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Analyzing templates used for multiple participatory renewable energy projects

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ABSTRACT

The concept that technology should be designed iteratively is a well-established tenet in participatory design. However, iteration has received insufficient attention regarding how and why we should also evolve tools that support participatory processes. Based on empirical material from five participatory renewable energy projects conducted in different school communities, this paper documents how a seemingly mundane participatory design tool, a paper template, evolves through iteration to better scaffold collaborative design work. We show how iteration has implications for the overall direction of the project towards sustainability by surfacing future issues. The templates allowed a collective move from designing a renewable energy generator towards making a school collective for sustainable use, management, and adjustment of the generator they built. The iterations illustrate how participatory design tools can collect mundane things relevant for design decisions and how such things can be translated at higher levels.

CCS CONCEPTS

• Human-centered computing; **• Interaction design**; **• Interaction design process and methods**; **• Participatory design**;

KEYWORDS

Codesign tool, Renewable energy, Iterative process, Community energy

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1 INTRODUCTION

The introduction of effective tools has long been a key concern of participatory designers and researchers seeking the inclusion of diverse stakeholders in the design of technology [6, 8, 18]. Brandt et al. [6], for example, define participatory design (PD) not as a single approach but as "a proliferating family of design practice that (. . .) comes with a varied set of toolboxes" (p.145). Accordingly, scholarly literature has presented and explored numerous PD tools with which designers can fill their toolboxes. Case studies describing the use of established PD tools such as scenarios [17], mock-ups [5], prototypes [3], design probes [14], sticky notes [16], or templates [1] abound. In this paper, our aim is not to add one more tool to the toolbox. Rather, we aim to document how a mundane tool – paper templates in this case – can evolve through multiple renewable energy (RE) design projects, implementing the RE in actual usage, and how the accumulated insights gained from multiple implementations reshape the overall direction of the project. Our interest is to contribute to the discussion on how tools evolve through iterations as they emerge at the intersection of mundane and strategic domains [4, 10].

1.1 Iteration in PD

Iterative processes are understood as successive cycles conducted through a process from planning, acting, reflecting to changing. This is not a new concept to technology design. It is often taken for granted as a fundamental activity in the design of software, services and physical products [13, 23]. The important role of iterative practice has also been acknowledged in the field of PD. For example, with the deployment of design games, Tekinbaş and Zimmerman [22] have emphasized the important role of iteration in refining relevant questions as well as robust design outcomes. Simonsen and Hertzum [19, 20] identify that iterative participatory design involves both anticipated and unanticipated changes. On the other hand, Elgaard and Thorsen [7] insist that iteration does not necessarily guarantee a process and outcome to be participatory. It can also shift a researcher's focus from creating participatory visions to simply removal of problems that block the development of technology.

2 CASE AND METHOD

2.1 Participatory Design Project: Making Energy Together

"Making Energy Together" (MET) is a design research project that aims to investigate how PD can support school communities' engagement in energy transitions by developing a set of PD interventions. To meet this aim, MET proposes a series of a codesign workshop where students, as main participants, codesign and built renewable energy generators (REG) for the school and, in the processes, reflect on what it takes to "make energy together." Our analysis is drawn from the experience of organizing five METs in four public schools. Initially, the project was conducted only in Finland. However, the outbreak of the COVID-19 pandemic led us to include cases in South Korea, where the first author had better access during the pandemic. The selection of participants

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Figure 1: From left to right, 1) A four-wheeled mobile phone charger named SOKI (MET1 in 2021); 2) An automatic lighting system for outdoor corridors (MET2 in 2022); 3) A Solar Mirror (MET4 in 2023).

Figure 2: Details of the paper templates being used by students to codesign their renewable energy generator in the "Making Energy Together" project.

(age and grades) was done together with the teachers following governmental regulations. A total of 95 students from grades 4 to 9 have participated in five METs and created 16 small-scale REGs (examples in Figure 1). While the project can be seen mainly as an educational project, we will not dwell on the educational aspect here. Instead, our aim is to explore the effect of iterative implementations of PD tools in an educational context. The project is part of the first author's PhD research, and she has played multiple roles as project manager, facilitator, codesign tool designer and researcher.

Each MET consists of three stages: seeding, codesigning and building (see Figure 3). The stage of seeding includes a one-hour introduction to the relationship between climate change and renewable energy technology and to different design examples of REGs. In the codesigning stage, students in groups start designing REGs. This stage comprises two workshops: Ideation Workshop and Materialization Workshop. In the Ideation Workshop, students set a goal for the project and generate initial ideas of REGs using sketches without deep consideration of real conditions. In the Materialization Workshop one idea is selected and materialized considering the technical and organizational realities of each community. Each workshop takes 1.5 hours and is guided by a paper template. In the building stage, the participants construct the REG they designed in the previous stage in collaboration with the researcher, technician, teacher and other relevant stakeholders. A whole MET takes between 4-6 weeks to complete, depending on how it can be adjusted to the school curricula. In this paper, we mainly focus on the role of two paper templates devised to support collaborative design work in each of the workshops of the codesigning stage (see Figure 2).

2.2 Method

For conducting the project with students, we received ethical approval from the Ethics Committee of Aalto University (D/291/03.04/2021). All students and their guardians received information on the research project before the project began and gave us informed consent. Data collection was done within two time frames. First, during the project, we documented how participants – students, teachers, and technicians – responded to and utilized the templates to codesign REGs through video and audio recording (approx. 25 hours) and semi-structured interviews (N=74/95). We also interviewed the school administrators who oversee administrative tasks and manage school facilities. In addition, the first author recorded field notes of her reflections from the observations and interviews. Second, after the project was completed, we followed how the generators in each site have been used and perceived by participants and non-participant members of the schools through site-visits (at least once at each site), follow-up interviews (N=~25 depending on count), and researcher's field notes. All interviews have been audio-recorded and transcribed for analysis. At the time of writing, the PhD project has not been completed, and additional observations online – via instant messaging and email – and offline are still underway. The first author has generated narratives about the iterations based on the empirical data, after which all authors held joint sessions to identify and refine themes iteratively. We focused on how sociomaterial factors have influenced the researcher to make changes in the templates and in which direction the templates move. The first author then produced a diagram illustrating the iteration cycles of the templates (Figure 3) which was checked against the empirical material.

3 EVOLVING TEMPLATES THROUGH ITERATION

After each MET, the researcher reflected upon the process and results related to the templates, and the reflection was used to adjust the templates for the following MET. The core structure of the templates remained unchanged throughout the five METs: A two-page template with the first page focusing on ideation (initial ideas) and the second on materialization (finalizing the idea with more details). However, each paper template evolved. The current form of the templates, as shown in Figure 3, is the result of four iterations through five METs. Below, we illustrate the iterative process with issues and adjustments at each turning point.

3.1 Iteration 1: localizing the templates

The initial design of the templates was based on the first author's prior knowledge and experiences in organizing solar Do-It-Yourself (DIY) workshops with young people [15]. In the preparation for MET1, the principal asked if the REG could be made mobile because the school was preparing to move (1). This request inspired us to introduce a series of Limitation Cards (1-1) in the template to collect prior administrative concerns about having the REGs in the school. The Limitation cards are filled out by administrators beforehand and shared with participants during the design process. As a result of MET1, SOKI, a mobile phone charger with four wheels, was designed and built (Figure 1). During the project, SOKI received a highly positive response from students, the principal, and even parents, some of whom emailed the principal to express appreciation for the project.

However, after the project was officially ended, the first author visited the school and found that SOKI was not being used. During a student committee meeting, she tried to pique students' interest in SOKI without success. The loss of the students' interest and poor usage of SOKI (2) prompted the addition of two questions to the templates: "who will use it?" (2-1) and "who will manage it?" (2-2) to support participants in reflecting on the usage and management of the REG during the design process. Additionally, starting from MET2, participants were asked to interview other students not participating in the workshops to gather wider users' views on REGs. However, we soon realized that interviews were an ineffective way of collecting non-participant students' opinion because only half of the participant students completed the interview, and even the completed interviews were mostly unrealistic (e.g., building a solar PV in a toilet). Therefore, in Iteration1, we retained only the two questions and removed the interview task from the templates (2-3).

3.2 Iteration 2: constraining the templates

Although the Limitation cards were developed to collect administrators' prior concerns on REGs in Iteration1 (1, 1-1), the need for communication with the administrators continuously emerged during and after design work (3). This is because most ideas required administrative permissions to be implemented within the schools' infrastructure, such as placing REGs on a bench on the playground or a roof of school buildings. However, school administrators tended to reject the researchers' invitation to the workshop because they perceived them as "students' projects". In MET2, it was identified that a one-week break between the Ideation and Materialization workshops allowed for sufficient discussions between participants and administrators outside the workshops (3-1). This rearrangement of time also addressed another issue: the increasing technicians' anxiety during the codesigning stage due to time constraints to prepare for the next stage (4). The one-week break (4-1) successfully decreased their anxiety by providing them enough time to purchase components and plan the building stage.

After MET2 was completed, a follow-up visit revealed that unlike the result of MET1, the REGs built in MET2 were in active use, but mainly by the project participants, and non-participating students did not even know who made them or how to use them. The teacher recognized the problem but did not have time to figure out a solution (5). This observation led to two additions to the templates to help participants address this issue during the design process. First, in the Ideation Workshop, we added the question to the template "how to encourage others to use it more?" (5-1). Second, the template in the Materialization Workshop guided participants to create a user manual of REGs that could help fellow students use them readily (5-2)

Additionally, another reflection on the series of design cards of the Materialization Workshop emerged during the follow-up visit. Among the four REGs built in MET2, only the automatic lighting system (in Figure 1) was actively used by all members of the school. From the perspective of the researcher and technician, it was too simple as a design and building project since it consisted of only three components, a light, a wire, and a sensor (6). Therefore, we identified that focusing on functionality may play a more important role in increasing the sustainable use of REGs than appearance factors. Accordingly, three design cards on physical factors, i.e., size, color and materials, were replaced by the cards on functional factors (6-1): "does it produce enough electricity for the intended purpose?", "where and how to check if the electricity is sufficient to use (monitoring)?", and "is the solar PV placed in a direction to receive more sunlight?"

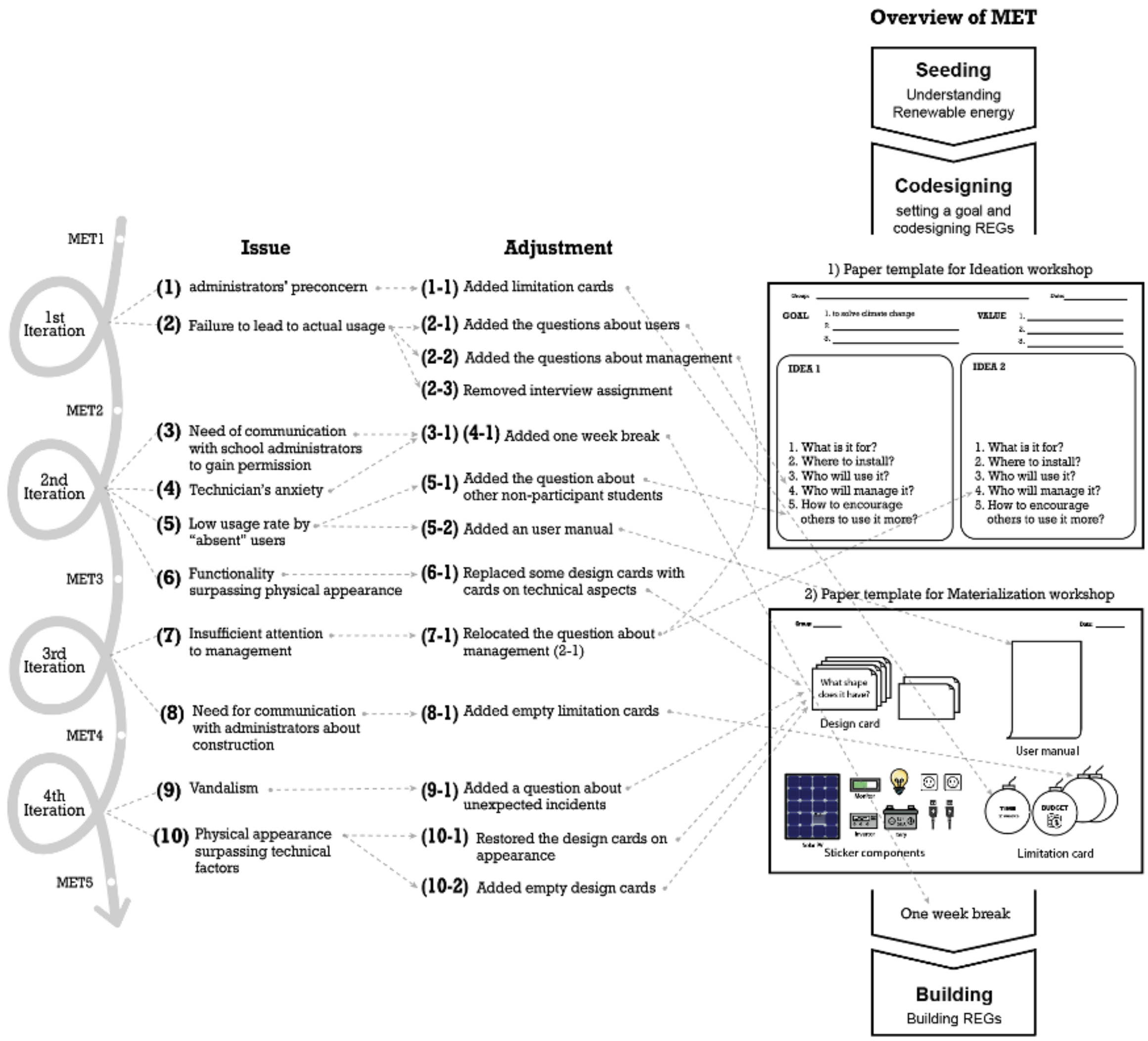

Figure 3: Iterative processes of the two templates used for the codesigning stage. Ten issues (1 to 10) and 13 corresponding adjustments (1-1 to 10-2) emerged through four iterative cycles.

3.3 Iteration 3: extending the templates

The first adjustment in Iteration3 involved relocating the question "who will manage it?" from the Materialization Workshop to the Ideation Workshop. In MET3, we noticed that during the materialization of ideas, participants focused heavily on practical and technical aspects, neglecting considerations about future usage and management (7). Hence, we moved this question to the Ideation Workshop, where students could adequately address its implications (7-1).

The second adjustment in Iteration3 entails introducing empty cards into the series of limitation cards. As explained earlier, although administrators' concerns were gathered beforehand, the necessity of communication with the school administrators arose during the codesigning process. Planning the installation and operation of REGs requires administrative cooperation and permissions (8). For instance, some student ideas necessitated electrical work for installation and operation on the school premises. Such issues can only be identified during the design work, and the inclusion of empty cards allows participants to promptly receive answers from the administrators (8-1).

Three months after the completion of MET3, the teacher reported that one of the REGs built outside the school was damaged during a holiday (9). During the workshops, students had already discussed the possibility of vandalism. However, due to disagreement on how to address this during the codesigning stage, it was insufficiently considered in the designing and building process. This unexpected incident prompted the third adjustment, which involved including the question, "what unexpected incidents could happen to the REG, and how can it be made resistant to such incidents?" (9-1) in the design cards. This enables participants to explicitly and adequately account for future use in their design decisions.

3.4 Iteration 4: opening up the templates

In MET4, one of the REGs developed was a Solar Mirror as illustrated in Figure 1. Throughout the project, both the researcher and technician held skepticism regarding the Solar Mirror, perceiving it solely as a decorative piece. However, during the follow-up visit, the first author observed students enthusiastically using the mirror as a spot for taking selfies (10). This experience prompted a reevaluation of the questions on the design cards. It also served as a reminder that participants can prioritize the factors embodied in the cards themselves. The templates should aid them in exploring diverse perspectives, ranging from technical and managerial to physical aspects. This reflection led to the restoration of the design cards (10-1), which had been removed in Iteration 2 (6-1), as well as addition of empty cards in case participants want to formulate their own questions (10-2).

Section 3 and Figure 3 have thereby presented the evolution of two paper templates, reflecting the issues and adjustments arising from each implementation. Through a series of processes including localizing, constraining, extending and opening up, theses templates underwent transformation. The iterative use of these templates expanded the scope of the collective design activity, particularly towards the phase following implementation of REGs. This iterative process helped young participants in better addressing issues related to use and maintenance. Across consecutive METs involving different participants, settings and contexts, the most significant issues were made explicit. This, in turn, reshaped the overall intention and focus of the project, emphasizing diverse sociomaterial aspects together pointing to infrastructuring.

4 FINDINGS

In this section, we delve into three observations that demonstrate how making adjustments to mundane paper templates can represent strategic moves. These adjustments surface, support, and address various aspects of making energy together including accommodating absent users and adapting infrastructuring practices. Additionally, we discuss how tailoring these adjustments to different local contexts can enhance the applicability and generalizability of the tools.

4.1 Reaching out to involve absent users

The iterative process of this project revolves around determining which questions should be asked to ensure the involvement of relevant stakeholders. Through iteration, it became evident that the changes in templates were motivated by the needs, conditions, and limitations of the diverse stakeholders of the project, particularly fellow students and school administrators who did not physically participate in the workshops. While issues concerning the construction, usage, and management of REG surfaced organically during the workshops, most school administrators chose not to participate directly because they viewed it as an educational project mainly for students. This initial gap in understanding of MET made it challenging to involve key decision makers in the workshop and address usability and management issues from the outset. Furthermore, it seems that students who were not participating in the workshop also did not contribute to the designing process (2, 2-3). However, as illustrated above, these "absent" users' perspectives profoundly influenced the design outcome. Therefore, the templates evolved to focus not only on face-to-face interaction within the workshops but also on distributed communications that extend beyond time and space to involve school administrators and non-participant students in the decision making process. The student participants, as novice designers, needed reminders of others' perspectives and knowledge that would impact the design and use of the REG, and this design awareness was fostered by adding questions about others' needs and viewpoints in the templates.

4.2 Reaching out to infrastructuring

The issue of future usage and management emerged frequently across the iterations. Despite its emergence, however, it was challenging for student participants to sufficiently address how and by whom the REGs should be used and maintained solely with instant verbal instructions during the design processes. This was partly due to the students' preoccupation with the form and functions of REGs when designing the generators. However, once the REG was built and ready for use, it became clear that establishing usage and maintenance practices and engaging diverse stakeholders in the practices are crucial for sustaining the REGs in the school community. As observed in the first MET where failure to build these practices resulted in storing the generator in a warehouse, much more effort is needed to establish the practices if these considerations are not adequately addressed in advance, particularly during design processes. Hence, the templates need not only to embed the issues of the future usage and management, but also keep participants' attention on the issues during the design processes. As identified in this paper, providing the questions in the paper form helps participants stay focused, sufficiently plan future routines aligned with the school circumstances, and increases the likelihood of sustainably using and maintaining REGs. One could thus say that the educational project transformed into an infrastructuring project [2, 11], from the perspective of what the novice designer participants (students) were asked to focus on during the design processes. It was therefore important that PD tools embed future issues so all stakeholders, particularly students, can expand their idea on designing REGs beyond just an educational activity. This approach helps them envision how the REGs could be used and managed successfully and sustainably in their community.

4.3 Localizing or generalizing the tools?

The objective of the PD research project is to develop and optimize PD tools through iteration so that they can be used by other school communities. As described earlier, the projects were conducted with different groups of participants in different countries due to the immediate social change caused by the pandemic. Even within the same grade in the same country, we observed a certain degree of local differences. One teacher noted, "(Even though they are in) the same grade and the same school, students show different characteristics every year, which shape the learning environment differently." Additionally, unexpected events such as vandalism, as seen in cases (9) and (9-1), can impact the projects. These local specifics and unexpected events have shaped the collective design process in unique ways, seemingly preventing researchers from finding generic solutions. Some might argue that adjusting to local, contextual specifics makes it impossible to create a "template" – something generic that can support school communities in engaging with METs. However, we argue that the adapting to diverse local contexts is actually a way to achieve generalizability. Adapting PD tools to contextual differences is inevitable for PD research, which inherently embraces non-linear and unpredictable social influences on design processes. Moreover, these multiple adaptations help identify larger themes that can be relevant across different contexts over time. A PD tool exposed to various contexts can embrace these differences and become flexible by providing a wide range of options and autonomy for participants – as shown in the additions of empty cards (8-1, 10-2) and restored cards (6-1, 10-1). Additionally, the sociomaterial aspect of energy technologies contribute to making the templates both localizable and generalizable, as current energy systems, components, and practices are largely standardized, particularly in developed countries such as Finland and South Korea. Interestingly, the age difference, often considered a key variable in educational literature, is not that notable, in our participatory design research project. As illustrated throughout this paper, the students' contributions are inseparable from the sociomaterial outcomes collectively shaped by other stakeholders, including teachers, principals, administrators, researchers and technicians.

5 DISCUSSION AND CONCLUSION

This paper has documented how a PD tool – paper templates in this case – has transformed through iterative cycles in school settings. The findings highlight the importance of iterative refinement in tools used in PD, showcasing how even minor adjustments can significantly impact the direction of a project. In line with the literature on the iterative design process [13, 19, 23], we identify that in general iterative processes would provide diverse reflections that can support better outcomes. However, while the focus of previous literature is limited to interim outcomes gained from a developmental stage in one site, we have illustrated here how iterative processes could bring more meaningful insights when implementing in multiple specific sites of actual use. Our analysis shows that the final templates are not the only outcome of the iteration; the templates embraced diverse themes and infrastructured processes inside and outside of the workshops, containing factors for designing and reaching out to future implementation. It was also possible through the issues and adjustments of the templates having been integrated, altered, and being defined throughout by responding to specific contexts of each case. More crucially, the small and trivial changes contribute to increasing sustainability of REGs to be built and used in communities by surfacing the questions of its usage and management as well as non-participant "absent" users and highlighting the goal of "Making energy together" at different levels. That is, a PD tool can collect seemingly mundane things that have relevance for collective design decisions, as well as how such things are translated at other levels, as others have also observed [4, 10, 12]. The templates revised through iterations can play a more effective role in engaging communities with sociotechnical issues that require local responsiveness, such as energy transition. By evolving tools iteratively, designers can better support collaborative design processes, foster greater stakeholder engagement including not only students but also other participants such as teachers, principals, technicians and researchers, and ultimately contribute to more sustainable and well-managed design outcomes.

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