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Creativity in the Design of Complex Socio-Technical Systems: Revisiting the Role of Digital Tools

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Abstract. The design and specification of socio-technical systems aimed at addressing today's complex challenges in relation to adaptation and sustainability requires creative thinking. Work on specifying the requirements for such systems in the early 2000s stimulated creative thinking through creative design workshops involving key stakeholders in creative thinking techniques that resulted in largely physical outputs. Since then, however, a lot has changed, especially regarding the roles played by digital tools in supporting creative thinking. The last two decades have seen a proliferation of digital creativity support tools and more recently still, empirical studies in a variety of domains are demonstrating how generative artificial intelligence can be used to augment or match human creative capabilities. Here we propose a research agenda through which to investigate the important question of how we might better support creative thinking in the design of complex socio-technical systems using current digital creativity support tools, including generative AI.

Keywords: creativity, innovation, socio-technical systems, creativity support tools, generative AI.

1 Introduction

Socio-technical systems are increasingly complex, and must address increasingly complex real world challenges, especially in relation to adaptive and sustainable science, engineering and technology. Addressing these new challenges requires innovation, which in turn implies a need for creative thinking in the design and specification of such systems. Here we draw on work completed over the last two decades to seek to answer the question of how we might better support creative thinking in the design of complex socio-technical systems using current digital creativity support tools, including generative AI.

Relatively little has been reported about how digital tools are currently used to support creative thinking in the design of complex socio-technical systems. Further investigation seems timely, as creative thinking in so many domains is being transformed by the advent of generative artificial intelligence (genAI).

In this paper, we revisit our previous research and practice in facilitating creative thinking in the design of complex socio-technical systems such as those employed in air traffic control. We draw out some of the general principles on which this work was based. We briefly review the evolution of digital creativity support tools, and in particular genAI, in the time since our work began and consider what this may imply for the practice of developing future adaptive and sustainable systems. We end by proposing an agenda for future research and practice.

2 Creative Design of Complex Socio-Technical Systems

The specification of new software systems has in the past been seen as a largely scientific exercise in which software or requirements engineers discover, document and manage the requirements of an intended system's users [1]. However such a view ignores what has been called the problem of 'driving by the rear view mirror', in other words of being too focused on what is past or already exists, and thereby missing what *could be* in future. This insight is aptly summarised in a statement attributed (though some argue incorrectly) to Henry Ford regarding the design of the radically innovative Ford Model T automobile: 'If I had asked people what they wanted, they would have said a faster horse.'

It is this issue which we sought to address in our work on the design and specification of requirements for complex socio-technical systems such as those used in air traffic control during the early 2000's. To do this we developed a process, named RESCUE [2], that brought together the then best practices of requirements management (from requirements engineering) and use case modelling (from software engineering) with current research on i* modelling and human activity modelling. In addition to these we introduced 'creative design workshops' during the early stages of the process with the explicit and deliberate aim of stimulating creative thinking about future possibilities and new ways of addressing challenges in existing systems - in other words introducing opportunities for more radical innovation. The process was applied in developing several systems in the domain of air traffic control [3,4], as well as others including work-based learning [5] and a food traceability system.

Workshop activities were planned based on our understanding of several different models of creativity. We incorporated activities that would stimulate both divergent and convergent thinking [6] at different points in the workshops; we offered opportunities for preparation, incubation, illumination and verification, according to Wallas's characterisation of the creative thinking process [7], and we incorporated creative thinking techniques designed to stimulate each of the types of exploratory, combinational and transformational creativity identified by Margaret Boden [8]. For example a technique which we referred to as 'constraint removal' was used to stimulate transformational creativity during divergent phases of the workshops; analogical thinking was used to stimulate combinational creativity during divergence; and storyboarding was often used to encourage combinational creativity during the final convergent stages of a workshop.

Our workshops made much use of concrete physical objects, as recommended by practice in design thinking, becoming increasingly popular at the time [9]. For example warm up exercises included balloon modelling; new ideas were recorded on paper cards that were pinned to boards representing the different system use cases; thoughts about how systems currently worked and could work in future were captured using ‘rich storyboards’ consisting of long rolls of paper annotated with post-its, string and marker pens.

Reflecting on these experiences we can characterise our approach as embodying three core principles for stimulating creative thinking in the design of complex socio-technical systems in ways that could lead to significant innovation:

1. Introduce explicit and deliberate opportunities for creative thinking and integrate these into existing processes for system design and specification through one or more creative design workshops
2. Include representatives of all key stakeholders in creative thinking by inviting them to join one or more creative design workshops
3. Encourage workshop participants to externalise and discuss their ideas through the use of concrete physical design artefacts

3 The Role of Digital Creativity Support Tools and GenAI

In the work described above, carried out during the early 2000s we used creative thinking techniques articulated by authors such as de Bono [10], Isaksen et al [11] and Michalko [12] but made little use of what have since come to be called ‘creativity support tools’ (CSTs) – digital tools designed to support creative thinking of various kinds. These tools and the research that underpins them have evolved significantly over the last two decades and have recently been joined by generative artificial intelligence (genAI) which has massively popularised the idea that digital tools can contribute significantly to the generation of new ideas and materials of many kinds. Here we briefly outline the evolution of such tools and consider the implications of the evolving capabilities of digital tools including genAI for future research and practice in the design of complex socio-technical systems.

From the early 2000s a body of work began to emerge in relation to creativity support tools (CSTs) defined as ‘software tools to support creativity’ [13]. As Shneiderman pointed out the ambition was at first quite vague and the definition was used to encompass a very broad range of digital tools including concept or mind map managers, generators of random words that could be used to stimulate new thinking according to some of DeBono’s creative thinking techniques, digital pens and whiteboards, guided writing environments, and tools with an emphasis on supporting creative collaboration.

An important contribution to the field was the identification in 2006 of a set of twelve principles for the design of creativity support tools following a U.S. National Science Foundation sponsored workshop [14]. These principles emphasised ‘easy exploration, rapid experimentation, and fortuitous combinations that lead to innovations’. Examples included the requirement for ‘Low threshold, high ceiling, and wide walls’ meaning that CSTs should enable novices to begin using them with ease while at the same time

enabling expert users to work on increasingly sophisticated and wide range of projects; ‘Support many paths and many styles’ meaning that people with diverse preferences, experiences and cognitive styles should be able to use CSTs in many different ways; and the reminder to ‘Choose black boxes carefully’ acknowledging that the building blocks provided by any tool would determine what could be built with it. In addition, in 2005, Todd Lubart had identified four key roles for computers as ‘partners in the creative process’ which he defined as ‘(a) the management of creative work, (b) communication between individuals collaborating on creative projects, (c) the use of creativity enhancement techniques, (d) the creative act through integrated human–computer cooperation during idea production.’ and named ‘nanny’, ‘pen-pal’, ‘coach’ and ‘colleague’ respectively [15]. Some of our own work, slightly later, investigated the role of digital tools in supporting creative collaboration and design, with a particular focus on ways in which physical and digital artefacts could be blended as part of a creative design process [16,17]. Finally, a comprehensive review by Frich et al [18] showed how interest in the field grew over the 2010s, meaning that the ways in which digital tools could support human creative processes was becoming increasingly well understood.

At the same time as this research on the role of digital tools in supporting human creative processes, work in the field of computational creativity aimed at using artificial intelligence to construct programmes or computers capable of human level creativity was also developing fast. While initial outputs were not impressive compared to works generated by humans, many now argue that generative artificial intelligence is capable of human level creativity in at least some senses. Empirical studies in a variety of domains are demonstrating how genAI can be used to match or sometimes augment human creative capabilities. For example, Pagani and Wind [19] have examined the role of AI in enhancing marketing creativity, while work by Eapen et al [20] has shown how a Large Language Model such as ChatGPT can be used to enable a creative thinking technique which they call ‘trisociation’ (building on the well-known creative thinking technique of ‘bisociation’) in the context of new product or venture concept development. Dell’Acqua et al [21] have conducted a large scale study of professionals working on real product innovation challenges and shown how AI can transform collaboration in this context, finding that individuals working with AI matched the performance of teams without AI in terms of the quality of ideas generated, and also that individuals working with AI had emotional experiences comparable to, or better than, those working in human teams.

Many of today’s genAI-powered tools fare well when evaluated in relation to key principles amongst those identified by Shneiderman et al [14]. For example, novice users are able to begin using them with ease, while expert users can achieve sophisticated results in a wide range of projects (‘Low threshold, high ceiling, and wide walls’); the range of different media supported (including text, audio, image, video etc) and the ability to interact with the tools in different ways (for example through text or voice interfaces) enable people with diverse preferences, experiences and cognitive styles to use them (‘Support many paths and many styles’); and the apparent aim of such tools to support and manipulate concepts that closely resemble those used in human thought

(‘Choose black boxes carefully’) all suggest that our ideal creative ‘colleague’ [15] may be close at hand.

In addition to the opportunities brought by today’s digital creativity support and genAI tools, there are, however, challenges. The apparent over-confidence of genAI in its outputs, its tendency to ‘hallucinate’ and to build in bias due to the unrepresentative nature of data on which it has been trained are well known. More concerning, in the context of creative design and innovation for socio-technical systems, recent research on the use of genAI for scientific discovery has suggested that genAI may only be able to make incremental discoveries, and is ‘incapable of having an epiphany’ [22]. Finally research in neuroscience has linked the prevalence of ‘cognitive off-loading’ through the use of digital tools to observed declines in IQ [23]. The time seems right for a re-examination of the potential role for digital tools, including genAI, in the creative design of complex socio-technical systems.

4 An Agenda for Future Research and Practice

A range of frameworks or approaches to the design of socio-technical systems currently exists, including systems design, a practice based on the principles of systems engineering; socio-technical systems engineering (STSE) that built on principles of work design, information systems, computer-supported co-operative work and cognitive systems engineering; and systemic design, or systems-oriented design, which can be seen as an advanced design discipline. However no comprehensive framework currently exists to guide the integration of digital creativity support tools, or generative AI, into such frameworks in a principled and evidence-based manner, with the aim of facilitating creative thinking and innovation. We take it as read that any such framework should draw, where possible, on established theories of creativity and creative thinking as this will tend to enable more effective use of today’s digital capabilities for augmenting human creativity. But beyond that, what are the important issues such a framework should seek to address?

Returning to the principles that emerged from our earlier reflections on experience of stimulating creative thinking in the design of complex socio-technical systems, we propose the following questions for further research.

4.1 How to introduce explicit and deliberate opportunities for creative thinking?

In our previous work we focused on the use of creative design workshops to introduce opportunities for creative thinking into the system specification process as a whole. However now that digital tools, such as genAI, that can support the generation of new ideas are so ubiquitous, might there be alternative ways of encouraging creative thinking through more of the process? Encouraging broader use of genAI could be part of wider initiatives to promote creative climate – though this would need to be done with caution, due to challenges such as those identified above. Empirical studies analogous to those conducted by Pagani and Wind [21], Eapen et al [22] and Dell’Acqua et al [23]

would be very useful in further investigation to determine the relative merits of concentrating creative activity in a few specific workshops vs spreading it throughout – or perhaps doing both.

4.2 How to include representatives of all key stakeholders in creative thinking?

As described above, we took care to invite representatives of all key stakeholder groups to our creative design workshops. However given the potential to instruct genAI to adopt relevant personae, and the findings of Dell’Acqua et al [23] on how AI can transform collaboration, might there be additional approaches to consider, in terms of integrating the perspectives of multiple stakeholders into the design process? Once again, further empirical studies would be useful to determine the relative efficacy of these approaches.

4.3 How to blend physical and digital design artefacts in stimulating creative thinking?

Our approach two decades ago focussed on the use of concrete physical artefacts as a medium through which individual workshop participants could externalise their thoughts, enabling discussion and collaboration between stakeholders. This had the advantage that such artefacts could be quickly, easily and playfully produced and shared. However, today’s landscape looks very different. Many people are much more familiar with working with digital artefacts, and genAI enables a wide range of outputs – text, images, videos, sound etc - to be produced with relative ease, meaning that the production of such artefacts may no longer act as any more of a block or delay to the fluency of the creative process than would the generation of something like a physical post-it. The ease of translation between different forms (eg text to image) also offers a range of additional combinations to explore. A great many possibilities remain to be investigated here – again, ideally, through empirical studies.

5 Conclusion

Innovation is essential in designing the complex socio-technical systems that are required to address increasingly complex challenges in adaptive and sustainable science, engineering and technology. This in turn requires creative thinking. Digital creativity support tools, and especially today’s generative artificial intelligence tools provide a host of intriguing possibilities for facilitating such thinking, but little is currently known about how to make most effective use of such tools while retaining the centrality of the human in the loop. We hope the proposals above can act as a catalyst for further critical reflection on existing work, empirical investigation of possible future approaches, and open collaboration to better support the creative design of complex socio-technical systems using today’s digital tools.

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