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Journal of Engineering Design

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cjen20

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To cite this article: Roger Jiao, Jianxi Luo, Johan Malmqvist & Joshua Summers (2022): New design: opportunities for engineering design in an era of digital transformation, Journal of Engineering Design, DOI: 10.1080/09544828.2022.2147270

To link to this article: https://doi.org/10.1080/09544828.2022.2147270

JOURNAL OF ENGINEERING DESIGN
https://doi.org/10.1080/09544828.2022.2147270

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EDITORIAL

New design: opportunities for engineering design in an era of digital transformation

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The subject matter of design has traditionally been focused on design of engineered (e.g., physical/mechanical) products. A multitude of profound changes and emerging trends in the design field have been witnessed in the new decade when digital transformation is in full swing. The confluence of cloud computing, big data, artificial intelligence and the internet of things is fundamentally changing how business and organisations will operate in the twenty-first century (Trappey et al. 2022). Companies are harnessing new digital technologies to transform into digital enterprises and leverage design innovation and product realisation to enhance their business capabilities, operational efficiencies and ultimately their customers' experiences (Luo 2022).

At the same time, engineering designers are facing new, complex challenges. Engineering design needs to take part in the massive collaborative initiatives, such as the United Nations Sustainable Development Goals (United Nations 2015), that are key to ensuring that our societies are sustainable and operate within the planetary boundaries. Engineering designers will lead and participate in the development of systems where the technology is one component, but complemented and constrained by social components, including laws, policies and taxation schemes. Co-creative development processes where many different stakeholders are engaged is essential for problem identification, idea generation and decision making (Kohn Råberg et al. 2020).

One eminent trend is the expanded spectrum of design encompassing technopreneurship, marketing, design, production, as well as the supply chain and the value chain. Engineering design becomes such a complex and comprehensive discipline that the product creation horizon is shifted from a physical product perspective to a total life cycle experience enacted via cyber-physical-human systems and even sociotechnical system. Product design becomes more than just dealing with pieces of hardware, but rather is realised through co-design of an entire product ecosystem, involving coordinated product fulfilment, services, experiences and human satisfaction at the individual and the community levels (Jiao et al. 2021).

A phenomenal opportunity for design research in an era of digital transformation is to shift towards a paradigm of 'New Design', that is, with more multidisciplinary focuses and interdisciplinary investigations of engineering design in the comprehensive context of an

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extended enterprise and societal sustainability. For instance, the readership of engineering design journals used to be mainly in the mechanical engineering community. It may be rewarding to include broader design issues in other related disciplines such as industrial engineering, systems engineering, operations engineering, engineering management, etc. In addition to the typical focus of 'how to design', good opportunities may exist for design research to embrace more about the new enabling technologies, particularly corresponding to recent advances in AI, machine learning, cybernetics, decision sciences. There is a growing consensus on the scope of 'what to design' to address more about the emerging global societal challenges including understanding 'wicked' problems (Rittel and Webber 1973), democratic and inclusive design processes, and design decision-making in very volatile and ambiguous contexts, to name but a few.

Design essentially entails a mapping from 'what we want to achieve' to 'How we want to achieve it'. While the 'What' and 'How' domains describe the respective problem and solution spaces, the mapping exemplifies design decision making per se. In the problem space, the design artefact does not have to be limited to physical products, but could take the form of service products, digital products, or even sociotechnical systems. In addition to design of product and systems themselves, design decision mappings have to do with an entire product realisation spectrum from very front-end marketing and customer concerns to the backend manufacturing and production processes, further to the downstream logistics and service issues, and further closing the loop with a circular product lifecycle involving many recycling, remanufacturing, repurposing and recovery issues (Potting et al. 2017). This holistic view of product realisation coincides with a series of systematic What-How domain mappings from the customer domain to the functional domain, to the design physical domain, and to the process domain (Suh 2010).

At the front-end customer and functional domains, 'New Design' is going to be growingly more data-driven and AI-enabled, more and more human-centred than engineering-centric, and increasingly focused on design innovation, business models and the value chain (Lu and Liu 2016). In this regard, 'New Design' calls for a marketing-engineering transdisciplinary approach that incorporates innovation engineering, strategic management, business administration and marketing engineering with engineering design practice (e.g., Cheng and Mugge 2022; Liu and Yang 2022; Ahmed et al. 2021).

At the backend manufacturing and logistics domains, product realisation processes and fulfilment systems are the key focus of 'New Design', which involves much of process design and planning decisions that are closely related to such disciplines as industrial engineering, production and operations engineering, and service engineering (e.g., Prabhu et al. 2022; Ziaei, Ketabi, and Ghandehari 2022; Nag, Sharma, and Kumar 2022; Stirgwolt, Mazzuchi, and Sarkani 2022). Besides, the move from linear to circular business models will force reengineering of the connections between the front-end and the backend, as new products increasingly need to be based on reuse of materials and re-purposing of already manufactured products.

In terms of domain mapping and design reasoning, the design process is subject to a variety of descriptive and prescriptive models, along with quantitative and qualitative decision making (Finger and Dixon 1989). It is promising for 'New Design' to enhance quantitative design decision making by exploiting advanced theory and methods in the fields of operations research and decision sciences. The qualitative nature of design decision making

necessitates 'New Design' to take advantage of new techniques in the fields of AI, machine learning and computational support.

In response to the grand trend and broader implications of 'New Design', the Journal of Engineering Design (JED) aims at

> a leading international publication for dissemination of research across all areas of engineering design, focusing on design of engineered products and systems, as well as product realisation processes and fulfilment systems related to engineering disciplines such as industrial engineering, manufacturing engineering, production engineering, operations engineering, service engineering, systems engineering, and engineering management.

In line with the strategic focus of 'New Design' on the multi/inter/trans-disciplinary perspectives, the JED welcomes papers that examine diverse topics within the expanded scope of the journal, including, but not limited to:

- *Design theory and methodology*, including foundations of design theory; design rationale; creativity and innovation in engineering; marketing-engineering interface; design synthesis; design cognition; models of design processes; design ideation; product cost and design economics; product families, platforms and reuse in engineering; configuration design; as well as resilience, reliability and robustness in engineering design.
- *Design automation and computational support*, including knowledge and information management in engineering; computer-supported cooperative work and social computing; design representation and languages; semantics in design of products, services and processes; generative design; feature-based design; shape grammars; product data management; virtual prototyping; cyber physical system prototyping; digital thread and digital twins; extended reality (XR); geometric design; engineering informatics; data-driven and data-informed design; machine learning and artificial intelligence in design; symbolic computing for design; simulation-based design; design decision support systems; augmented intelligence and design; integrated intelligent design environments; and big data analytics for design.
- *Design optimisation and decision science*, including design evaluation; engineering optimisation; multi-disciplinary optimisation; multi-attribute decision making; design decisions under uncertainty; reliability-based design; shape and topology optimisation; decision-based design; preference modelling; design for market systems; and behavioural economics in design.
- *Design of product realisation systems* with focus on planning, optimisation, control and management of processes, fulfilment and systems, including systems design and design complexity; integrated engineering design development; manufacturing systems design; design for changeable and reconfigurable production systems; supply chain design; design for logistics; operations engineering design; service delivery system design; integrated product and process development; global and distributed engineering design; and multi/inter/trans-disciplinary engineering design.
- *Human frontiers in design*, including engineering design aesthetics, style and form; emotive design and Kansei engineering; inclusive design and universal design; industrial design engineering and total design; user experience design; integration of customers in product/process design; user-centered design; behavioural design and smart nudging;

multi-modal perception and psychology in design; ambience intelligence for human factors design; future of work at the human-technology frontier; workplace design; design collaboration and teamwork; creative behaviour; design culture; and the design process of ergonomics.

- *Design for product lifecycle and sustainability*, including DFX (manufacturability, assembly, production, quality, maintenance, remanufacture, recycling, reuse, end-of-life); design for additive manufacturing; design for prognostic health management; sustainable/green/ecofriendly design; design considering carbon emissions and energy consumption; and design for circular economy.
- *Design management and systems engineering*, including collaborative design in engineering; design project planning and workflow management; requirement engineering; new product development and introduction process; product quality management and improvement; product lifecycle management; evolutionary design activities in engineering; model-based systems engineering; risk management; system of systems; as well as best practice and empirical studies.
- *New and emerging engineering design trends*, including smart and connected products; product-service systems; innovation design, product ecosystem design; inverse problem solving in design; design for digital transformation; design as strategic engineering; design and operation of human-cyber-physical systems (e.g., smart mobility or smart factories); design with smart sensing and AI technologies; design in Industry 4.0 and 5.0; product servitisation and XaaS (anything-as-a-service); design in the metaverse and Web3; platformisation for the sharing economy; open innovation and co-creation; crowdsourcing design; as well as digitalisation and product development cycle.
- *Design education*, including design education and pedagogy in engineering; design thinking and design doing; complex sociotechnical systems; public policy design; design engineering epistemologies; design learning mechanisms and learning systems; design ethics; design diversity, equity and inclusivity; as well as design education assessment methods, instruments, and metrics.
- *Design research methodology*, including qualitative, quantitative, observational, participative and retrospective methods for investigating; verification and validation; and evaluating design processes, methods and tools, at the strategic as well as tactical levels.

In the initial issue of 1990, the goal for the JED was to 'promote through quality refereed papers the quality platform for a substantially higher status for engineering design and the designer than has been the case hitherto'. While the field of engineering design research has evolved and matured, this goal is still relevant. In the tenth year of the journal, a goal was stated about getting the journal 'into many more design and development offices in industry', thereby sharing the current work of academia with our industry partners. Being rooted in an engineering field, the JED is committed to promote scientific research anchored in meaningful problem contexts that are generalisable and of explicit industry relevance.

To continue to support these broad goals of serving the society as a premier repository for academic scholarship that directly and indirectly support industry, it is of primary importance that the traditional subject matter of design should be expanded and extended in scope, expectations and integration, i.e., in line with the strategic vision of 'New Design'. Towards this end, the JED

> publishes pioneering research and best practices on the principles of design, as well as design management, techniques and methodologies, rather than specific domain applications. Papers can be focused on fundamental research leading to new methods or adaptation and synthesis of existing methods for new problem formulations.

In addition to achieving research results in a typical form of regular papers, the JED recognises multiple forms of contributions, with a good will to better facilitate dissemination of research and intellectual exchange in the design community. Due to the fact that design research mostly deals with open-ended questions (Papalambros 2015), it is not uncommon that significant research innovations often come from the bottom up, in that the crowd of researchers are the ones who define the directions, push the innovation, and advance the field. For the Journal, decentralisation and diversity may be a timely strategy for prompting open innovation, intellectual collaboration and knowledge sharing, in order to better serve the research community. Therefore, 'Submissions can take the form of original research contributions, technical notes or perspectives/editorials from all areas of engineering design. The journal also publishes state-of-the-art review and positioning papers'.

The multi/inter/trans-disciplinary perspectives and the expanded scope of JED are certainly not mutually exclusive nor even collectively exhaustive; however, some open discussion is conducive, and common consensus has been achieved in making sense of a body of research that is expending rapidly in many exciting and promising directions. The engineering design research community has made major advances in the past decades. The research community has made significant progress not only in advancing our knowledge of design, but also in clarifying the research methods necessary to study design. The JED is committed to promote academic scholarship toward a better understanding of design, and hence toward better design methods and tools to address industry and society needs to thrive in the twenty-first century.

Acknowledgements

The strategic version and the expanded scope of JED were refined and updated through communications with a number of editorial board members who provided many constructive and inspiring comments and suggestions.

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