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A Case Study Exploring the Role of Design in Maturing University-Developed Technology

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Abstract

Universities struggle to commercialise scientific research. However, designers can help scientists bridge the research-market gap in different ways. Although the value design can bring to science is understood, how design outputs deliver value to scientific research remains unexplored. Our paper reports findings from a designer-scientist collaboration developing a graphene-based water desalination technology. By reflecting on this case study, we found that design outputs serve different purposes in developing technology and assist in progressing technology maturation efficiently.

Keywords: technology development, product development, collaborative design, designer's skills

1. Introduction

Technological innovation is invention taken to market (Chesbrough, 2003). This transition to market requires implementation and adoption, usually in the form of new products accessible to mass consumers. In industry, the exploration of commercial opportunities for emerging technologies and the generation of design concepts to exploit such opportunities are activities within the product development process and usually done by multidisciplinary teams that combine marketing, design and engineering skills (Eppinger and Ulrich, 2015, pg. 3). Although other skills may also be required depending on the type of product to be developed, designing for targeted users is an essential element of new product development, and designers play a crucial role in such a process. In universities, however, recognising opportunities for new technologies is less multidisciplinary than it should be; scientists are sometimes expected to push technologies to market on their own but tend to misunderstand users and industry needs (Zappe, 2013). Such disconnection with users could be mitigated by leveraging design-thinking and user-centred design. Additionally, while design methods can bring benefits to commercialising technology, other challenges restrain technologies from reaching the market. For example, the vast resources required for developing technologies are critical elements that hinder university technology commercialisation (Wessner, 2005). Likewise, a recent study indicates that scientists had limited product development knowledge and didn't tend to collaborate with other non-science disciplines (Mesa, 2021). The resulting gap between research and market is called "the valley of death", a place where many scientific research projects perish and are not commercially exploited (Wessner, 2005).

Nevertheless, not all scientific innovation perishes. The valley of death can be bridged. Some countries like United States, Israel and South Korea have programs that help technologies reach market by connecting multiple stakeholders, providing funding for development and giving business and technical support. For example, the US NSF I-Corps helps researchers understand entrepreneurship and industry barriers and requirements and has helped many scientific innovations reach the market. However, some of such programs require substantial investments and government support.

A better understanding of how design activities support technology development could help identify alternative ways to push research to market in instances where government programs or funding are limited. Thus, the paper foci is exploring how design methods can assist technology development in universities. While the value to science of collaborating with designers is known, the way in which certain design activities can deliver this value is not yet reported in the literature. Hence, this paper reports findings from a collaboration case study between the lead author, a product design engineer, and a nanophononics scientist developing a water desalination technology. By reflecting on this case study, our paper aims to identify how design outcomes communicate potential benefits outside the laboratory to demonstrate technology maturation.

The paper is structured a follows. First, we survey literature on the topic of design science collaborations to outline key types of contribution design can make. These key topics define the areas to explore in the case study. Next, the context of collaboration is explained, followed by an overview of the information gathered during the case study and the design outcomes investigated. Key findings are presented and then discussed, reflecting on implications for future collaborations and areas for further research.

2. Background

2.1. Design's Contribution to Scientific Research Commercialisation

Although recognising commercial opportunities for technologies remains a challenge in most university scientific research, case studies of designer-scientist collaborations have shown involving designers can help push technology to market.

The contributions design can bring to science are suggested from each discipline's different aims and methods; as Simon (1969) explains, while design focuses on creating what does not exist, science, on the other hand, focuses on understanding what already exists. Roozenburg and Eekels (1995) support this idea arguing that the design methodology uses the knowledge generated by science to transform the world we live in. This complementary principle explains why designers are useful in the commercialisation of scientific research. While scientists are trained to generate knowledge by experimentation, designers are trained to be creative and innovative when solving problems and creating artifacts for the human-made 'artificial world' (Cross, 2001).

Design contributions to science are evidenced in different aspects of technology development. **First, existing works have reported that designers help identify plausible applications to connect technologies to suitable markets.** This can be achieved through; stimulating creativity via problem reframing and visualisation (Rust, 2004), market research (Design Council, 2015, Driver et al., 2011), facilitating creativity workshops (Design Council, 2015, Mesa et al., 2020) and prototyping (Page and John, 2020, Thong and Kuys, 2012). Exploring many opportunities to exploit emerging technologies is crucial for introducing technologies to market; more options enrich the selection process and facilitate innovation, allowing a more careful use of the vast resources needed to develop a new product (Brem and Voigt, 2009). As successful technology companies explore opportunities broadly, and designers have shown to be good at it, it is evident that designers' contributions can help address some of the challenges of developing university technology (Mesa et al., 2019, Mesa et al., 2020).

Second, designers also help demonstrate technology performance outside laboratory settings in the context of products through prototyping. Designers can create prototypes with different levels of complexity depending on the purpose they are made for and its stage in the product development process (Camburn et al., 2017). As Camburn et al. (2017) explain, prototypes can be used to learn more of a problem or for exploration, refinement, or communication. Their level of ambiguity can also determine how they are used and their benefits to idea generation (Ranscombe et al., 2019). This flexibility design prototypes offer supports scientists and technology development regardless of how mature technologies are (Moultrie, 2015). Furthermore, demonstrating performance with prototypes can convince potential investors by demonstrating the maturity of technologies (Moultrie, 2015), ultimately enhancing commercialisation potential (Driver et al., 2011).

Third, design offers an opportunity for end-user engagement and assists collaborations. The contributions to science are not only related to designers' ability to sketch or create prototypes. Designers' understanding of user needs, ideation skills and ability to communicate with multiple stakeholders throughout the technology commercialisation process can obtain funding for further technology development (Design Council, 2015). Thus design outcomes can act as translators of complex information between multiple stakeholders and facilitate multidisciplinary research and collaboration (Simeone et al., 2016, Simeone et al., 2017).

Finally, design demonstrates value beyond the advancement of science. It demonstrates the value of technology to people. Studies have also shown that presenting demonstrators of technologies still under development to the public helps understand end-users concerns, fears and needs; this conversation that prototypes enable helps refine the development of the technology (Lüneburg et al., 2020).

2.2. Design's Role Within Technology Maturation Frameworks

The design process' opportunity recognition and concept generation phases rely heavily on the broad consideration of ideas (Design Council, 2019, Eppinger and Ulrich, 2015, ch.3). One of the most common tools designers use for this purpose is sketching, which facilitates iteration using minimal resources (Yang, 2009, Ranscombe and Bissett-Johnson, 2017). Additionally, sketches are an excellent tool for communication, as they can carry information about the form, function and materials of the concept visualised. So relevant is this tool to the initial design phases that correlations have been shown between the number of concepts explored by sketching with the quality of design outcomes (Yang, 2009). Moreover, sketching facilitates the creation of prototypes by providing visual references to the objects and elements to be constructed (Yang, 2009). This connection with the creation of prototypes is essential to developing universities technologies, as research has shown that designers' creations can demonstrate the value of technology outside the laboratory environment (Moultrie, 2015), which, as Mesa et al. (2019) argues, is one of the most crucial aspects bridging the valley of death. Research that can't be demonstrated outside the laboratory doesn't give confidence to investors, and without money, subsequent stages of the product development process can't be funded.

There are different ways to assess the maturity of a technology. Still, the most commonly used model for this purpose is the Technology Readiness Levels framework (TRLs) developed by NASA in the 90s (Mankins, 2009). Although the TRLs were initially created to assess technologies in the aerospace industry, they describe general objectives that technologies need to reach a new level of maturity on a scale from 1 to 9 that have been applied to other industries. For example, a technology proven to work only in the laboratory on such a scale obtains a level of 4. In contrast, a demonstration of an application of that technology outside the laboratory is assessed as level 6 (Mankins, 2009). In this model, the subsequent levels require further testing and certification of the technology, which is considered fully matured when it has been proven in aerospace mission operations. This scale is practical and straightforward to use, but because it was intended to be used in NASA projects, it leaves aside certain aspects of technology development that are crucial in other contexts and industries; value proposition, business creation and market adoption. Such aspects are relevant to university technology development as technologies are commercialised through spinoffs or licensing (Minshall et al., 2007).

Unlike the context of NASA, a business opportunity needs to be identified when commercialising university technology. Without demonstrating that technology can work in a determined application, obtaining the resources required to fully develop and commercialise it is challenging, as industry funding is rare in early-stage technologies (Wessner, 2005). It is of great benefit, then, that technologies from scientific research are further matured in universities, with practical applications identified and proved outside the laboratory.

Another technology maturation model called STAM (Science-Technology-Application-Market) is more suited for university technology assessment and determining how design can contribute to university technology development because it also considers the markets in which technologies are used (Moultrie, 2015). This model is composed of four main phases and the transitions between them, for a total of seven stages (see Figure 1). Phaal et al. (2011) explain that a scientific research project needs to produce a particular type of demonstrator to reach a new stage, which can be understood as milestones for maturing emerging technologies. For example, in the Precursor phase, a new theory needs to be demonstrated with enough support of the scientific phenomena (Phaal et al., 2011). Experiments to support such new theories are common in universities and considered fundamental research. Additionally, to reach the Science-Technology transition, a research project must demonstrate the feasibility of such a phenomenon to support a market-directed technology platform (Phaal et al., 2011). Such maturity phase can be considered applied research. The potential to use the technology is shown in the laboratory, even if a route to market is unclear.

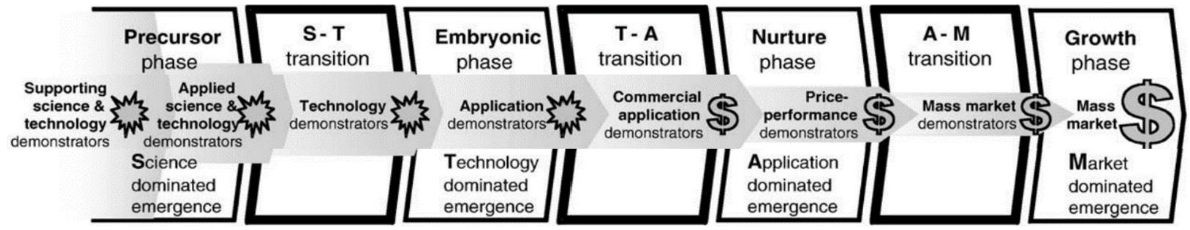

Figure 1. Phases, transitions and demonstrators in emerging technologies (Phaal et al., 2011)

However, to reach the embryonic phase, an emerging technology must be market-directed and demonstrated in a market-specific environment (Phaal et al., 2011). Unfortunately, this is what most scientific research fails to achieve. Nevertheless, as previously explained in this paper, designers have the skill set required to create prototypes to test and display technologies in market-directed environments. A number of researchers present instances where this can be achieved (Thong & Kuys, 2012, Moultrie, 2015, Lüneburg et al., 2020, Page & John, 2020). However, while these examples show positive outcomes from design helping mature technologies, they fall short on giving specific insight on the design activities and their implementation.

2.3. Research Aims

This research examines how design activities in designer-scientist collaborations help demonstrate university technology potential benefits and market readiness. While prior studies have shown that designers can contribute to scientific research, we were more interested in understanding how design outcomes (sketches, prototypes and accompanying documentation) communicate potential benefits outside the laboratory to demonstrate technology maturation. This paper specifically aims to explore the role and inclusion of design outcomes on;

1. Scoping plausible ideas derived from technology;
2. Contextualising technology in market applications; and
3. Progressing maturation of technology.

3. Case Study

The role of design sketches and prototypes assisting the development and communication of scientific research is explored in this paper through a case study. As data we collected images of sketches, 3D models and prototypes created by the designer while collaborating with the scientist. These are defined as design outcomes throughout the analysis as they are the result of different design activities. We also analysed notes and accompanying documentation generated during meetings. Within these artifacts, we analysed how the fidelity of the multiple design outcomes changed over time and how they benefited the technology's maturation. Through this example, we explain how the design-science collaboration occurred and how the designer's work assisted the communication and development of the technology while presenting the outcomes produced. Our explorative research also shows that design skills can benefit scientific exploration and improve experimentation results. Moreover, we use the case study to show that such contributions can help mature scientific research and bridge the market gap. Thus, we propose further research to understand the role of design artifacts in maturing scientific research.

3.1. Context: Development of a Graphene-Based Water Desalinator

Graphene is a single layer of graphite, with its carbon atoms stacked as honeycombs. What makes this material so popular in a wide range of research fields are its outstanding physicochemical properties, such as excellent electric and thermal conductivity, high mechanical strength, specific surface area, among others (Chen et al., 2012). And although pure graphene is expensive and hard to produce, graphene oxide, which contains some oxygenated groups within the carbon structures, is cheaper and can be modified using different methods to highlight specific properties (Chen et al., 2012). This production flexibility makes it useful for water desalination, as scientists can modify (reduce) the material to the desired permeability while having outstanding light absorption. For example, scientists can reduce the oxygen groups by using a powerful flashlight over a graphene oxide film, leaving behind a highly dark material with nanopores (Zhang et al., 2019). In this case, the pores would facilitate light absorption and work as a filter allowing water vapour to go through it, but not other water contaminants.

The collaboration we describe in this paper took place at Swinburne University of Technology between the lead author (a product design researcher and practitioner) and a nanophotonics scientist. The designer was researching processes to develop university scientific research into commercially-viable technology. The scientist was studying the potential of a graphene-based material to desalinate water. When the collaboration occurred, the nanophotonics scientist's research was showing promising results for desalinating seawater. Thus, the technology was entering the Science-Technology transition in the STAM model. It could potentially work in a market-directed product, but such a product had not been yet identified. The designer assisted in designing and constructing a prototype to demonstrate the technology outside the laboratory. Unfortunately, other activities beneficial for commercialising technology, such as market research, analysis of the intellectual property and commercialisation opportunities, technology roadmapping and concept scoring, as recommended by Mesa et al. (2019), could not be conducted due to time and resources constraints. Thus, the collaboration focused entirely on proposing design concepts that could show the technology working in a public setting and that could be built within four months.

3.2. Collaborative Design Process and Outcomes

The case study was analysed using notes taken during meetings, photographs of sketches used in the collaboration, images of the CAD models and pictures of the prototype. A general timeline of the activities conducted is presented below in Figure 2. During the first month of the collaboration, the designer and scientist met once a week to define the demonstrator's technical requirements, and a design brief was produced. During such meetings, the designer used sketches to facilitate the discussion and help brainstorm ideas. After a concept was defined, the designer produced 3D models in the second month to refine the design and make sure it could be prototyped with the university equipment in the timeframe required. Next, digital images of the model were shown to the scientist for approval. Then, materials were purchased at the end of the second month. The third month was used mainly for the prototype's construction, and pictures were taken to record the process. Once the construction was completed, the prototype was given to the scientist for testing. Finally, after the device proved to work, it was presented at a conference as planned, where more pictures of it working outside the laboratory were taken. Notes from interacting with the scientist, sketches, images of the prototype and feedback during the conference are the outcomes that are reflected on/analysed in the subsequent section.

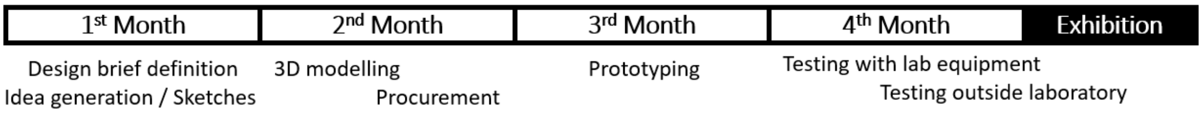

Figure 2. Collaboration timeline and activities conducted

4. Findings

The section below describes the design outcomes produced; sketches, CAD models, design visualisation and photographs of the water desalination prototype used as a technology demonstrator. Then, it analyses how those outcomes 1) scoped out plausible ideas for demonstrating the potential of the water desalinator technology, 2) contextualised technologies in a market-directed application, and

3) progressed the graphene-based technology maturation from a precursor phase of maturation — being only tested in the laboratory— to an embryonic phase, where the technology worked reliably outside the laboratory. The findings are presented by explaining the design process through the author's self-reflection on the collaboration and are compared with the contributions of design to scientific research previously presented in the literature review.

4.1. Scoping Out Plausible Ideas for a Water Desalinator

The designer used sketches to brainstorm and communicate his ideas during the collaboration meetings in the first month, which evolved from lower (Figure 3) to higher fidelity (Figure 4). These sketches teased out what desalination devices and applications were plausible based on the results of the scientist's experiments and spotlighted, through concurrent discussion of the design concepts, the material's limitations, such as the size of filter that could be produced with the existing lab equipment. This demonstrated Yang's (2009) argument that the sketching process provides visual references to improve design outcomes, enabling a more precise judgement of the material-prototype compatibility. Next, the designer created CAD models of the preferred design concept (Figure 5) in the second month.

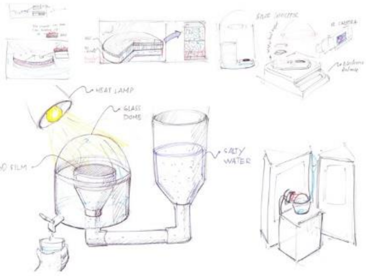

Figure 3. Basic Sketches

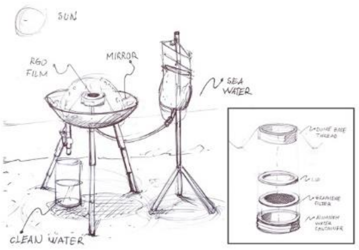

Figure 4. Detailed Sketch

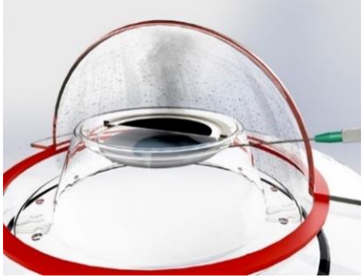

Figure 5. CAD Model

Figure 6. Initial prototype

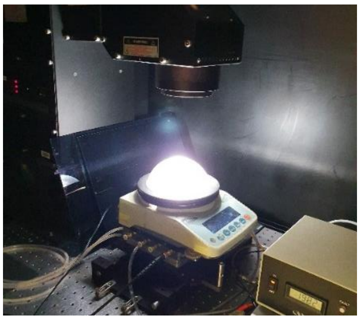

Figure 7. Final prototype 1

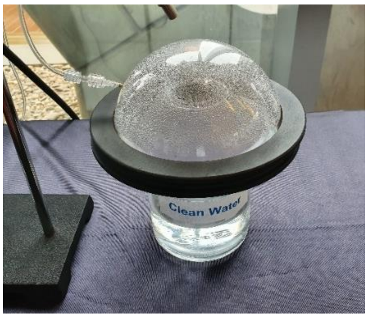

Figure 8. Final prototype 2

By modelling design details, the designer could test viability as critical elements of the design were visualised in a manner that the necessary scale, materials and manufacture process became somewhat defined. Thus, the 3D model allowed judgement and refinement to be made. Since the prototype would be built in the university, the workshop equipment determined fabrication constraints that affected the 3D model, such as the size limit of the thermoforming machine required to create the artifact's chambers.

The designer used existing medical equipment in the design concept that would not be part of a final product. Using existing components facilitated the construction of the demonstrator and saved resources as all the parts didn't have to be built. This meant that a lower fidelity prototype could be produced faster and cheaper than a final product while still demonstrating the essential function of the design. For example, an enema bag for colon irrigation stored the seawater, while an intravenous system with a needle served to control the seawater input into the evaporation chamber inside the dome (Figure 5). The designer constructed the prototype (Figure 6) in the third month. By building the prototype, the designer and scientist clarified assumptions about how the new material could be applied in a commercial product. Unexpected construction issues, such as the sealing of the evaporation and condensation chambers, were also resolved thanks to the fidelity achieved. This further scrutinised the idea for product feasibility. Next, the scientist tested the material properties in the prototype (Figure 7 and 8) in the final month, which validated the design concept proposed. The prototype produced was then exhibited at a conference and presented to the public at Swinburne University of Technology. It helped communicate to the public how the technology worked, its potential impact and its maturity by desalinating water during the exhibition (Figure 8).

These design outcomes further support prior research (Thong and Kuys, 2012) that design methods help explore potential applications for new materials and demonstrate the technical feasibility of specific applications (Moultrie, 2015). In addition, the process of producing these outcomes, from sketches to prototype, also support prior research (Simeone et al., 2017, Simeone et al., 2016, Lüneburg et al., 2020) about the ability of design techniques to translate complex information. In this case, the communication of the working principle of the graphene-based material to the general public. Similarly, the research supports Page and John (2020) findings that prototypes save time and technology development costs and provide a tactile experience to communicate a real-world application to end-users and potential investors.

4.2. Contextualising the Graphene-Based Water Desalinator in a Market-Directed Application

Collaboration with the scientist applied the laboratory-based material into a market-directed application to be shown outside the laboratory. The scientist hypothesised that the graphene-based material could perform in a commercial water desalinator. However, although he wanted to show the progress of his research in an exhibition, he couldn't do it without laboratory equipment. This is where the designer's capability and process brought a lens of realism to the technology under development. The designer showed that the technology could operate outside the laboratory by working with the scientist through sketch design and prototype testing. The range of low to high fidelity prototypes demonstrated what Moultrie (2015) argues; different design outcomes can demonstrate different aspects of emerging technologies. The data obtained in the laboratory test showed that the working prototype achieved the highest desalination efficiency ever registered to the date in that type of device configuration. The laboratory results of the material and prototype are currently under review in a scientific journal.

This collaboration also demonstrated the advantages of leveraging the individual skillsets of the scientist and the designer in bringing an aspect of realism to laboratory-based scientific inventions. In this case, how the water desalinator working prototype showed market-directed applicability for the lab-developed graphene-based material. Cross (2001) argues that scientists are skilled at generating knowledge through controlled experimentation, whereas designers are skilled at using divergent thinking to create artifacts that users can adopt. In this project, the scientist relied on the designer's skillset to ideate and create a working prototype to demonstrate the applicability of his experiments. In contrast, the designer relied on the scientist's skillset to test the working prototype to laboratory/technical standards. This case study adds to Driver et al. (2011) findings that working prototypes test the viability of scientific technology and extends the argument that working prototypes may even provide a reliable medium for scientists to test and report in scientific journals.

4.3. Progressing Laboratory-Based Technology Towards Market Readiness

Collaborating with the scientist also accelerated, to an extent, the maturation of the water desalinating technology to become more market-ready through three means: 1) scoping of plausible demonstrator designs, 2) using minimum viable outcomes to transform ideas into demonstrators, and 3) expediting the transition stage of the STAM model (Phaal et al., 2011) by focusing on the embryonic phase.

Firstly, the sketching and ideation of design concepts, which involved both designer and scientist, scoped out potential demonstrators for the technology. While the designer focused on showing what the material could be used for through sketches, the scientist offered instant feedback on what the concept had to be for the material to work. In other words, divergent and convergent thinking occurred concurrently during the project meetings. At the start of the project, this helped define design specifications, and then these conversations served to evaluate the viability of the concepts. Our case study showed similarities to a design-science collaboration described by Driver et al. (2011) and later by Moultrie (2015). Even if scientists working in applied research may have a general idea of how their technology could be applied, they struggle to integrate their research findings into a product that could work outside the laboratory. Rather than exploring applications for the scientist's technology, the designer's role, in our case study, was better suited at scoping out feasible prototypes that would demonstrate the viability of the scientist's technology to work in the context he had envisioned.

Secondly, while the scientist initially had an idea for applying the graphene-based material, the design process produced design outcomes of progressive fidelity that transformed that idea into a plausible market-directed application under four months. Rather than exploring a range of ideas and investing in multiple prototypes, the designer and scientist had to approve each design outcome (sketch, CAD model and prototype) before proceeding to the next phase. Due to time and budget constraints, the designer and scientist had to strategically choose minimum viable prototypes. In this case, the combination of practical and technical knowledge accelerated the construction of the technology demonstrator, which aligns with Page and John (2020) findings that designers help scientists save resources when demonstrating the maturity of technologies. The designer's ability to adapt to different design constraints supported Moultrie's (2015) findings that designers can produce demonstrators in any technology maturation phase. Not only has the collaboration helped the scientist prepare the technology to work outside the laboratory, but it shows that the working prototype serves the scientist as a means to assess and benchmark the technology's performance in a market-ready setting.

Thirdly, the graphene-based material developed by the scientist, which could be classified in the Precursor phase of the STAM model and entering the Science-Technology transition (Phaal et al., 2011), jumped to an early Embryonic phase, if judged on how the technology could be demonstrated. This occurred only through the collaboration between the designer and the scientist. Without the designer, the scientist would need to show how the material could be integrated into a working prototype (S-T transition) and then find a market-specific environment to demonstrate the technology application (Embryonic phase). By working together, the designer and scientists combined the Science-Technology transition and the Embryonic phase. As a result, the scientist was able to integrate the material within a working prototype that the designer created to work within a market-directed environment within a few months.

5. Discussion

We achieved the aim of this explorative study by explaining how different design outcomes that resulted from the different activities in the collaboration assisted the maturation of technology originating from scientific research considering the three aspects outlined in Section 3. However, there are some limitations of our findings and some opportunities for further work. Although the STEM model served as a valuable tool to assess the maturation of the water desalinating technology, it does not provide enough guidance to determine which activities should be conducted to create the demonstrators in each of the maturation phases. We found that although the working prototype created allowed testing the water-desalinating technology in real conditions and displaying it to the public, it was still unclear how such technology could be commercialised to reach customers. Thus, although the collaboration suggested how a product could perform in the market, other activities from business and manufacturing would be required for commercialisation.

Additionally, we learned from this study that designers should not take full responsibility for idea generation or scientists for improving the technical performance of the technology. As Rust (2004) stated, designers ability to visualise future scenarios can stimulate scientists' creativity and idea generation. We evidenced in the case study that design sketches and 3D models facilitated discussions between both disciplines and opened the door to gather the scientist's feedback. Similarly, the designer's skills not only served to create a physical prototype. The thermodynamic properties within the prototype created helped the technology achieve a higher water desalination performance.

Based on our case study, we believe that an earlier collaboration between the designer and other disciplines could substantially impact the project's potential for commercialisation. There are existing works that suggest specific activities to support the development of university technologies (Mesa et al., 2019). However, the constraints of time and resources forced the project to evolve quickly from an idea to a physical prototype. Thus, further case studies are required to validate the impact of missing activities. Also, as this work was explorative, it is hard to generalise the results.

Thus, to corroborate the findings, it is important to determine to what extent a demonstrator that followed the activities proposed by Mesa et al. (2019) would be perceived differently by the public. A survey during exhibitions, for example, can gauge the public's opinion on demonstrators produced using frameworks for design-science collaborations. A control group of demonstrators produced only by scientists would be required for such a survey. Alternatively, interviews would also be critical to consider the scientist's perceived contributions of the designers to the maturation of their research projects. Although this study showed that design-science collaborations could progress technology maturation, more work is needed to understand variables in the design activities (fidelity of prototypes and timing of design activities), the consequences of this 'accelerated' maturation, and ultimately the value of such collaboration. In-depth case studies of longer collaborations and in a range of scientific fields should be analysed to achieve this.

6. Conclusions

Throughout this paper, we have explained that, although there is a large gap between research and commercialisation in universities, research has shown that designers can provide substantial contributions to technology development. Still, we wanted to know how specific design outcomes could help progress university technology development as this detail is not discussed in extant literature.

We achieve this by presenting an explorative case study of a designer-scientist collaboration developing a graphene-based water desalinating technology. We found that design sketches of low fidelity facilitated the quick exploration of multiple plausible applications and served as a platform to obtain the scientist's feedback on technical feasibility. Thus, the sketches enabled both divergent and convergent thinking in the designer and scientist. As the design concepts increased on fidelity, they allowed a deeper analysis of the integration with the technology, considering existing components that could be used, components that had to be built and the manufacturing processes required for their construction. Prototypes were shown to demonstrate how the technology could work in a market-directed platform, and they increased the water-desalinating performance previously obtained by the scientist in the laboratory. Based on the STAM model, the technology progressed from a late Precursor phase to an early Embryonic phase, completing the transition between Science to Technology.

On reflection, we believe the collaboration could have been more significant in the early stages of technology development. Doing so would have allowed paying more attention to potential markets where the technology could be commercialised and how it would be presented during the exhibition. Further research will expand this study into multiple case studies exploring such factors and further validating the contributions of design activities in university technology transfer.

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