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Research Article

Inclusive interactive simulation: stakeholder empowerment, satisfaction, and confidence in solution design and decision making

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Abstract

In transdisciplinary engineering, the development of solutions increasingly relies on the utilization of computational modeling and simulation tools, skillfully wielded by experts in the field. Although these tools possess great power, they often inadvertently sideline individuals who lack technical expertise, excluding them from the solution design process. Recognizing this issue, we delve into a discussion concerning an experiment aimed at gauging the effectiveness of "inclusive" computational modeling techniques. These techniques are designed to actively involve non-technical stakeholders in the solution generation process. In our experiment, participants assumed the role of empowered citizens tasked with selecting their favored design for a real estate development project within their city. We provided them with access to a web-based digital design tool, enabling them to view, modify, and create various building scenarios. Ultimately, participants were asked to specify their preferred solution as the final choice, while also sharing their levels of satisfaction and confidence regarding their decision. The results of our study revealed a noteworthy willingness among non-expert participants to exercise their personal judgment in decision-making. The most satisfied and confident participants were even willing to override or disregard professional recommendations when making their choices. This research bears significant implications for the integration of technology-driven participatory design processes within the realm of transdisciplinary engineering.

Keywords: decision support systems, collaborative design decisions, interactive simulation, transdisciplinary engineering, urban design.

1. Introduction

Transdisciplinary projects often strive to incorporate broad stakeholder participation. The word 'participation' merits careful definition. In the context of design, participation implies a dichotomy of interaction between at least two groups: professionals who conduct a design process, and those who are allowed to participate in that process. We often refer to the former group of professionals as engineers or designers, while the latter group of participants might consist of users, clients, or stakeholders. For this research, we refer to either side of this dichotomy using the above terms interchangeably. Arguably, participation is a necessary and implicit quality of transdisciplinary engineering, as professionals and stakeholders must reconcile objectives and requirements across multiple domains.

Furthermore, we should clarify the nature of stakeholder involvement that constitutes true participation. Specifically, we believe that participation implies a certain degree of shared power and shared responsibility between engineers and stakeholders. This is quite different than merely inviting a stakeholder to voice their opinion. Rather, we embrace a definition of participation that seeks to empower stakeholders with decision-making responsibilities.

There is a good deal of literature that reviews the potential benefits of participatory design, as well as methods for implementing participatory processes. However, we are concerned that existing participatory design methods are not keeping pace with the rapid development of digital design tools used in many engineering fields. Power over design has become increasingly concentrated in the hands of engineers who happen to be trained in the use of specialized tools or software. The gap in technical skills between stakeholder and engineer have made true participation harder to achieve. Increasingly, design alternatives are ultimately created, modeled, and simulated within arcane digital tools that are detached from the process of participation. Stakeholders may spend a token afternoon chatting around tables with post-it notes, but

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they might feel rightly skeptical about their chance of having any real influence over a digital design process that has become far removed from their own abilities. To achieve genuine participation in transdisciplinary design processes, engineers need to consider how their tools of practice interface with stakeholders. Specifically, tools and processes should empower stakeholders, allowing them to influence designs and make decisions in an authentic way.

In prior work, we designed and built a novel digital design tool called Open Simulation User Interface (OpenSUI) with this goal in mind (Figure 1). OpenSUI allows engineers and stakeholders to co-create digital models in a sandbox-like environment that is specified in advance by an engineer (Winder & Hiekata, 2021, 2022). Design configurations are left malleable, so that stakeholders may exercise their own discretion. As a demonstrative case, we built a model for designing the form and use of a real estate development project. However, much work needs to be done to demonstrate the efficacy of such tools.

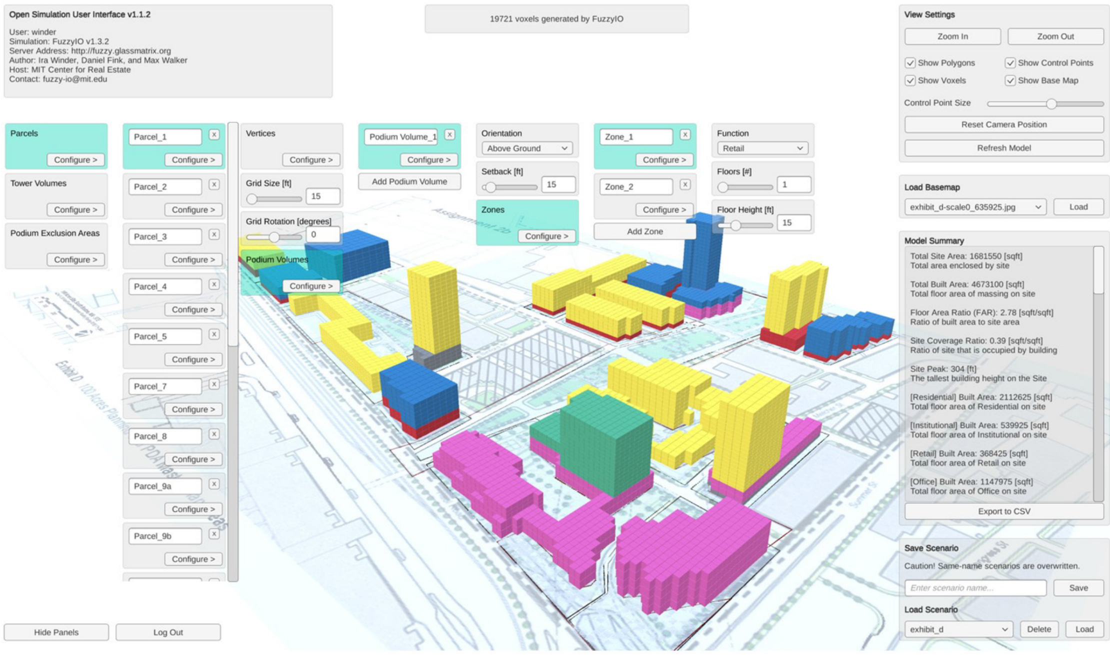

Figure 1. Screenshot of OpenSUI configured to enable urban design and modeling.

2. Objectives

Our objective is to observe and gain insight into the experiences of stakeholders involved in a participatory digital design process. While innovative digital design tools theoretically empower stakeholders with discretion and authority, it remains uncertain whether stakeholders will seek or utilize this newfound capability. For example, when presented with the choice to either endorse an existing design by a professional, make edits to that design, or initiate the creation of an entirely new design, our aim is to discern which option they prefer. Regardless of the choice made by a stakeholder, we are also interested in gauging the level of satisfaction and confidence they experience when making a final design selection. Additionally, we intend to investigate how the provision of baseline, pre-generated design scenarios may impact stakeholder participation, for better or worse.

3. Literature review

According to architect John Habraken (1986), ideas and methods concerning participatory design first emerged during the early 1960s as a response to demands in public housing. Though Habraken himself doesn't identify as a transdisciplinary engineer, he holds many sentiments that a transdisciplinary engineer might relate to. Specifically, he recognized that "we [architects] cannot be responsible for everything, nor can we control everything." This seems like tacit acknowledgement of how something as complex as the built environment cannot be handled by a single profession. Relatedly, Habraken felt that architects were falling short of their obligations to offer true participation in design processes.

References to stakeholder participation across disciplines have become common in contemporary literature (Reed, 2008; Wesley & Ainsworth, 2018). However, consistent definitions for what constitutes true ‘participation’ have remained elusive. Terms such as ‘involvement’ and ‘engagement’ often indicate paternalistic processes more concerned with public relations than empowerment (Iazzi et al., 2020; Zarzycka et al., 2021). When precedents do specifically refer to stakeholders as empowered, the term “design democratization” is often seen (Vardouli, 2012). Curiously, some even explore the benefits of “hidden design,” a process that purposefully keeps stakeholders in the dark (Pols, 2017). Suffice to say, it seems that we are far from a golden age in stakeholder participation. Rather, it’s possible that legitimate participation in design is in decline.

Prior work concerning novel digital tools for stakeholder participation is also abundant. However, much of this work focuses on technical implementation. While stakeholder participation is often mentioned as a motivating factor in the development of such tools, their specific efficacy as vectors for participation and empowerment is often presumed or taken as an a priori assumption. For instance, tangible interfaces for urban planning, such as the Tactile Matrix, CityScope, or Urp, are developed specifically to be user friendly and engaging (Underkoffler & Ishii, 1999; Alrashed et al., 2015; Rose et al., 2015; Winder & Larson, 2017). While there is indeed evidence that such platforms may be useful in educational design exercises, it is yet to be demonstrated how such tools might empower stakeholders to have genuine influence over design outcomes.

The mere act of making design tools user friendly does not necessarily empower stakeholders. Even worse, such tools might become playful distractions, far removed from how real design decisions are made.

Overall, existing literature leads us to conclude that participatory design is a near-universally embraced concept across disciplines. However, much work needs to be done to articulate what is truly meant by participation. Furthermore, novel digital tools that claim to democratize design, encourage participation, or empower stakeholders need to be subjected to rigorous experiments and trials that demonstrate the efficacy of such claims (Pelegrin et al., 2019; Winder et al., 2020).

4. Method

We devised a hypothetical urban planning design process, inviting individuals to assume the role of an empowered stakeholder in a participatory design exercise. Using a combination of surveys and instrumentation, we observe the behavior and thoughts of participants as they use a digital design tool to review and adjust pre-generated designs or create their own designs from scratch. Pre-generated solutions were created by an urban design professional in advance. Ultimately, we asked each stakeholder to choose a single design for implementation and report their levels of satisfaction and confidence.

When given the opportunity to directly influence design decisions, we are interested in how non-professional stakeholders handle such responsibility. For instance, we might find that stakeholders lack the confidence required to make changes to a design that was made by someone they perceive as an ‘expert’ relative to their own standing. Alternatively, we might find that a stakeholder embraces their responsibility enthusiastically, either by editing designs or creating their own from scratch. Of course, we might also find a good deal of variation among stakeholders depending on their prior background and experience. We also created a variant of the exercise where participants are asked to create designs from scratch, without the aid of pre-generated designs. We wish to see if there are any noticeable effects on satisfaction or confidence when stakeholders do not have a baseline scenario to work from. We also collected detailed data about user activities during the exercise, such as instances where they changed, saved, or loaded a model state.

5. Experimental design

To accommodate individuals working remotely, we implemented the experiment as a structured exercise to be completed online within a specified time limit (Figure 2). Specifically, volunteers participated by logging in to a browser-based interface designed and created for this research. First, participants are guided through account creation and informed consent. Then, after completing an entry survey, participants are briefed on their roles and responsibilities. After a short tutorial, participants are then given access to a digital design tool, that allows them to view, edit, and create designs. After participants are given a set amount of time to work freely, they are asked to select a final design and complete an exit survey.

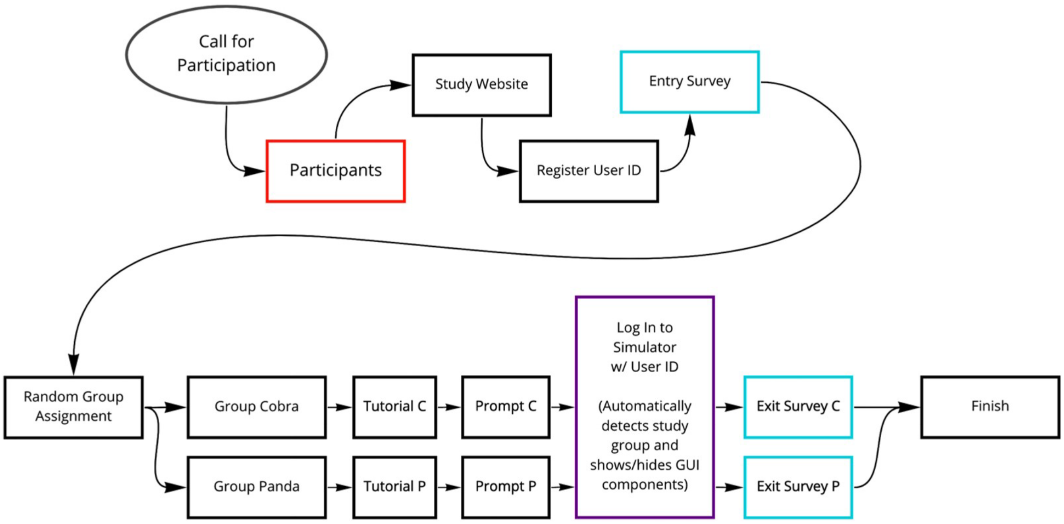

Figure 2. Flow chart of a participant experience during the course of the experiment.

Volunteers were solicited via open calls for participation on various mailing lists and social media. To some extent, participants were drawn from the social and professional networks of researchers, so some selection bias was a concern. However, invitations made it clear that all persons were welcome to participate regardless of background or experience, and persons with prior knowledge of the research were excluded.

Conducting the experiment through a custom web interface had several benefits. Firstly, it allowed us to enforce a consistent and controlled experience for participants. It also allowed us to automate data collection and entry, as all user interactions were logged as digital fingerprints. We also used the system to randomly assign participants to one of the two treatment groups at the time of account creation. This helped us mitigate potential bias in our treatment allocation process.

Subjects independently completed surveys and performed exercises over the course of 50 minutes. Each user had access to their own unique instance of a digital design tool, and no data was shared between users. Each user experience was an isolated exercise, and subjects remained unaware of other subjects' activities. Users' faces and voices were not available to any other users throughout the entire experience and were not recorded.

All participants were provided a consistent mission statement regarding a hypothetical site in the imaginary city of "Beaverton". Specifically, they were informed that a vacant piece of land had been donated to the city, and that they had been elected by their community as a trusted representative to finalize the design of a building upon the land (Figure 3). The participant was also given a small number of functional requirements, such as minimum areas for residential and institutional uses, as well as an overall maximum density (Table 1). Aside from specified requirements, other objectives and value judgements were left to the discretion of the participant.

Figure 3. Image of the building site, provided to all participants.

Table 1. Design Requirements.

Building Requirements	Amount
Minimum Residential Built Area	50,000 square feet
Minimum Institutional Built Area	80,000 square feet
Maximum Floor Area Ratio (e.g. building density)	5.0

Participants were placed into one of two treatment groups. Both groups could freely use the digital design tool to create urban design scenarios (Figure 4). One treatment group, dubbed panda, also had comprehensive access to three pre-generated designs for the site (Figure 5). These designs were created in advance by an alleged professional. Participants in the panda group were free to utilize or ignore the pre-generated designs as they pleased. The second treatment group, dubbed cobra, was not given access to any pre-designed scenarios. Implicitly, they had no choice but to use the tool to generate their own designs from scratch. Otherwise, the amount of information, time, and tools at either groups' disposal was the same.

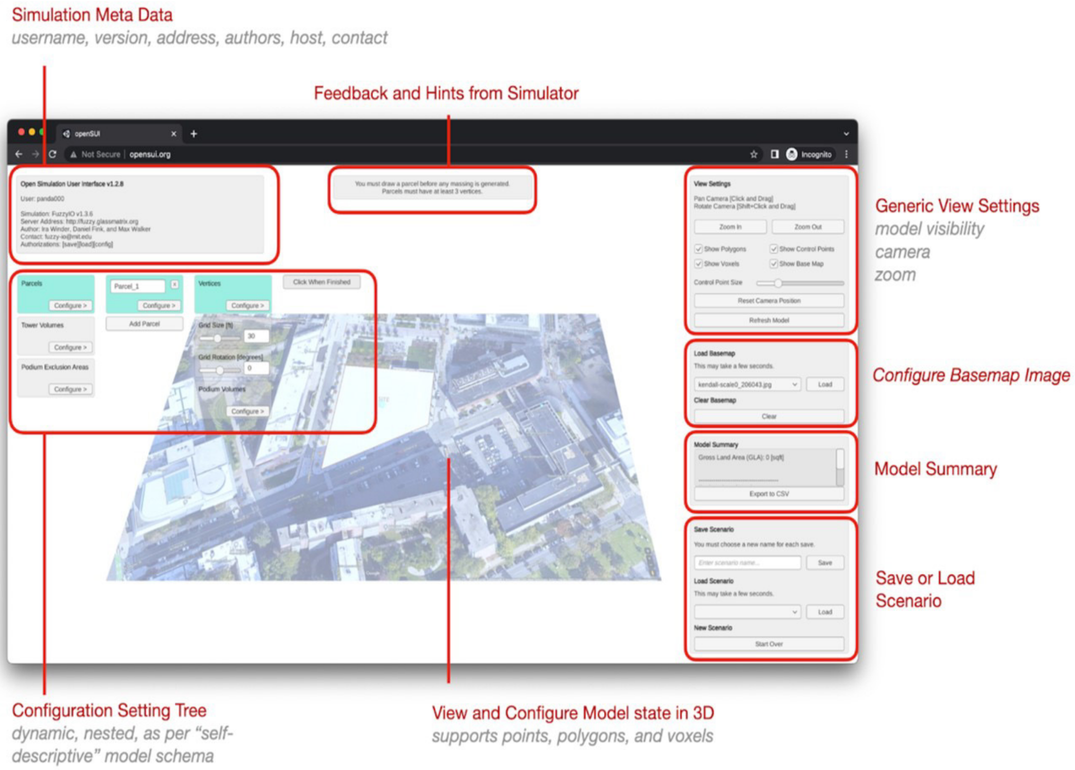

Figure 4. User interface components that facilitate creation and editing of urban design scenarios.

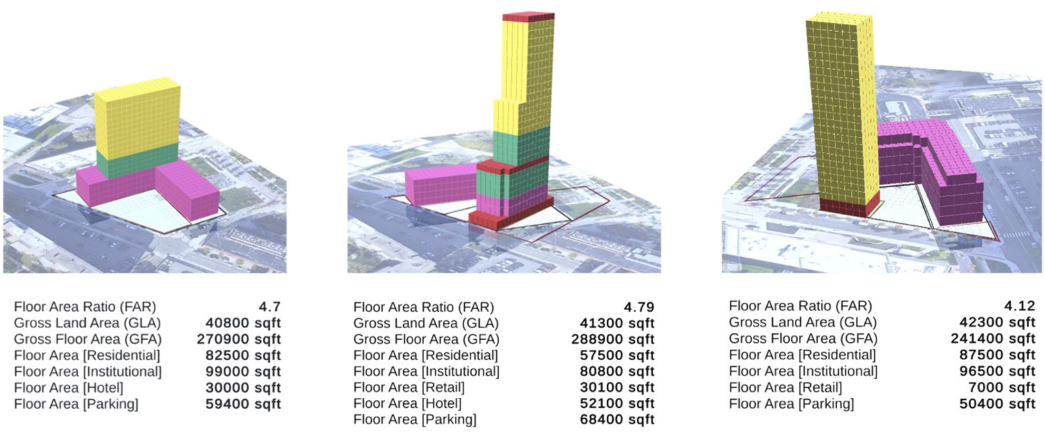

Figure 5. Three pre-generated baseline scenarios exclusively provided to 'panda' group.

6. Results

We were able to successfully collect data from 14 participants from various backgrounds. Three of these individuals reported that they had some background in architecture, urban planning, or real estate, but only one participant reported that they considered themself to be an expert in one or more of those fields. Participants' prior experience with computer-aided design software was variable (Figure 6). We expected and even hoped for such diversity in our responses, as our users need not, nor should they, resemble professional architects or urban planners. Overall, sampled participants seemed like a potentially realistic mix of lay citizenry for the purposes of a participatory urban planning scenario.

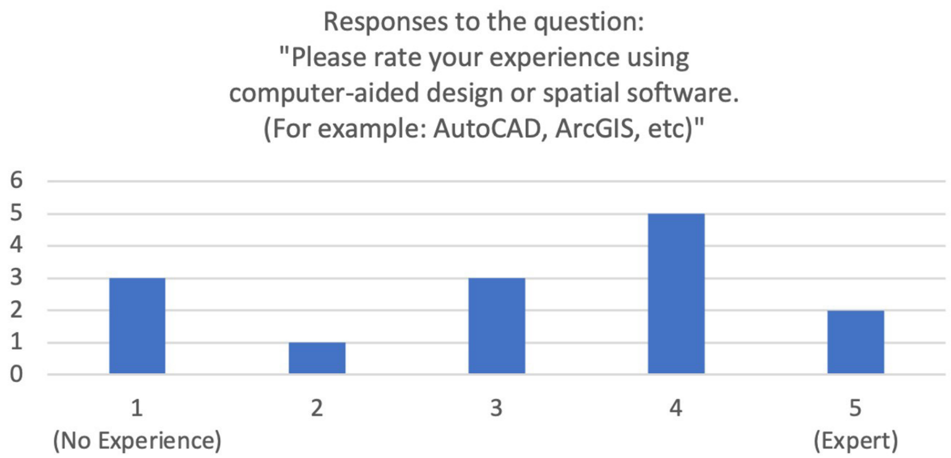

Figure 6. Self-reported participant experience using computer-aided design software.

Reported levels of satisfaction and confidence across participants covered a wide range of values (Figures 7 and 8). Satisfaction and confidence were highly correlated ($p = 0.005$), while CAD experience was correlated with neither satisfaction nor confidence. Levels of satisfaction and confidence between the two test groups were not significantly different according to one-way ANOVA test ($p = 0.79$). We feel that this is likely an indicator of insufficient sample size, but it could also indicate that stakeholder satisfaction in participatory design is not affected by the inclusion of pre-generated scenarios.

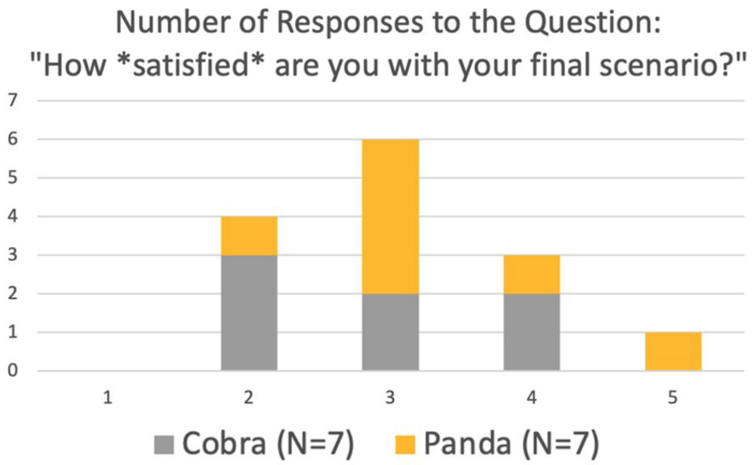

Figure 7. Distribution of participant satisfaction.

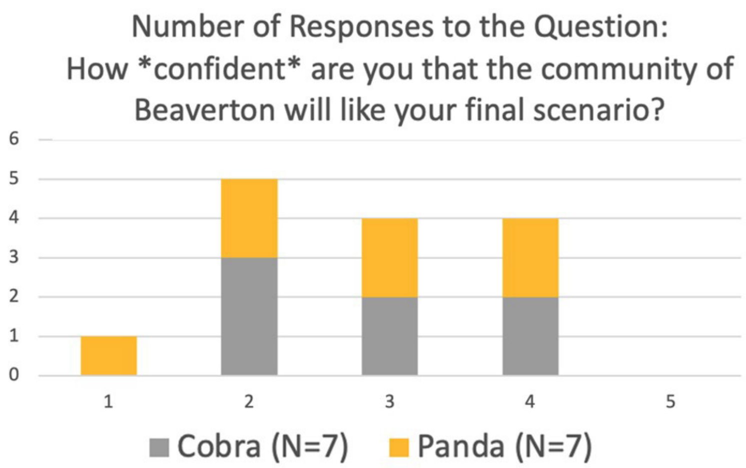

Figure 8. Distribution of participant confidence.

In the panda group, participants had multiple options to choose from when selecting a final scenario. Not only could they design their own scenario, but they could also choose a pre-generated scenario or modify it (Table 2). Of the seven participants in the panda group, five elected to disregard the existing scenarios completely, opting for their own original designs. The remaining two chose an edited version of a pre-generated design. No participants chose to implement a pre-generated solution in its original form. Even with this relatively small sample size, a Shapiro-Wilk test for normal distribution shows that the results are statistically significant ($p = 0.0017$). In other words, if stakeholders were just as likely to choose a pre-generated design as their own design, it is highly unlikely that we would see these results. Therefore, we predict that further participants would also favor designs that they themselves modified or created.

Table 2. Participants overwhelmingly opted for their own completely unique design.

Responses to the question: Which best describes the scenario you ultimately chose? (Test Group: Panda)	**Number of Responses (N = 7)**
I chose Option 1, 2, or 3	0
I chose a modified version of Option 1, 2, or 3	2
I chose my own completely original scenario	5

We also visualized a timeline of digital "fingerprints" of various user actions over the course of the exercise (Figure 9). While we did not have any pre-conceived hypotheses to test with such data, we wished to glean any surprising patterns or other qualitative observations. Notably, the most satisfied and confident participant stood out as having created the largest amount of design iterations, while other users seemed to be more timid and linear in their design sequences. This high-performing user ultimately chose their own completely unique design, as well. While we reach no conclusive findings from these digital fingerprints, they hint at a possible alternative explanation for the variation among levels of satisfaction and confidence among our participants.

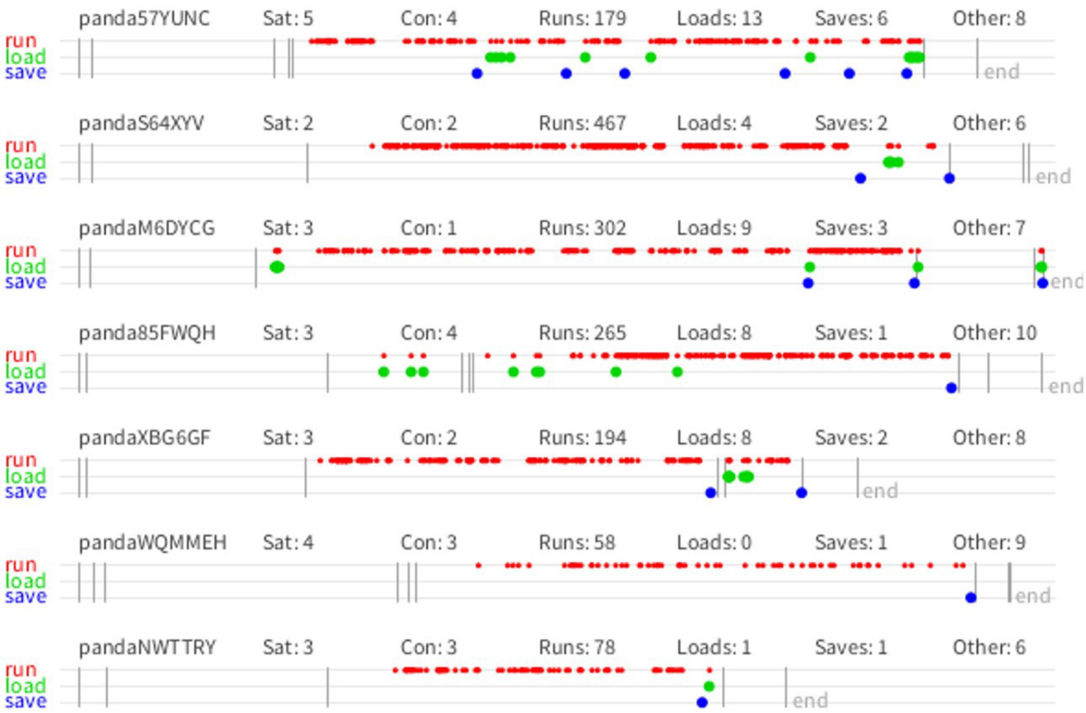

Figure 9. Actions of seven individual stakeholders captured during their exercises. "Runs" are instances of a stakeholder changing the state of a model. "Loads" are instances of a stakeholder retrieving a previously saved model state. "Saves" are instances of a stakeholder committing a model state to memory. For each stakeholder, the final save is the model state that they chose as their final solution. Vertical lines are instances of a stakeholder interact with an accompanying website that contained directions and information about the exercise. The final satisfaction and confidence (self-reported value from 1 to 5) is included for each stakeholder.

7. Discussion

The findings appear to indicate that digital design tools for participatory design effectively empower non-professional stakeholders to take charge of design decisions. Initially, we anticipated that most participants might choose from the pre-generated scenarios, potentially making minor adjustments to them, given the embedded expertise. We did not anticipate nor require users to create their designs entirely from scratch. Surprisingly, most participants exhibited a high level of autonomy, opting to create entirely new designs when provided with the choice.

The presence of pre-generated designs seemed to have little measurable impact on stakeholder satisfaction and confidence, though it's conceivable that they may have influenced the process in subtle ways. To fully understand this influence, a more intricate analysis of design outcomes is required, which falls beyond the scope of this study. Nevertheless, the inclusion of pre-existing scenarios did not seem to significantly affect stakeholder satisfaction or confidence. This prompts us to reevaluate the fundamental utility of pre-generating solutions in the participatory design process within the realm of transdisciplinary engineering.

Previous research has examined designers' tendencies to favor their own ideas (Lazar et al., 2022). Our study further supports this notion by suggesting that stakeholders, when acting as designers, also exhibit a preference for their own ideas, even when they have knowledge of other potentially superior design alternatives.

8. Conclusion

In this study, we aimed to assess the feasibility and investigate the impact of granting decision-making authority to stakeholders in the context of digital design. We developed an innovative experimental platform that facilitated the automation of remote subject participation in a carefully controlled design experiment. Surprisingly, we observed a high degree of willingness among participants to exercise their own discretion in making decisions, even to the extent of overriding established professional recommendations.

Remarkably, we found that the inclusion of pre-generated recommendations from professionals had limited influence on stakeholder participation. While our findings remain preliminary, they open new avenues for research that can inform how practitioners may choose to integrate their expertise into participatory design processes. Rather than providing predefined design scenarios, it may be worthwhile for transdisciplinary engineers to consider delivering tools that empower stakeholders to create their own scenarios.

Furthermore, we believe that these findings represent just the initial steps towards numerous exciting discoveries that can be facilitated through instrumented experimentation on digitally accessible design platforms.

9. Acknowledgements

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