CROWDSOURCING ENGINEERING DESIGN PROBLEMS: LEARNING FROM EXPERIENCES

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ABSTRACT

The availability of digital data in the fourth industrial revolution brings different trends with new opportunities and challenges for the engineering design community. As an opportunity, these trends would impact engineering design. However, the challenge is finding applications for these trends in engineering design. Crowdsourcing is one of the trends inspired by digital data. It is outsourcing an individually performed task to be mass-performed. This paper explores the application of crowdsourcing in identifying engineering design problems. Identifying an engineering design problem is an aspect of engineering design considered challenging but necessary for inventions. Secondary data from 63 invention-related cases and an interview with a renowned UK inventor are presented. The data contains scenarios on how the engineering design problems solved to qualify for a UK patent grant or application are identified. Lessons from the case studies are presented and discussed, especially regarding crowdsourcing engineering design problems. These seem to be promising ways of supporting the identification of new engineering design problems with inventive benefits once solved.

Keywords: Design engineering, Crowdsourcing, Early design phases, Digital Data, Problem-exploring

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1 INTRODUCTION

The trends and technologies in the fourth industrial revolution (4IR) are believed to impact engineering design (Crawford, 2018). Crowdsourcing is one of the emerging trends in the 4IR with potential usefulness in yet-to-be-identified areas (Neiat and Bouguettaya, 2018). It could be defined as outsourcing an individual task to be mass-performed by random and unspecified people (Howe, 2008). Increasingly, crowdsourcing is being used to accomplish challenging tasks using the power of the crowd (Naderi, 2018). In engineering design, crowdsourcing has been used for idea generation, product development and innovation (Han et al., 2020; Forbes et al., 2020, 2019). However, an unknown or unobvious engineering design problem (EDP) of global benefits could also be discovered through crowdsourcing. Some engineering design problems are obscure and not easily perceptible (Getzels, 1979), albeit of societal benefits once solved. Identifying unobvious EDP could be challenging, primarily when intended, as suggested by studies (Kershaw et al., 2019; Grigorenko, 2019). Most EDPs are discovered when unintended and could be described as serendipitous (Obieke et al., 2023). Serendipity is discovering a concept or something others may be searching for by chance (Darbellay, 2020). Hence, on the one hand, individuals and corporations are looking for an EDP to solve. On the other hand, some unspecified individuals have discovered useful EDPs by chance, professional observation or involvement and lack the will or capability to explore solutions. The discovery of an EDP largely depends on knowledge, experience, and background (Hubbell et al., 2010). "The amount of knowledge and talent dispersed among the numerous members of our species has always vastly outstripped our capacity to harness those invaluable quantities. Instead, it withers on the vine for want of an outlet. Crowdsourcing is the mechanism by which such talent and knowledge is matched to those in need of it. It poses a tantalizing question: What if the solutions to our greatest problems weren't waiting to be conceived, but already existed somewhere, just waiting to be found, in the warp and weave of this vibrant human network?" (Howe, 2008).

This study aims to highlight the use of crowdsourcing in discovering/seeing important and unobvious or unknown EDPs, an unexplored research area. Secondary data from 63 cases of individuals who have discovered useful EDPs are reviewed, analysed, and presented. The cases are selected based on data availability and inventions granted or awaiting United Kingdom (UK) patents. An "invention must represent a practical solution to a problem" (NIPO, 2022). Hence, the analysis of the cases focuses on the problems discovered and the circumstances/contexts of the discovery. The secondary data is validated with primary data obtained from an interview with a renowned UK inventor. Essential lessons from the cases are presented and discussed, especially regarding crowdsourcing and computational EDPs. The results from the analyses of the cases suggest that crowdsourcing and computational EDP could support the discovery of new and vital EDPs of societal benefits. The EDPs could be obscure and would otherwise remain undiscovered without an effort, as presented in this study, to discover them. Also, as mentioned in this study, innovations and inventions would continue to be incremental/delayed if the neglect of finding unknown EDPs continues.

In the following section, a literature review of the sources of EDPs is presented. The presentation includes market pull and technology push. The previous crowdsourcing applications in engineering design are also reviewed, especially at the early stage. In Section 3, the data sources in this study are presented. The section includes the primary and secondary data used in this study and how they are analysed to obtain helpful information. The study's results are presented in Section 4, which provides insights into how EDPs are identified besides market pull and technology push. A detailed discussion of the results is presented in Section 5. The study is concluded in Section 6, including its future direction.

2 ENGINEERING DESIGN PROBLEMS AND SOURCES

The early stage in engineering design activities involves conceptualising, identifying, and solving an EDP (Olewnik et al., 2020; Vale et al., 2020; Molecke and Pache, 2019). The closeness of these activities makes them appear to be the same process, albeit distinct. Once an EDP is perceived, spontaneous/random ideas towards the solution or its benefits occur. Usually, those initial random ideas differ significantly from the final solution. The process of engineering design problem-solving has received significant research focus. On the contrary, the equally important process of conceptualising, discovering, and identifying an EDP is significantly less researched or ignored (Obieke et al., 2020; Ding et al., 2019; Einstein and Infeld, 1938).

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An EDP could be "any important, open-ended, and ambiguous situation for which one wants and needs new options and a plan for carrying a solution successfully" (Treffinger, 1995). Hence, albeit they have substantial potential societal benefits (Revell and Andersen, 2021), an EDP is not necessarily a situation, occurrence, or threat that needs urgent attention to fix in the general sense of the word "problem" (Isaksen and Treffinger, 1985). There are two popular approaches through which EDP could emerge. One is based on a market pull, and the other is on a technology push. A market-pull-based EDP refers to a noticeable or emerged EDP for which society needs a solution (Du Preez and Pistorius, 1999). An EDP resulting from a market pull develops over time (sometimes unnoticed), leading to reactive, incremental, or delayed innovation (Heikkilä and Heikkilä, 2017). Technology-push-based EDP refers to an EDP resulting from the search to apply radical or breakthrough solutions elsewhere (Arifin, 2019; Sutherland, 2019). When an unexpected solution occurs in a field, it usually inspires the search for problems the solution could address in other areas. Hence, an EDP identified through a radical solution application-induced search could be regarded as a technology-push-based EDP. Albeit a technology-push-based EDP is usually obscured and not obvious, it is of societal value once solved. An EDP resulting from a technology push leads to a proactive and "radical" innovation (Brem and Voigt, 2009). Hence, the nature of an EDP solved correlates with the solution to be realised (Obieke et al., 2021).

Apart from the market pull and technology push, an EDP could emerge through conscious conceptualisation. It can also emerge through serendipity and apophenia phenomena. A consciously conceptualised EDP could be called a "created" or "discovered" EDP (Getzels, 1979). A created EDP would remain unknown or not exist if not conceptualized and translated as an apparent EDP. It is without any known formulation, method of solution, or solution. A discovered EDP exists, is identified by oneself, and may or may not have an existing formulation, method of solution, or solution. Serendipity is a natural phenomenon related to unintendedly discovering an EDP (Mednick, 1962). An EDP discovered momentarily through serendipity could otherwise take years to discover or be known (Ishikawa, 2010). Usually, serendipity discovery is triggered by an observation which coincides with experience, knowledge, and personal background. Serendipity could contribute to innovation and invention (Hubbell et al., 2010; Dawes et al., 2006). Apophenia is another phenomenon related to the discovery of an EDP. It could be described as a natural ability to associate unrelated or random data and produce a meaningful concept (Thaler, 2020). A "created" EDP could emerge through the apophenia phenomenon leading to an "invention: creating new, previously unimaginable meanings through accident" (Revell and Andersen, 2021). However, conceptualising or discovering an EDP for which no solution exists, mainly when intended, is considered "difficult" (Kershaw et al., 2019). Studies suggest that conceptualising or discovering an EDP is relatively more difficult and time-consuming than conceptualising an engineering design solution (Harris and Zeisler, 2002; Fischer, 1994). A conscious effort to conceptualise or discover an obscure, unknown, and unspecified EDP, independent of any problem-solving, is distinct from encountering a constraint in creatively or innovatively solving an EDP.

Crowdsourcing EDPs

Crowdsourcing could have many benefits for identifying EDPs, as a difficult task. This approach could be a way forward in rapidly discovering technological breakthroughs. Crowdsourcing is applied "to solve a problem that needs basic human intelligence" (Naderi, 2018). According to Gao et al. (2015), crowdsourcing "is used primarily for complex or expensive problems that may be solved efficiently by dividing tasks between different participants who each have a different set of resources or expertise." The role of crowdsourcing in the 4IR is studied by Vianna et al. (2020), who state that the use of crowdsourcing in searching "for solutions to problems, innovation and product development" is increasing. The study identifies five areas of application of crowdsourcing in the 4IR. Three of the five areas are directly related to engineering designs and are 1) product development, 2) innovation, and 3) problem-solving or problem-troubleshooting. As cited in the study, "reduced costs and the expansion in the reach of ideas and perceptions" are reasons for using crowdsourcing in the 4IR. Crowdsourcing uses the collective power of random and unspecified individuals forming a crowd. As acknowledged, individuals within a crowdsourced network could willingly contribute free of charge (Ioniță and Onișor, 2016; Barrington et al., 2011). For example, Wikipedia could be described as one of the biggest crowdsourcing platforms in the world (Makris et al., 2020; Lee and Seo, 2016). Many contributors to Wikipedia do so for free (Fallis, 2008). Despite the increasing and emerging uses of crowdsourcing for problem-solving in engineering design, its use for identifying EDP of societal benefits remains

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unexplored. It is believed in this study that there are significant potential benefits in using crowdsourcing for identifying EDPs to advance innovations and inventions in the 4IR and beyond.

3 METHODS

Qualitative methodology is used in this study to gain insights into how EDPs are identified or discovered (Clark et al., 2021). The secondary data of 63 cases of discovery of valuable EDPs with inventive solutions are descriptively analysed using NVivo qualitative data analysis software. The cases are retrieved from online sources, including innovate-design.co.uk. They contain information from the experience of inventors who have been granted or awaiting a UK patent for the problem they identify and solve. The cases are retrieved and saved as a Portable Document Format (PDF) file and imported into the NVivo software (version 20 Pro). All imported files are opened, inspected, and explored - reading each case report. The relevant lines of words in the files related to the experience of the inventors in identifying the problems solved with their inventions are coded (collected) into a common theme. The coded theme is queried for frequently occurring terms in all the cases retrieved for analysis. The frequently occurring terms in the query are used as keywords to perform a text search to review the sources of the keywords. The keywords are reflected from the sources, and their interpretations are noted. The results of the query are then presented in suitable formats for visualisation. The query results are analysed and visualised in this study using a word cloud and word tree. A word cloud analysis provides a graphical representation of term frequencies. Its use as a tool to identify the focus of text documents is increasing in the public and private sectors (Atenstaedt, 2017). A word tree is used to analyse text documents to provide visualisation and keyword information retrieval to provide contextual meanings (Wattenberg and Viégas, 2008).

In addition to the secondary data, an interview is conducted with a renowned inventor in the UK who holds UK patents with over 40 years of experience in engineering design-related inventions. For confidentiality, the famous inventor is given the code name *Inventor A*. The interview lasted for 40 minutes and was semi-structured (Brinkmann and Kvale, 2018), allowing the flexibility to obtain more details for a response. *Inventor A* provided consent to record the sessions for the research and permission to use their data for publication. The oral answers provided by *Inventor A* during the interview are based on the questions presented in Table 1. The interview is used as a triangulation to validate the information from the secondary data (Gall et al., 1996). The interview responses are transcribed, and helpful information is extracted, corroborating information from secondary data.

Interview Questions

Table 1. Questions used for discussion during the interview

	Discussion Questions
1	What is the basis for your inventive skills? Would you say it is due to your educational background, technical knowledge, or something else?
2	Would you say that identifying the problem is more important than finding the solution to the problem?
3	If you had not had a personal experience or discovered the problem you solved yourself, had someone else presented the problem to you, would you have solved it the way you did?
4	Would you describe the problem you solved as a random/accidental discovery?
5	Do you think others might have faced the same problem you solved but could not offer solutions themselves?

4 RESULTS

Cases analysis: Understanding the discovery of an EDP

A word frequency analysis is performed using the cases of how inventors identify the problems they solved. The coded cases are searched with a criterion to return the 100 most frequent words with a minimum length of three characters to be meaningful. Another criterion used is the word stemming. For example, the terms "helped", "helpful", and "helping" are stemmed from the word "help." The top ten words typically used in analyses (Xue et al., 2022; Hossain et al., 2022; Lee et al., 2018) are selected from the search result. The top ten words are presented in Table 2 with the weighted percentage - the word frequency relative to the total words counted.

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Table 2. Top ten words in word frequency query

Top ten words	they	idea	product	came	moment	problem	time	using	working	needed
Weighted percentage (%)	9.08	1.66	1.60	1.43	0.91	0.91	0.86	0.80	0.80	0.74

While coding the cases of the inventors, their personal and product identities are protected. The reported cases are reworded without impairing the meaning. For example, it is replaced with "they", where an inventor's name is mentioned. Also, the personal pronouns - "she", "he", "I", and "our" are replaced with "they" and "their". Correspondingly, the terms "he was", "I was", and "she was" are replaced with "they were" to maintain grammatical clarity for interpretation purposes. Hence, "they" has the highest weighted percentage of 9.08% of the total words counted. The second word with the highest weighted percentage of 1.66% is "idea." The inventions/products of the inventors are replaced with "product" wherever mentioned in the cases. Using the common pronoun "they" is beneficial in this study. It allows greater insight into the scenario that led to the identification/discovery of the EDP solved by the inventors, as the word tree in Figure 3 shows. Each of the top ten words is used as a root word in a word tree analysis. This helps to understand the context in which the words are used to describe how the inventors identified a problem they solved. All the top ten words give similar results. The contexts of the top ten words are depicted in Figures 2 and 3. For simplicity, the analysis results with "moment" as the root word are presented in Figure 2. The interest is understanding the "moment" that led to discovering a problem/EDP. On either side of the root word, ten words are displayed to understand how the problems the inventors solved are identified.

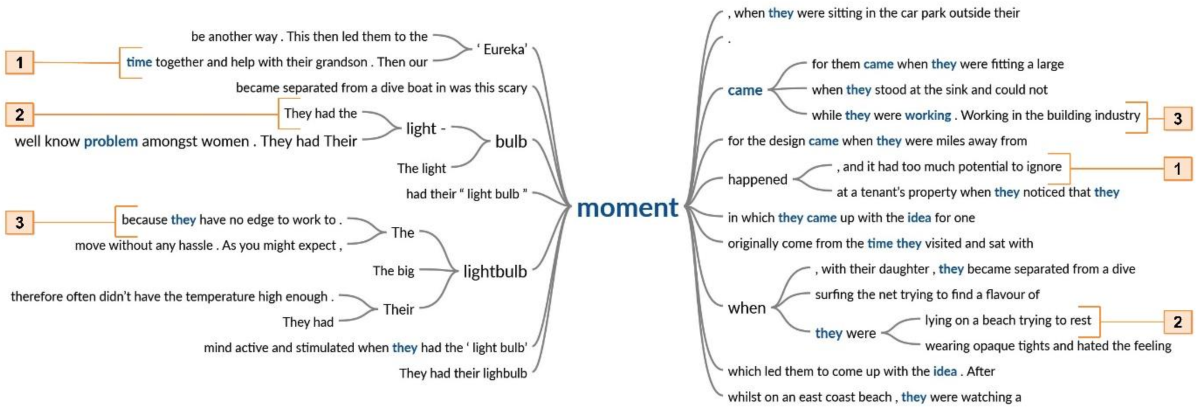

Figure 2. Word tree result showing the "moment" a problem is identified

In Figure 2, the moment a problem/EDP is identified by an inventor in the cases analysed is shown. Three cases numbered 1, 2, and 3 in Figure 2 are randomly selected for explanation purposes. In Case 1, the inventor decided to have "time together and help with their grandson. Then our ‘eureka’ moment happened, and it had too much potential to ignore". In this case, the inventors are not specifically engaged in an engineering design activity when a problem is discovered. In Case 2, the inventor's scenario is, "They had their lightbulb moment when they were lying on a beach trying to rest" or relax. This case depicts a leisure activity where there is no intention to identify a problem. In Case 3, the inventor discovered a problem which exists "because they have no edge to work to. The lightbulb moment came while they were working." This problem is identified due to the inventor's knowledge, experience, and background in the field where they work. Hence, because of their knowledge in that area, they can tell when they see a problem for which no solution or suitable solution exists. A more detailed scenario of the situations that led the inventors to discover a problem is presented in Figure 3. The result is obtained when the word tree analysis is performed with "they" as a root word. Only a section of the word tree results is shown in Figure 3, as the entire word tree could not be presented without impairing clarity. As already explained, using the term "they" is a coding technique used in this study to obtain a detailed result. The scenarios in cases represented in Figure 3 differ. They reflect the uniqueness of individual experience, knowledge, and personal/cultural background that could be

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useful in discovering an EDP. This uniqueness could be explored for crowdsourcing EDP in the 4IR. Although not all the cases presented could be considered an EDP, many are EDP. The same discovery concept generally applies to the discovery of EDPs.

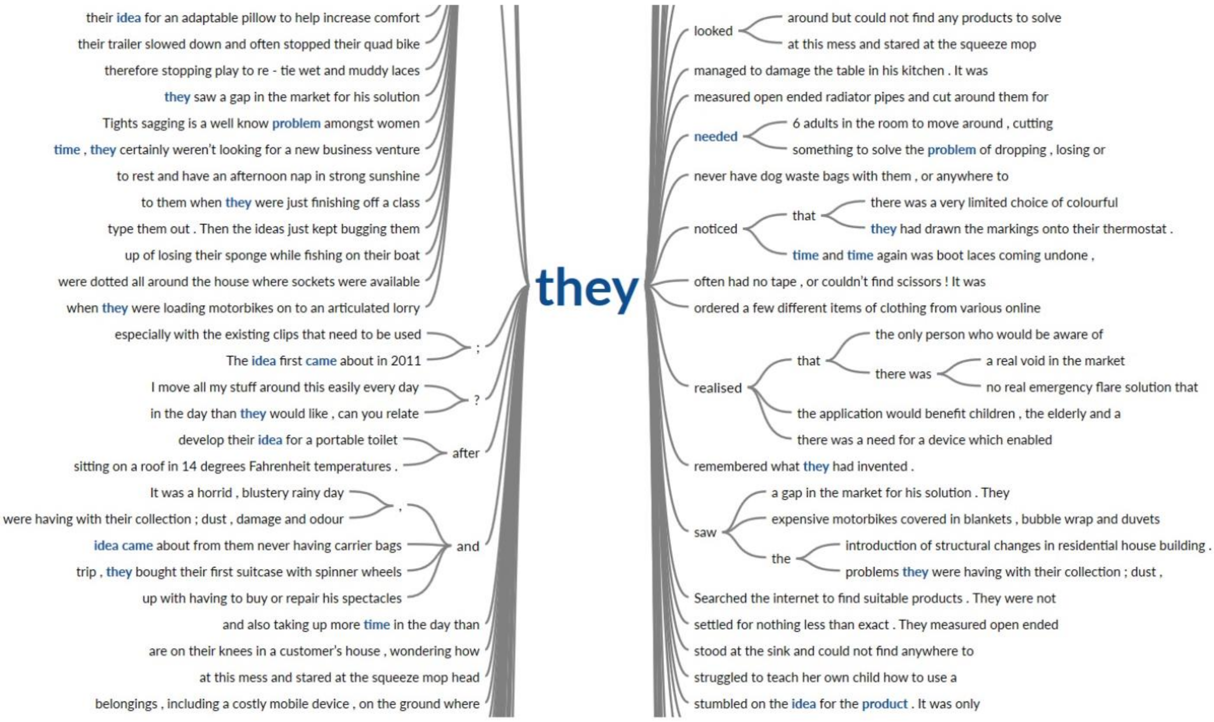

Figure 3. Detailed scenarios of situations leading to the discovery of a problem

Analysis of interview responses

Table 3. Responses from inventor A to interview questions

	Interview Questions and Interpretations of Responses
1	*What is the basis for your inventive skills? Would you say it is due to your educational background, technical knowledge, or something else?* *Inventor A* mentions that their educational background plays a role in their inventive skills, albeit to a smaller percentage. They believe that a greater percentage of their skill in identifying a problem comes from their personal/cultural background. They mention, "I think it's my upbringing and personality that has led me to become the sort of person that sees a problem instead of throwing my hands up in horror, I think well how can I make that better."
2	*Would you say that identifying the problem is more important than finding the solution to the problem?* *Inventor A* responds thus, "I think identifying the problem is the big thing and then it's a question of skills to be able to solve the problem. And, you know, if you need an Engineer or if you need a designer or somebody at that point. But the point is that the Designer or Engineer would not have come up, would not design a solution to that problem until you identify it. So, I think it is identification problem and the understanding of what is actually needed to solve that problem. To me, that is the biggest thing. And, there can be very many ways of solving a problem and engineering is required to the extent of finding what is the simplest and most elegant solution. What is going to be the most practical solution. That is what excites me." The inventor's response to this question points out the early stage engineering design activities - 1) identifying a problem and 2) developing a solution to the problem. These are standard expectations in engineering design (Olewnik et al., 2020; Vale et al., 2020).

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3 *If you had not had a personal experience or discovered the problem you solved yourself, had someone else presented the problem to you, would you have solved it the way you did?*
Inventor A believes that they could have offered the same solution. However, they state that "understanding the problem is key." The inventor further said, with respect to the question, "I wouldn't have the practical experience and understanding of all the issues surrounding that problem. I think that if you had not had that personal experience yourself, I think that if you were to do your homework and really research and speak to people and find out really what the needs are, what the wants are and then you probably are able to come up with the same solution. But, I think that having personal experience is a very powerful and helpful thing to finding the right solution"
This question is asked to understand the effectiveness of a crowdsourced EDP. This is further discussed in Section 5.

4 *Would you describe the problem you solved as a random/accidental discovery?*
Inventor A mentions that they discovered their invention when at a friend's house on a visit. They made an observation that became the "lightbulb moment", resulting in the invention. They mention that while there, "I suddenly realised that is a big problem and it doesn't have to be like that." Further, they mention that "it's not random. I think that it is just seeing the random occurrence triggered memories of my own experience and that's what made it powerful for me to think about it."

5 *Do you think others might have faced the same problem you solved but could not offer solutions themselves?*
The response here is "Yes." *Inventor A* went on to say that there are firms that could have solved the problem before the inventor did, but it just did not occur to them to do it, or they were waiting for people to complain or have tried to solve it and failed. This response points to the delay disadvantage in the market pull and the advantage of technology push or "created" and "discovered" EDP (Section 2). Despite not being based on a market pull, the inventor's product is selling massively in the UK, Europe and the rest of the world.

5 DISCUSSIONS

Crowdsourcing: Learning from experiences

The results presented in this study show the possibility of using crowdsourcing to support the discovery of obscure/unknown EDPs. The evidence presented in this study suggests other sources of EDPs besides the popular market pull and technology push. It is shown in this study that experience, knowledge, and cultural background contribute to the discovery of a new EDP. Also, serendipity and apophenia contribute to discovering a new EDP. These could be seen from the results of the invention cases analysed in this study. In Figure 2, a case of an inventor (Case 1) who identifies a problem while engaged in an informal activity could be described as a serendipity discovery. In Case 2, a problem is identified due to an observation made by the inventor that "they have no edge to work to", resulting in the lightbulb moment of inventive discovery. This case shows that an EDP is likely to be identified in a familiar area of knowledge, experience, and background. A similar scenario could be seen in a case in Figure 3, where a new problem is discovered when the inventor "are on their knees in a customer’s house, wondering how they are going to secure the socket." This is a case of personally encountering a challenge and not knowing how to overcome it. This defines a problem in engineering design, as discussed in Section 2. The primary data obtained from the interview with a famous UK inventor corroborates the information from the cases analysed. In Question 5 of the interview questions in Table 3, the inventor mentions, "I think that it is just seeing the random occurrence triggered memories of my own experience and that's what made it powerful for me to think about it." In the 63 cases analysed, the inventors were able to see a problem when they observed a situation that triggered an active or dormant knowledge in them to act. This suggests that any approach that could increase the chances of individuals, especially design engineers, in seeing potential EDP that could have a useful solution needs to be encouraged. Crowdsourcing is one of the trends in the 4IR that could support the approach. As a reiteration, "The amount of knowledge and talent dispersed among the numerous

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members of our species has always vastly outstripped our capacity to harness those invaluable quantities. Instead, it withers on the vine for want of an outlet. Crowdsourcing is the mechanism by which such talent and knowledge is matched to those in need of it. It poses a tantalizing question: What if the solutions to our greatest problems weren't waiting to be conceived, but already existed somewhere, just waiting to be found, in the warp and weave of this vibrant human network?" (Howe, 2008). Crowdsourcing EDP would encourage individuals who identify a useful EDP and are willing to freely contribute it to a crowdsourcing platform where those with the capability to offer a solution could see the EDP. Using crowdsourcing to highlight important EDPs would enhance opportunities for inventive and innovative solutions.

Infinite knowledge: Collective effort in identifying EDPs of societal benefits

Design engineers and non-engineers could equally identify an EDP. However, it seems that the education and skills of design engineers could be a competitive advantage in discovering a new EDP. The engineering design community is regarded as future technology innovators who identify a problem of societal value and provide a solution (Molecke and Pache, 2019). However, as pointed out in Section 2, research and focus on identifying EDP of societal benefits is lacking in engineering design. Identifying an EDP is a challenging activity, as mentioned in Section 2. It becomes more challenging when there is a purposeful intention to identify any obscure EDP. As reported, "it is difficult to identify a design problem for which no benchmark solutions exist" (Kershaw et al., 2019). However, as reviewed in Section 2, crowdsourcing is increasingly used to support challenging activities. A challenging task such as identifying an unknown EDP could be easier using the power of the collective effort of the crowd. The response to Question 4 of the interview in Table 3 shows the potential benefits of crowdsourcing EDP. Some individuals' strength lies in identifying an EDP, while others' strengths may lie in providing solutions. It is possible that *Inventor A* may not have been the first to observe the problem they solve. The response in Question 4 shows that had someone else identified the problem before *Inventor A* and made *Inventor A* aware of it, the inventor would have offered the same solution. This is because the awareness of the problem would trigger the same potential or dormant solution knowledge in the inventor, even if the inventor may not have had a personal experience or encounter with the problem. This way, the inventive solution would have existed earlier than it did. Although knowledge is infinite (Wood, 2013), it is limited for everyone. Also, knowledge "cannot be measured quantitatively" (Saad and Chakhar, 2010). So, a design engineer cannot precisely determine all the knowledge they have. However, they can recall knowledge when presented with a trigger or prompt for that knowledge. When exposed to a new EDP, there is a tendency to map it to previous knowledge for a solution. In Question 6 *Inventor A* mentions that some firms and perhaps individuals could have offered a similar solution as the inventor. However, it could be that no one made such firms or individuals aware of the problem. This is where crowdsourcing EDP would be helpful to flag obscure problems and prompt solution concepts from firms and individuals with the solution capability.

As mentioned, crowdsourcing is applied in many innovation and solution process tasks. In these applications, an EDP is the process input and how to identify that EDP is not the focus (Wang et al., 2018). As the results in this study show, crowdsourcing can be used to source unknown or obscure EDPs from unspecified individuals who discover, identify, or conceptualise them based on their unique experience, background, and knowledge. These EDPs would drive the creative innovation or inventive process, which focuses on solving an identified EDP.

6 CONCLUSIONS AND FUTURE DIRECTION OF THE STUDY

In this study, the potential of using crowdsourcing to identify obscure EDPs with useful societal solutions is investigated. Crowdsourcing is outsourcing an individual task to be mass-performed by random and unspecified people. As an emerging trend in the fourth industrial revolution, crowdsourcing is increasingly used to support challenging tasks, including identifying solutions in engineering design. Studies suggest that identifying an EDP is more challenging than developing a solution to a problem. However, an investigation into the use of crowdsourcing for discovering obscure EDPs with valuable solutions is lacking. An interview is conducted with a renowned UK inventor. The interview discussion is about how they discovered the problem solved with their inventions. The responses from the interview are analysed, and the results are presented. Also, 63 cases of individuals who hold a UK patent on an invention, are awaiting a patent grant, or have identified a problem are analysed. The analyses focus on

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the scenarios leading to discovering the problem they solved. The results of the analyses suggest that crowdsourcing would be a promising approach to identifying new EDPs. Market pull and technology push are two popular sources of EDPs. However, the results of this study show the discovery of the problems leading to the inventions analysed is not mainly based on a market pull or technology push. Instead, the problems are discovered through personal challenge, observation, and involvement in daily activities. This indicates that the discovery of obscure problems in engineering design results from individual experiences, knowledge and background. Hence, crowdsourcing would enable participating individuals to exchange knowledge, leading to the rapid discovery of obscure EDPs with valuable solutions. This way, innovations and inventions would be expedited.

Unlike innovative solutions to EDPs, crowdsourcing remains unexplored for flagging new, unknown, or obscure EDPs. Future studies would investigate an appropriate structure for a crowdsourcing platform to make vital EDPs apparent, which is lacking rapidly. Albeit available experts limit the interviews for this study, more interviews will be conducted in future studies. A crowdsourcing platform for EDP would globally benefit firms with the solution capability but rely only on the market pull or technology push as sources of EDPs.

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REFERENCES

Arifin, Z. (2019), "How is utility firm dealing with disruptive technologies? An empirical research of Indonesia Electricity Company", 2019 *IEEE Technology & Engineering Management Conference (TEMSCON)*, 2019, IEEE, pp. (1-8).

Atenstaedt, R. (2017), "Word cloud analysis of the BJGP: 5 years on", *British Journal of General Practice*, 67, 231-232.

Barrington, L., Ghosh, S., Greene, M., Har-Noy, S., Berger, J., Gill, S., Lin, A. Y.-M. and Huyck, C. (2011), "Crowdsourcing earthquake damage assessment using remote sensing imagery", *Annals of Geophysics*, 54.

Brem, A. and Voigt, K.-I. (2009), "Integration of market pull and technology push in the corporate front end and innovation management—Insights from the German software industry", *Technovation*, 29, 351-367.

Brinkmann, S. and Kvale, S. (2018), *Doing interviews*, SAGE Publications Ltd, London.

Clark, T., Foster, L., Sloan, L. and Bryman, A. (2021), *Bryman's social research methods*, Oxford University Press, Oxford.

Crawford, M. (2018), "How industry 4.0 impacts engineering design". [Online] ASME Available at: (https://www.asme.org/engineering-topics/articles/manufacturing-design/industry-40-impacts-engineering-design) (Accessed November 22, 2022).

Darbellay, F. (2020), "Serendipity", In: PRITZKER, S. & RUNCO, M. (Ed.), *Encyclopedia of Creativity (Third Edition)*, Academic Press, Oxford, pp. (470-474). https://doi.org/10.1016/B978-0-12-809324-5.23791-7

Dawes, H., Dawes, C., Martin, G. and Macfarlane, A. (2006), "Making Things from New Ideas", *History of Technology* Volume *26*, *2005: Including Special Issue: Engineering Disasters*, 26, 1.

Ding, R., Han, Q., Li, R., Li, T., Cui, Y. and Wu, P. (2019), "Unconscious versus conscious thought in creative science problem finding: Unconscious thought showed no advantage!", *Consciousness and cognition*, 71, 109-113. https://doi.org/10.1016/j.concog.2019.03.010

Du Preez, G. T. and Pistorius, C. W. (1999), "Technological threat and opportunity assessment", *Technological Forecasting and Social Change*, 61, 215-234.

Einstein, A. and Infeld, L. (1938), *The evolution of physics*, Simon & Schuster, New York.

Fallis, D. (2008), "Toward an epistemology of Wikipedia", *Journal of the American Society for Information science and Technology*, 59, 1662-1674.

Fischer, G. (1994), "Turning breakdowns into opportunities for creativity", *Knowledge-Based Systems*, 7, 221-232. https://doi.org/10.1016/0950-7051(94)90033-7

Forbes, H., Han, J. and Schaefer, D. (2020), "A crowdsourcing data-driven approach for innovation", *The International Journal of Systematic Innovation*, 6, 9-19.

Forbes, H., Schaefer, D., Panchal, J. and Han, J. (2019), "A design framework for social product development", *IEEE Transactions on Engineering Management*, 69, 302-313.

Gall, M. D., Borg, W. R. and Gall, J. P. (1996), *Educational research: An introduction*, Longman Publishing, NY.

Gao, R., Wang, L., Teti, R., Dornfeld, D., Kumara, S., Mori, M. and Helu, M. (2015), "Cloud-enabled prognosis for manufacturing", *CIRP annals*, 64, 749-772.

Getzels, J. W. (1979), "Problem finding: A theoretical note", Cognitive Science - *A Multidisciplinary Journal*, 3, 167-172. https://doi.org/10.1207/s15516709cog0302_4

Grigorenko, E. L. (2019), "Creativity: a challenge for contemporary education", *Comparative Education*, 55, 116.
Han, J., Park, D., Forbes, H. and Schaefer, D. (2020), "A computational approach for using social networking platforms to support creative idea generation", *Procedia CIRP*, 91, 382-387.
Harris, S. D. and Zeisler, S. (2002), "Weak signals: Detecting the next big thing", *The Futurist*, 36, 21.
Heikkilä, J. and Heikkilä, M.(2017), "Innovation in Micro, Small and Medium Sized Enterprises: New Product Development, Business Model Innovation and Effectuation", *Bled eConference*, 2017, pp. (36).
Hossain, A., Wahab, J. A. and Khan, M. S. R. (2022), "A Computer-Based Text Analysis of Al Jazeera, BBC, and CNN News Shares on Facebook: Framing Analysis on Covid-19 Issues", *Sage Open*, 12, 21582440211068497.
Howe, J. (2008), *Crowdsourcing: How the power of the crowd is driving the future of business*, Crown, New York.
Hubbell, M., Hard, S., Boots, M., Clarke, M. A. and Smith, J. E. (2010), "Pitch Stability of an Unpowered Ground Effect Vehicle", *ASME International Mechanical Engineering Congress and Exposition*, 2010, pp. (191-199).
Ioniță, D. and Onișor, L.-F. (2016), "Crowdsourcing and Outsourcing: Friends or Foes?", *Journal of Emerging Trends in Marketing and Management*, 1, 52-61.
Isaksen, S. G. and Treffinger, D. J. (1985), *Creative problem solving: The Basic Course*, Bearly, NY.
Ishikawa, A. (2010), "Discovery, invention and serendipity", *Chinese Business Review*, 9, 61.
Kershaw, T. C., Bhowmick, S., Seepersad, C. C. and Hölttä-Otto, K. (2019), "A decision tree based methodology for evaluating creativity in engineering design", *Frontiers in psychology*, 10, 32.
Lee, J. and Seo, D. (2016), "Crowdsourcing not all sourced by the crowd: An observation on the behavior of Wikipedia participants", *Technovation*, 55, 14-21.
Lee, L., Yu, R., Kan, J. and Gero, J. S.(2018), "Exploring the Differences Between Designing and Describing Designing", *Design Theory Research Symposium* 12, 2018,pp.
Makris, C., Pispirigos, G. and Simos, M. A. (2020), "Text Semantic Annotation: A Distributed Methodology Based on Community Coherence", *Algorithms*, 13, 160.
Mednick, S. (1962), "The associative basis of the creative process", *Psychological review*, 69, 220.
Molecke, G. and Pache, A.-C. (2019), "How do we know when social innovation works? A review and contingencymodel of social impact assessment", *Handbook of Inclusive Innovation*, 83-105.
Naderi, B. (2018), *Motivation of workers on microtask crowdsourcing platforms*, Springer, Switzerland.
Neiat, A. G. and Bouguettaya, A. (2018), *Crowdsourcing of sensor cloud services*, Springer, Switzerland.
NIPO - Norwegian Industrial Property Office. (2022), What can be patented? [Online]. Patentstyret. Available at: www.patentstyret.no/en/services/patents/what-can-be-patented (02.02.2022).
Obieke, C., Milisavljevic-Syed, J. and Han, J. (2020), "Supporting Design Problem-exploring with Emergent Technologies", *Procedia CIRP*, 91, 373-381. https://doi.org/10.1016/j.procir.2020.02.189
Obieke, C. C., Milisavljevic-Syed, J. and Han, J. (2021), "Data-driven creativity: computational problem-exploring in engineering design", *Proceedings of the Design Society*, 1, 831-840. https://doi.org/10.1017/pds.2021.83
Obieke, C. C., Milisavljevic-Syed, J., Silva, A. and Han, J. (2023), "A computational approach to identifying engineering design problems", Journal of Mechanical Design, 145, 041406. https://doi.org/10.1115/1.4056496
Olewnik, A., Yerrick, R., Simmons, A., Lee, Y. and Stuhlmiller, B. (2020), "Defining open-ended problem solving through problem typology framework", *International Journal of Engineering Pedagogy (IJEP)*, 10.
Revell, T. and Andersen, K. (2021), "The Telling of Things: Imagining Through, With and About Machines", In: ROZENDAAL, M. C., MARENKO, B. & ODOM, W. (Ed.), *Designing Smart Objects in Everyday Life: Intelligences, Agencies, Ecologies*, Bloomsbury, London, pp. (57 - 71).
Saad, I. and Chakhar, S.(2010), "Aggregation procedure based on majority principle for collective identification of firm’s crucial knowledge", *World Summit on Knowledge Society*, 2010, Springer, pp. (346-352).
Sutherland, B. R. (2019), "Lighting Policies Spur Global Innovation", Joule, 3, 639-640.
Thaler, S. (2020), "The creativity machine paradigm", In: CARAYANNIS, E. G. (Ed.), Encyclopedia of creativity, invention, innovation, and entrepreneurship, Springer Nature Switzerland AG, pp. (650 - 658).
Treffinger, D. J. (1995), "Creative problem solving: Overview and educational implications", *Educational Psychology Review*, 7, 301-312.
Vale, J., Gordon, K., Kirkscey, R. and Hill, J. (2020), "Student and Faculty Perceptions of Capstone Purposes: What can Engineering Learn from Other Disciplines?", *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://doi.org/10.24908/pceea.vi0.14149
Vianna, F. R. P. M., Graeml, A. R. and Peinado, J. (2020), "The role of crowdsourcing in industry 4.0: A systematic literature review", *International Journal of Computer Integrated Manufacturing*, 33, 411-427.
Wang, K., Nickerson, J. and Sakamoto, Y. (2018), "Crowdsourced idea generation: The effect of exposure to an original idea", *Creativity and Innovation Management*, 27, 196-208.
Wattenberg, M. and Viégas, F. B. (2008), "The word tree, an interactive visual concordance", *IEEE transactions on visualization and computer graphics*, 14, 1221-1228.
Wood, D.(2013), "Fichtes Conception of Infinity in the Bestimmung des Menshcen", 2013, *State University of New York Press*, pp.(155-171).
Xue, L., Leung, X. Y. and Ma, S. D. (2022), "What makes a good “guest”: Evidence from Airbnb hosts' reviews", *Annals of Tourism Research*, 95, 103426.