electrons. Einstein argued that this could only be explained if light is made up of particles, or photons. When a photon strikes the metal surface, its energy is transferred to the electron, as when two billiard balls collide. In 1905, Albert Einstein proposed the wave-particle theory of electromagnetic radiation. This theory states that electromagnetic energy is released in discrete packets of energy, now called photons, that exhibit both wave-like and particle-like behavior. With this theory, Einstein was able to bridge the gap between

the two theories by showing that light behaves like a particle interacting with matter when it's emitted or absorbed, and it exhibits wave-like behavior when it travels through space, air or other media. Thus, it can be stated that depending on the data that a certain researcher is looking for and the experimental set up she/he applies, they can observe light behaving like a wave or like a particle. Both theories are valid, depending on the phenomenon being examined.

Once the basics of light duality are established as the analogy source, a transference to the design field, as target, can be mapped. What was proposed by the argument presented in Sect. 2.1 is that the role of design project in design research can be examined from two different perspectives, depending on the desired outcome, and the 'experimental set up'. The proposed 4-categories model for doctoral design research included research ABOUT, THROUGH, FROM and FOR design. Since research ABOUT design does not involve any kind of design project conducted by the researcher, the role of design project is not under discussion in that case. For this reason, research ABOUT design is not targeted by the presented analogy.

The other three categories always involve design projects conducted by the researcher. In research FOR design, which is conducted outside the academy, the research intends to contribute to a given design output, answering to a design brief. Inside academy walls, the remaining two categories of research involve design projects authored by the researcher, who assumes a dual role as researcher and design author. In research THROUGH design, the design project occurs during the doctoral research project timespan, but only starts after the formulation of academically worthy research questions. In this case, the design project is not the end but a means through which research questions are answered. Finally, in research FROM design, the design project which is the object of the research occurred somewhere in the past typically outside the academy following research FOR design, and the research questions are only formulated after the project being completed and validated.

What is now to be argued is that the nature of that knowledge resulting from design project is dualistic, analogous to the wave-particle duality of light. Research FOR design would be analogous to the photoelectric experiment. Particle-like knowledge would be 'clustered' in quanta and applied in close interaction with matter, aiming to answer project briefs. Resulting knowledge is implicit, embedded into design products and or processes of the design project and is not directly usable for academic purposes. This knowledge is not explicit, declared or even noticed, exactly as the ejected electrons are not directly observable. On the contrary, what is observed is the project output, the solved problem, as in the photoelectric experiment, where what can be observed is the metal plate acquiring positive charge.

Wave-like knowledge, on the other hand, would be the type of knowledge that spreads and diffuses throughout the academic community, adding contributions, confirming, expanding or even questioning previous knowledge. The key difference leading to the observation of this behavior is the fact that the experimental setup, which refers to the ontological and epistemological values framing the research and the methodological options adopted to conduct affects the outcome. Thus, for a doctoral research project, it is important to design it in a way that allows for the diffusion of knowledge, akin to the behavior of a wave.

This is analogous to the double-slit experiment, in which two slits are opened with the specific aim of observing light waves to interfering with each other. Similarly, research THROUGH design and research FROM design also require as well conceived 'experimental setup' aiming at producing explicit knowledge and observing how it reacts, interferes, and changes the body of existing knowledge.

The two slits would represent in this case an analogy for the research question and the design question. The main goal of academic research is to answer a research question (one slit), but a design project, led by a design question (another slit), may be the mean to provide the answer.

After establishing this first version of the analogy, the following step was dedicated to communicating it visually, through digital illustrations. As the following section will demonstrate, the process of drawing allowed to expand and refine the analogy.

2.3 Using Digital Illustrations to Clarify the Light Analogy

As perceived in the previous section, a particular aspect of the proposed analogy is that it is based on a source that is not necessarily familiar to most design communities. While the light duality theory is commonly taught in schools, the details of the experimental setups carried out to observe each one of the behaviors may not be something that non-specialized audiences will necessarily recall from their past experience as students. For that reason, the first of this 3-step approach consisted in creating two similar and comparable images to illustrate the basic elements of experimental setups used in physics to demonstrate the corpuscular and undulatory nature of light. There are so many illustrations showing both experiments, that even in online sources, it is not easy to find images sharing similar graphic language. And that was the starting point, to uniformise the graphic language of these two experiences so that interpretation would be easier. Two images (Fig. 2 and 3) were developed. In both cases the focus was not on scientific rigor, regarding light phenomena, but instead, in capturing features from the experiments that are pivotal to the analogy establishment. Also, considering that the audience is non-specialized in physics, it seemed more appropriate to clean out any technical details unnecessary to the analogous reasoning. As an example, while it is true that photelectric effect is only observable for some light wavelengths, this was intentionally left outside in the representation for Fig. 3.

Given that the experiences to be translated graphically had light as a common element, the color yellow was the obvious choice to start this process and introduce a degree of literal interpretation. We then proceeded to a complementary combination, using yellow and purple, to ensure that the composition harmonized in terms of colors and adhered to fundamental principles of communication design, especially those related to color theory. Orange, being an analogous color to yellow and located adjacent to it on the color wheel, is typically associated with 'warmth,' which, in this context, we connected to the concept of light waves.

The next step was to adapt the previous images to the context of academic research resulting in diagrammatic illustrations. Diagrammatic illustrations, intended to communicate information, are diagrams accompanied by notes or captions that explain or clarify concepts or methods or describe objects or places, for example. They are widely

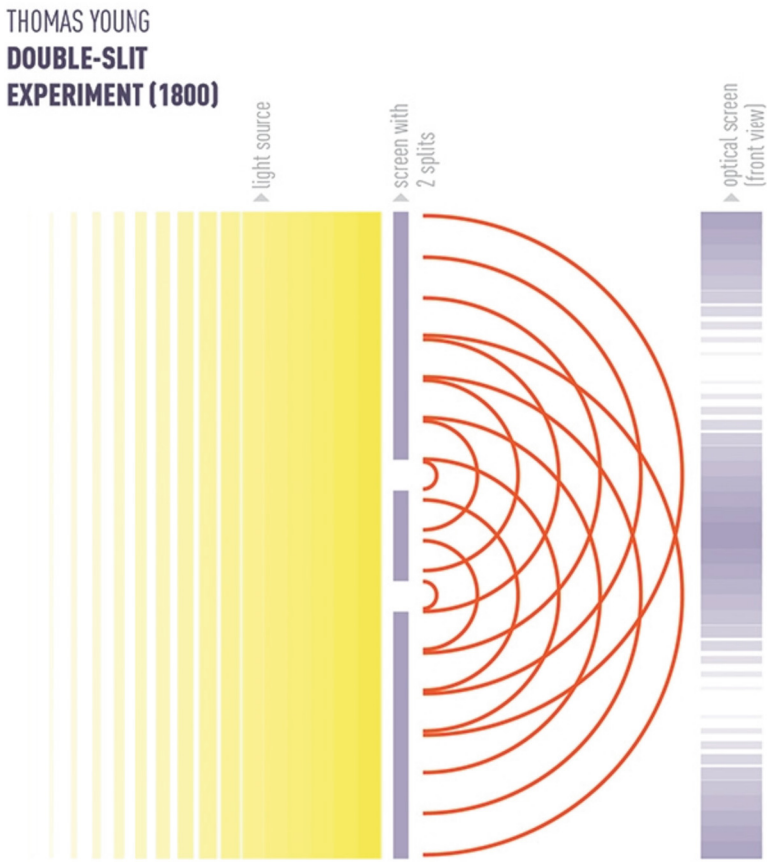

Fig. 2. Double slit experiment representation @Authors

used in education as an instructional medium to show how things work, move or change, because "information can be ingested more readily when conveyed visually" [25].

Research FOR design is represented, by analogy, by the photoelectric effect experiment, as already explained at Sect. 3, and illustrated at Fig. 4. Representation of research THROUGH and FROM design, however, were reevaluated due to recent light theory developments. Precisely at the time the drawing process was being conducted, a new study about light undulatory nature was published. In April 2023, 200 years after Thomas Young double-slit experiment, the slits in the screen, separated in space, were replaced by "slits" in time. A team led by Riccardo Sapienza at Imperial College London, shot light through a material that changes its properties in femtoseconds (quadrillionths of a second), only allowing light to pass through at specific times in quick succession [26].

A new interference pattern was observed. Instead of showing up as bands of bright and dark, they showed up as changes in the frequency or color of the beams of light. That means light also interferes with its past self with a wave-like behavior. This new discovery presented another opportunity to reflect again on our analogy. Now, with this

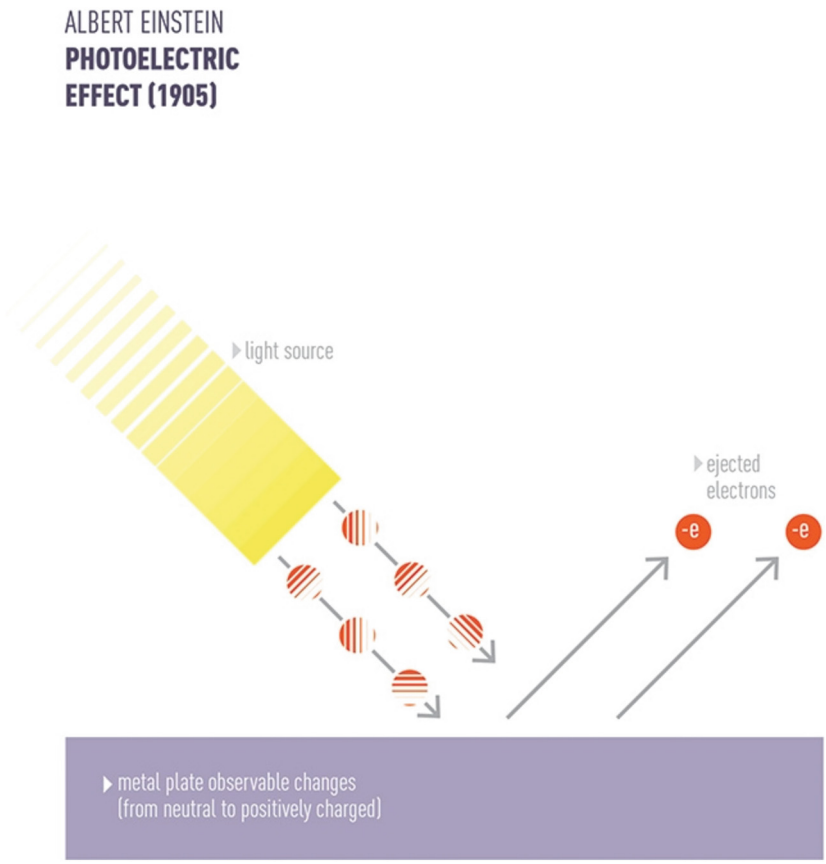

Fig. 3. Photoelectric effect representation @Authors

'diachronic' light behavior it was possible to have a specific analogy to illustrate research THROUGH design and another one to illustrate research FROM design.

That way, the classical Young experiment from 1800, where the slits are coincident in time but separated by space, would constitute an analogy to the type of research where design project and academic research occur simultaneously, at the time the doctorate is being conducted (Fig. 5).

To that end, two splits must be opened at the time: the research question and the design question. They interact with each other in the sense that solving the design question will provide data to answer the research question. And they also interfere with the means where these waves travel, which is the academic milieu and the academic knowledge already existent.

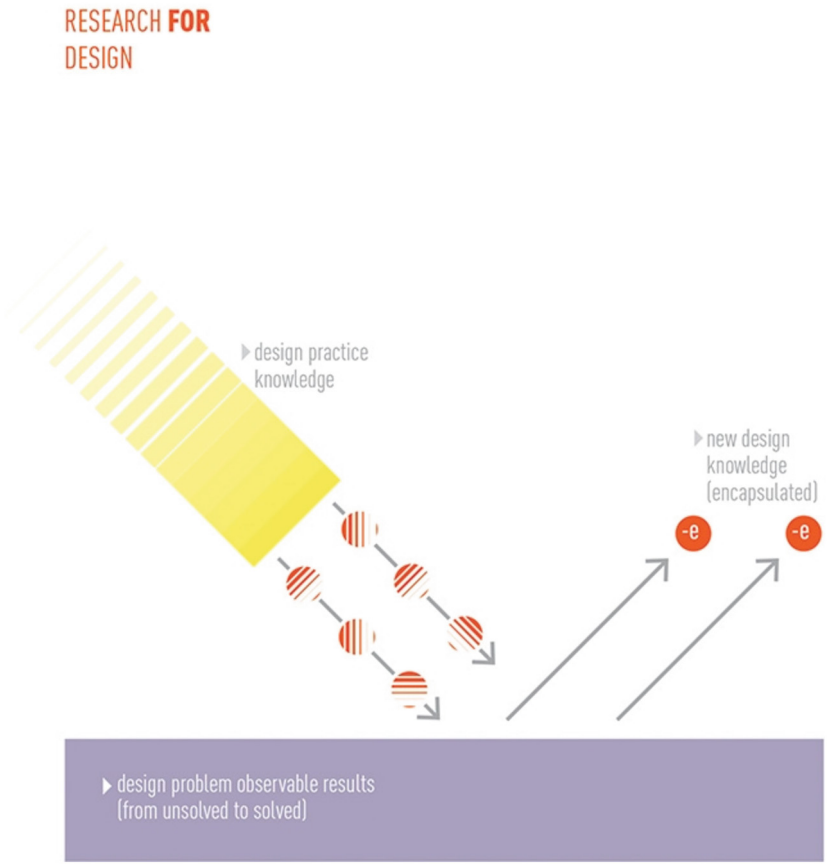

Fig. 4. Research FOR design analogy @Authors

The new double-slit experiment from 2023, where the two splits are separated in time, on the contrary, presents an even more suitable analogy for research FROM design. In that case, the design question happens before, and it is only later that the research question is formulated. But they still interfere, and they still create a visible pattern of interference between them and with the milieu. A third image was then developed to illustrate this analogy. In this case, the two slits are slightly displaced in the horizontal axis to indicate the timelapse, and the resulting pattern is illustrated by a multicolor band (Fig. 6).

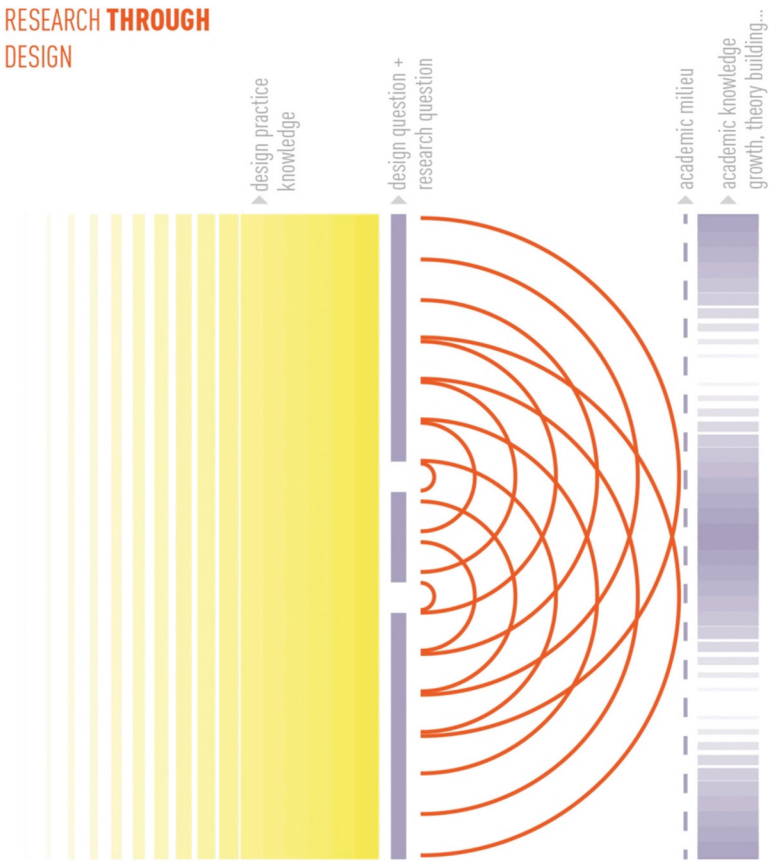

Fig. 5. Research THROUGH design analogy @Authors

3 Reflecting on the Process and Envisioning Future Work

Aiming to explore how design thinking can assist dissemination of academic design research findings within design communities, beyond traditional academic communication formats, two approaches were followed: the use of analogies and the combined use of analogies with digital illustrations. The team included three academic researchers in design who worked previously on the scientific argument here explored as an example, one graphic designer, and one education researcher specialized in science communication. The analogy with light duality was first proposed by one of the authors, who possesses a background in engineering, thus more familiarized with physics concepts. The analogy was primarily discussed among the first three authors and the necessity to develop images to make the analogy more accessible to non-specialized audiences was identified. Schematic illustrations were developed to communicate with the graphic designer co-author and some meetings were scheduled to verbally explain the analogy. Finally, the design communication specialist was invited to contribute on the role of consultant to check the viability of the analogy and imagery.

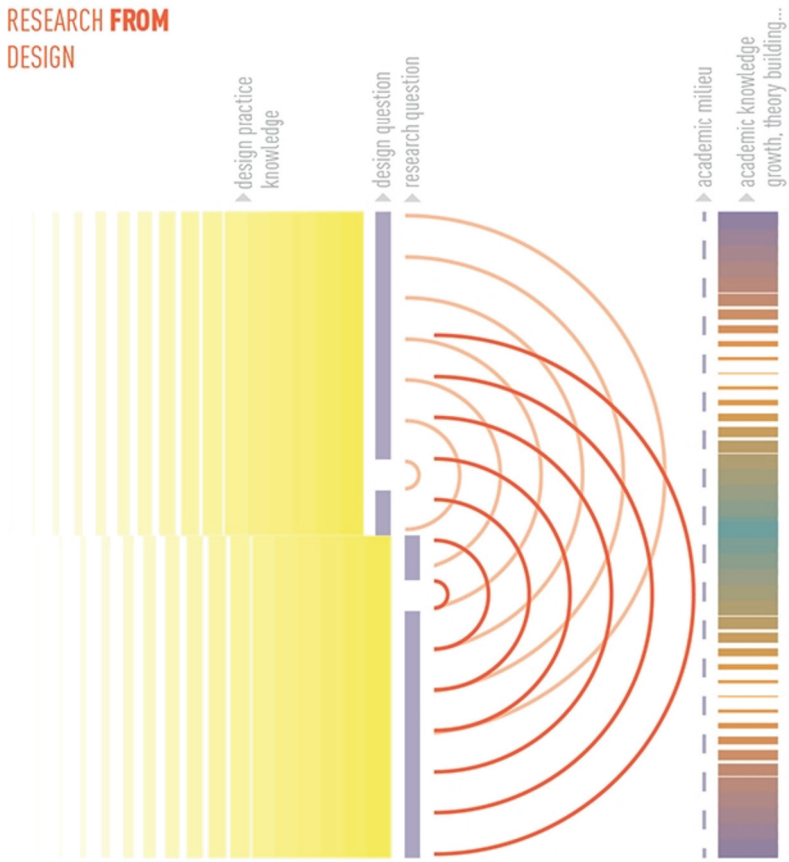

Fig. 6. Research FROM design analogy @Authors

While the work was mainly conducted with the objective of developing innovative tools for science communication, the process itself confirmed how design thinking can contribute to enhance multidisciplinary teams' communication and idea generation. Design can leverage analogies to explain complex concepts in a relatable and understandable way, making research more accessible and appealing to design educators, students, and practitioners. By using analogies creatively, design can make a significant contribution to science communication and help bridge the gap between academic researchers from different fields and with the wider public. Another feature of design thinking is the use of drawing as a way not only to communicate but also to support the thinking process. In the explored example, it was clear that during the process of thinking and discussing illustrations the argument became clearer. Additionally, the importance of joining analogies and imagery was reinforced.

Through our three step example, we venture into the realm of design-driven science communication, unveiling the art of crafting captivating narratives. The next step is to validate the developed visual analogy with a group of design academics, educators,

practitioners and doctoral students, and thereby contributing to the consolidation of three categories of design research and our proposed category of Research FROM Design.

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