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RISE OF THE MACHINES: TRENDS, CHALLENGES AND FUTURE DIRECTIONS FOR AI IN DESIGN EDUCATION

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ABSTRACT
At the Engineering and Product Design Education (E&PDE) 2024 Conference, 53 research papers were published on AI a significant increase over previous years. These papers revealed how students and educators use AI and their perspectives on its use. To better understand the nature of these papers and their contribution to the scientific community, a workshop was held at the conference asking 24 education experts to code the abstracts and share their insights. This activity supported delegates shared understanding of the AI education landscape. Following the conference, a meta-analysis was conducted on the workshop outcomes. This research goes beyond a literature review of the conference papers through quantitative and qualitative analysis, revealing the challenges of conducting research in an E&PDE context. This reveals opportunities for future research and a reflection of the value of AI research within this context.

Keywords: Artificial intelligence, generative AI, educational technology, technology-enhanced learning, pedagogy

1 INTRODUCTION
The AI landscape has drastically changed in recent years, impacting all parts of society. With the potential to be an alternative to human involvement, at least in theory, the exploration of AI impact is fraught with the paradox of uncertainty [1]. From rules-based computer systems in the 1980's [2], to machine learning and neural networks in the late 1990's [3], research has played a significant role in the development of AI. The latest breakthroughs in deep learning originating from around 2010 [4] have enabled advances in how engineers work, how educators teach and how students learn.
In this ever-evolving domain, researchers and educators are exploring how novel AI functionality can be used to support teaching and learning activities. This led our curiosity to investigate the complexities and unknowns of this domain through the lens of the Engineering and Product Design Education (E&PDE) Conference 2024. The theme of the conference focused on AI for the first time and there was a significant number of papers related to explorations of AI use within an E&PDE context.
The authors recognise this trend in other conferences, journal publications and popular media. As the technology advances, new functionality is created and new uses for the technology are discovered. This leads us to consider how educators must respond to the bombardment of information on AI potentials, and therefore the unknowns before educators change their approach to teaching.
This paper details the outcomes of a workshop 'Navigating the AI Terrain: Mapping Knowns and Unknowns in Design Education' held at the E&PDE 2024 Conference. Education experts contributed their skills and knowledge to code paper abstracts and discuss their perspectives on AI use. The coding outcomes are presented in section 3 and discussed in section 4 with references to the paper source. The education experts' perspectives are shared in section 4 looking to the future. The outcomes reveal what is known by this community and where opportunities for further research exist.

2 METHODOLOGY
Building on the notion by Meron and Tekmen Araci [5], the fear of limiting creative and analytical challenges when incorporating AI provides an ethical stepping stone. To overcome such hurdles, design educators need to consider efficacy and capability when designing future learning scenarios where AI

is integrated purposely into the design education syllabuses. The use of novel technologies must be appropriate for the educational intervention intended [6].
A meta-analysis of the E&PDE 2024 publications was conducted to build a comprehensive understanding of the knowledge published by authors of the conference. In total, 53 papers were identified discussing AI. 24 delegates were asked to code the abstract of a paper to established criteria. 22 delegates were able to code two abstracts in the time allocated. An example of this coding template is included as Table 1 populated with the response for paper 1005.
In addition to the coding activity, delegates were asked if they could indicate the sentiment of any of these aspects from the abstract, for example, if a technology was identified but it was discussed as having a negative benefit to the design process then it was coded as a negative sentiment.
By engaging with this activity, delegates built their own knowledge of AI from the E&PDE publications to discuss the benefits and challenges, and future use of AI use in E&PDE.

Table 1. Example worksheet provided to code the information from abstracts for paper 1005

Criteria	Coded as (one word or small phrase)	Sentiment
Purpose	*Ai can be used to support ideation*	+
Context	*Engineering Design course*	
Method	*Survey*	
Sample size	*Three student groups*	
Technology	*ChatGPT*	
Outcome	*Ai can increase novelty of ideas, but student rely on its use*	-
Contribution	*Insights for how AI could and should be used in teaching*	+

Following the workshop, the 12 incomplete coded abstracts were completed by experienced engineering educators at the University of Strathclyde. The initial coding had some inaccuracies where data was missing or incorrect. To complete the data the authors checked for mistakes against the paper copies of the worksheet. A coding schema was used to align the delegates' response and draw conclusions. This coding is shared in the results section against each criterion. Coding was verified amongst the authors.

3 RESULTS

3.1 Purpose

To determine the purpose, the submitted responses were coded and reviewed by the authors (Figure 1). The most common purpose across the reviewed abstracts is '*exploration of AI tools*' (30%) supporting teaching and learning. This is an expected outcome considering the audience of the conference. This is followed by abstracts detailing the '*perceptions of AI use*' by students, educators, and industry (17%) in design in engineering, and considering '*ethical and societal issues*' (13%). This is due to the rapid popularisation of AI and the enthusiasm to explore and understand the affordances of the technology.

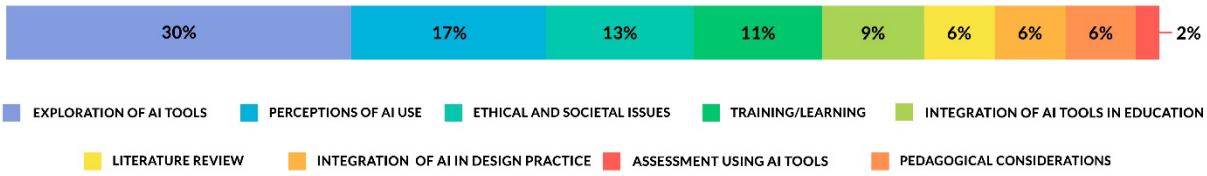

Figure 1. Analysis of purpose

Few abstracts (6% and 2% respectively) discussed '*pedagogical considerations*' and '*assessment using AI tools'* highlighting that this community lacks pedagogical exploration currently.

3.2 Context

The research presented at the conference spans a variety of contexts, with product design and engineering education expectedly prominent. Disciplines of mechanical design (one paper), computer science (two papers), and general engineering (four papers) are discussed. Further papers did not mention a specific area of education or a discipline within the abstract, however, focused on a more general aspect of design, such as '*PhD influence in education*' (one paper) and '*accessibility in design*'

(one paper). Papers involving industry (two papers) were the least common, comparing the perceptions of design practitioners against students, and skills requirements for future society.

3.3 Methods

Figure 2 highlights the range of research methods mentioned in the reviewed studies. Qualitative methods were highlighted 17 times, including interviews, case studies, and observations of students' work. Quantitative methods were mentioned 12 times, with surveys being the most frequently mentioned method (21%), primarily aiming to gather perceptions of AI use among students, educators, and professionals within an engineering or design context. Mixed methods approaches were employed 14 times, including workshops and experiments which integrated AI technologies with traditional design methods/activities. Notable examples of these experiments include the incorporation of AI into creative brainstorming sessions (one paper) and the comparison of hand-drawn sketches to AI-generated sketches (one paper). 14% of the abstracts reported the use of literature reviews, aiming to map and analyse the existing knowledge base of AI in design and education. Only five (9%) did not name any research method as part of their studies.

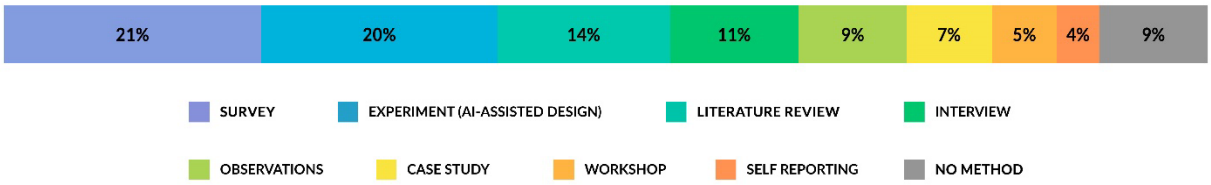

Figure 2. Analysis of methods

3.4 Sample size

Nine abstracts clearly defined the number of participants involved in their research within the abstract. Of those that included survey size, survey-based studies typically had a larger participant pool, ranging from 20-80 participants, while workshops and case studies had smaller pools of 10-30 participants.

3.5 Technology

The outcome of this meta-analysis highlights that participants are comfortable using the general term '*AI*' which was mentioned 15 times, with '*generative AI*' mentioned 10 times. Specific AI sub-categories were highlighted, for example, technologies categorised as '*text-to-image*' were mentioned nine times, including applications such as '*Adobe Photoshop*', '*Vizcom*', and '*DALL-E*' and technologies categorised as '*text-to-text*' were mentioned eight times, specifically mentioning '*ChatGPT*' six times. Other notable mentions include coding language and digital software, namely '*Python*', '*Microsoft Excel*', '*Jupyter Notebook*' and '*AI-assisted CAD tools'*.

3.6 Outcome

20 papers highlighted insights into the '*impact of AI on education and design*', detailed within 25% of the abstracts (13 abstracts) being the '*impact on teaching and learning*' and 13% (seven abstracts) with outcomes on '*impact of AI on design processes and workflows*'. Outcomes related to the real and potential impact of AI technologies include the 'state of AI tools and technology' (15%, eight abstracts), '*perceptions of students and industry*' (9%, five abstracts), and the '*challenges and barriers of AI use*' (9%, five abstracts), all contributing to the talk around the capabilities of AI in aiding students and professionals in design. Fewer abstracts mentioned '*reflections on ethical issues*' (4%, two abstracts), which offered critical insight into ethics and IP concerns surrounding AI-generated work, and '*recommendations and future research*' (13%, seven abstracts), including '*recommendations for Generative AI and supervision*' (one abstract) and the '*rethinking of education with generative learning*' (one abstract). Overall, 11% of abstracts did not have any listed outcomes.

3.7 Contribution

The most prominent area of contribution from the reviewed papers was the '*impact and effect of AI technologies*', accounting for 25% of abstracts (13 abstracts), which highlighted the use and effect of AI on design, including '*pros and cons of AI use in design education*' (one paper) and the 'design of an AI tutor' (one paper). Similarly, 19% of abstracts (10 abstracts) explained their contribution in the '*use cases of AI*', detailing instances of the experimentation and integration of specific AI technologies.

Another significant contribution was from the introduction of '*new frameworks and educational approaches*' (17%, nine abstracts) for successful integration of AI into traditional practices. '*assessment of AI*' contributed 11%, with six abstracts evaluating the performance and implications of AI use. Contributing to 9% of abstracts (five abstracts), '*identified perceptions*', detailed the perceptions of students and professionals. Lastly, '*Ethical and cultural considerations*' (9%, five abstracts) and '*knowledge/skill requirements*' (4%, two abstracts) both detailed a necessity for ethical and responsible use of AI technology. 6% of abstracts (three abstracts) did not explain their contribution to knowledge.

3.8 Sentiment analysis

To understand if there were any strong sentiments towards or against the use of AI within the abstracts. Sentiments for the criteria of outcome, technology and purpose were collected. Figure 3 details the sentiment identified for each criterion by the workshop participants and reviewed by the authors.

Of the abstracts where sentiment was identified and recorded, the purpose (43% positive) and outcome (45% positive) of the abstract demonstrated a strong positive sentiment, whereas the technology (21% positive) was balanced. Positive sentiment aimed to discuss the benefits of AI technology and the potential impact of AI in an educational environment, where these studies list typically positive outcomes such as the enhancement of creativity and/or productivity.

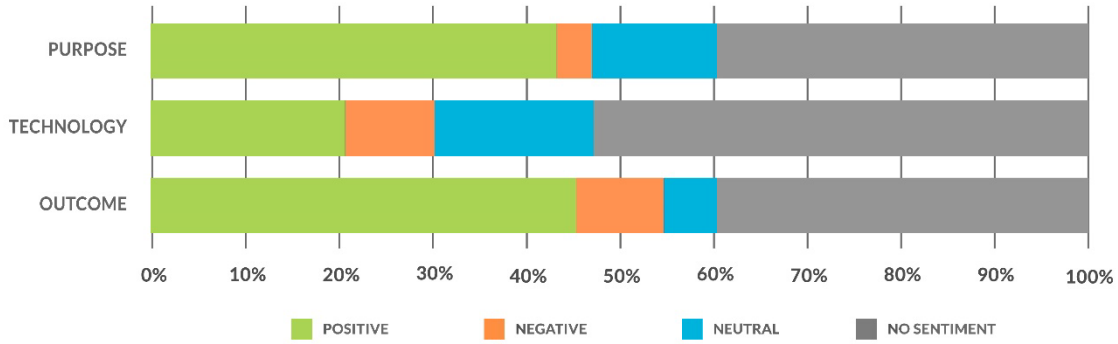

Figure 3. Outcomes of the sentiment analysis

4 DISCUSSIONS

The E&PDE 2024 papers act as a snapshot of the interests of the community at this moment in time. We expect interests to change as knowledge of AI and its usefulness changes through exploration and discussion. From our meta-analysis of the abstracts, authors are within the initial exploratory stages of the field. Key insights are shared in this section justified by the arguments of the papers.

There are challenges raised in the inability of AI to integrate successfully with traditional design methods [7] and the steep learning curve with advanced AI applications that may require previous training and experience to produce suitable outputs [8]. Educators have a role in developing new educational experiences to teach students about digital design methods.

A major theme was around the creativity and innovation stages of the design process. This appears to be the nature of the abilities of novel generative AI tools [9] e.g. the ability to create images, videos, CAD and the ability to hallucinate on a prompt generating blue sky thinking ideas [10]. However, some debate the appropriateness of the technology to ideate, and therefor propose its use as inspiration only [11, 12]. Further exploration using robust research methods is required.

As a tutor, AI can help to ensure that students have a full consideration of difficult to consider aspects of design [13]. However, we should consider if this AI team member would be serving a role in critical thinking that is necessary to build within our students [14].

E&PDE attracts few industry delegates, and papers reflect this. Education does not operate in isolation. Educators must understand AI use in practice [15] to ensure that students have the required skills.

Assessment lacked discussion at this conference, yet it plays a crucial aspect of education. The community must find a forum to discuss the inherent challenges of this new AI landscape, and the appropriateness of our existing assessment methods [16, 17].

A limitation of this study was the focus on abstracts and not full paper data due to time restrictions. Sample size and methodology were often not reported in the paper abstract which reflects the nature of the E&PDE format. Other disciplines, such as medicine, demand a structure to abstracts making it easy

to determine methodological information of the study. The E&PDE community might reflect if clarity is desired within the abstract, contributing to transparency and robustness of our research.
The coding schema used was not shared with delegates prior to the coding activity. This was successful in reducing the influence on the delegates' independent coding, however, there may be bias in the validation of the coding. The method of research used, involving the delegates of the workshop was successful in building specific knowledge of the papers to ensure discussion was grounded in real-world examples and not the delegates' speculation. However, it was less successful at establishing a common coding schema and common language around the topic. A more robust study is required to achieve this. There currently remains limited research by this community on ethical [18] and pedagogical [19] impact of the use of AI tools. Appropriate use of AI requires further exploration and discussion.

4.1 Key outcomes from the workshop discussion

The E&PDE 2024 papers will act as case studies of novel ways to use AI. This will support educators to design novel learning experiences and teach novel digital design methods. Workshop delegates argued that current AI tools are too generic for design activities e.g. to support creativity and ideation. There was a sentiment that to tackle specific E&PDE challenges requires the development of specific digital design tools leveraging the power of AI functionality.
AI is specifically useful for systems-level decision-making [20], yet there are few examples in the E&PDE paper outcomes. From the outcomes of the E&PDE papers, the authors are not likely involved in the development of these technologies, and so, there are limitations to the knowledge and impact of the community. Further collaboration with individuals in the management science, computer science disciplines, and industry practitioners, can overcome this.
It was suggested that there is a need for students to learn a coding language as part of their skills development for their discipline. This will, as a minimum, allow for editing of code in future job roles. Python is a popular AI language which was suggested.
The use of AI allows for the off-loading of the cognitive exploration of form and aesthetics. This can be applied to coordination tasks enabling more time for engineering design activities. This becomes a consideration for educators as we evaluate the required knowledge and skills development of our students. The E&PDE community should remain open to the exploration of AI in engineering education.

5 CONCLUSIONS

This research delivers a coded analysis of the E&PDE 2024 publications related to AI. This serves as a snapshot in time within the E&PDE context. The outcomes of this research reveal a focus of this community to explore the use of AI tools, and a lack of pedagogical and assessment focused papers. There have been clear successes in the use of AI with an E&PDE context highlighting support for ideation, assisting with repetitive tasks, and providing inspiration for design work. Challenges include The integration of AI with traditional design methods and steep learning curve. This research has revealed future directions including the need to explore appropriate integration of AI with traditional design methods and how to educate the next generation of engineers.

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