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Experimenting with Polymorphic Design Aids in Participatory Ideation

Abstract

The importance of creativity support tools for novice designers has long been recognized in human computer interaction community. However, little work is found in the particular context of innovative systems and participatory innovation. The creativity support needs of end-user designers in an innovation ideation context are atypical and multi-fold, including—but not limited to—supplementation of 1) domain knowledge, 2) design knowledge, 3) feasibility and scope knowledge, and 4) divergence triggers. Classically, one design aid serves only a few aspects due to inherent constraints, leaving other requirements unfulfilled. Based on our findings, we recommend that facilitators shall design polymorphic (multi-part) design aids when working in PIN/PD contexts to innovate tools for healthcare, education, or alike fields. Each part shall serve a few purposes to help, discover target domain, stimulate divergent thinking, provide feasibility and domain boundaries, etc. Though, clear part boundaries are not necessary.

Keywords: Design Aids; Creativity Support Tools; Participatory Design; Participatory Innovation.

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1. Introduction

Participatory Design (PD) and innovation are coming together. Their marriage has given birth to Participatory INnovation (PIN). Ranging from Healthcare to Education, and industry to the government, the role of HCI, in general, is rapidly increasing in the design and development of innovative systems. As Schneiderman notes [1], the HCI community is now challenged with brining better creativity support tools. Nonetheless, this challenge is even harder in PIN contexts where the problem of limited creativity worsens due to several reasons.

Contrary to typical PD context, the end-users may not have enough domain/task knowledge at hand when ideating in PIN context. The insufficiency of domain knowledge affects their confidence negatively, inculcating the feel that they are not creative [2]. Further, the lack of design expertise hinders expression even if good designs have been formulated in mind [3]. Both deficiencies contribute in further narrowing of the solution search space [4]. Moreover, naïve designers may extend beyond the desirability and feasibility scope [5, 6]. It is thus desirable to build and employ creativity support tools (design aids) that provide basic design and feasibility knowledge, trigger divergent thinking and foster creativity in naïve designers of innovations [7, 8]. Nonetheless, covering all these requirements in one typical design aid is not possible. To solve this problem, the authors introduce polymorphic design aids.

1.1. Polymorphic Design Aids

A number of design aids (or design inspirations, creativity triggers etc.) have been reported in cognition, psychology, innovation, engineering, design and related fields. Design aids have several attributes of interest, including—but not limited to—level of abstraction, structure, relation to the problem domain, and bias factor. Each attribute influences observers' entry into the solution search space via some mechanism. In general, abstract and unstructured tools (like storyboards) ignite broader divergence but provide little to no design/domain knowledge [9]. Contrastingly, concrete and structured sources (e.g. exploratory prototypes) bring domain and design knowledge but do not spawn divergence. The lack of abstraction translates into guided entry points for observers resulting in narrower search space [9]. Metaphors and analogies (e.g. Interactive illustrations and design games) trigger solution search but induce bias and may result in solutions not equally applicable to target domain [5].

For PD/PIN contexts, a careful balance of tool attributes is important to supplement participants' design/domain knowledge, foster creativity and divergence, minimize bias, and to keep the design activity in scope and feasibility boundary [5]. Nonetheless, such a blend is difficult to achieve with one typical design aid. The authors, hence, break the stereotypical design approach and mix several types together into one [polymorphic] tool to realize the benefits of all. However, such approach needs careful design to mitigate the risks associated with each type.

1.2. Background

The current work is a part of a larger project aiming at developing an ideation framework for innovation in participatory contexts. The authors use a case tool for their experiments, namely Jeliot Mobile (JM) [10]. Jeliot Mobile belongs to Jeliot family of Software Visualization (SV) tools. It is aimed at teaching Java through animations on a mobile platform in a context-free socio-constructivist way. The project primarily employs design-based research methodology to create knowledge in HCI, PD and PIN, as well as to materialize the concept of this tool.

In this part, the authors report on designing, developing, deploying and evaluating polymorphic tools. These tools were applied to the participants in three distinct ideation workshops in which they generated design ideas for JM. The design output of these workshops was used in the second phase of the research, in which a distinct group of participants evaluated the design output for creativity.

The rest of the report is organized as following. The next section provides brief discussion on some notable related works. The authors detail the research methodology in Section III, with analysis and results presented in Section IV. Discussion and Implications follow in Section V. Finally, the authors conclude the paper in Section VI.

2. Related Work

Kwiatkowska et. al. (2014) [9] compared the impact of structured and unstructured cards used as introductory tools of a co-design ideation activity. They found that unstructured cards worked better due to their abstraction, did not lead participants' creative process, and hence resulted in a broader creative output.

Pommeranz et. al. (2012) [3] conducted a large study to find the influences of several variables in participatory and co-design activities. They studied the role of facilitators and the role of materials used during design activity on triggering creativity, and the group composition.

Goldschmidt and Sever (2011) [4] experimented with textual stimuli to foster creativity in novice designers in controlled laboratory settings. They found that novice designer who were given textual stimuli performed better than those who were not. Their assessment criteria included evaluations of design ideas for originality and practicality.

Lopez et. al. (2011) [11] reported on the differences of impact of visual and sentential stimuli given to design teams. They found that one method was not wholly superior to other. It was instead the situation and the objectives of the design session that defined which stimulus shall be used.

Wilson et. al. (2010) [12] studied the impact of different kind of examples given to designer during a design activity. They found that biological examples (surface dissimilar but structurally similar) worked better than human-engineered surface similar examples. They performed the experiment with engineering students from an undergraduate program and evaluated the resulting design ideation for novelty and variety.

Goldschmidt and Smolkov (2006) [13] studied the impact of presenting visual stimuli to design teams prior to a design activity. The visual stimuli varied in intensity for three independent designer groups, whose design outputs were later judged for creativity by experts. They found that the variation in visual stimuli was accounted for variance in their creative output.

3. Research Methodology

The authors conducted the study in three stages, namely productive stage, evaluation stage, and analysis stage. In the Productive stage, three groups of end-users treated with different design aids participated to co-ideate the case tool. In the evaluation stage, a distinct end-users' group evaluated creative ideation generated by productive groups. Finally, in Analysis stage, the authors analyzed how much variance can be accounted for varying design aids. In the following sections, the authors detail the entire study methodologically.

3.1. Participants

The participants of productive and evaluation stages belonged to real users' population of the tool under design, complying with the notion of PIN/PD. All the groups were uniform in all characteristics of interests. They belonged to the same Program at the faculty of Information Technology of ANONYMOUS University, studied same courses, learned same skills, and shared a similar background.

The productive group—12 females and 68 males—was divided into three treatment groups, namely PA, PB and PC with 30, 23, and 26 participants respectively. The treatment groups were further divided into groups of 3 to 6 participants. The group size varied because the participants were allowed the formation by themselves to facilitate a comfortable in-group working environment. The evaluator group—8 females and 50 males—was further divided into 15 subgroups of 3 to 5 participants, with one exception of a singleton. The facilitators allowed him to work alone, however dropped his evaluation from analysis.

3.2. Procedure

There were three stages, 1) a quasi-experimental Participatory Innovation Stage to apply various interventions and collect creative output, 2) a Participatory Evaluation Stage to evaluate creativity in the work of treatment groups, and 3) an Analysis Stage.

3.2.1. Participatory Innovation stage

The participatory innovation stage comprised of three ideation workshops, intervened with different design aids, but proceeding in a similar fashion. The design aids used were 1) exploratory prototype with use scenarios, 2) storyboards, and 3) exploratory prototype with storyboards, for workshops PA, PB and PC respectively. Fig. 1. and Fig. 2. provide snapshots of exploratory prototype and storyboards respectively.

The authors used the framework of [2] to structure their participatory protocols. The framework divides a PD session into four broader activities, namely *Probing* (understanding participants), *Priming* (preparing participants), *Understanding* (understating impact of interventions) and *Generating* (ideating, designing, or evaluating etc.). Table 1 details the protocol used identically at workshops PA, PB and PC.

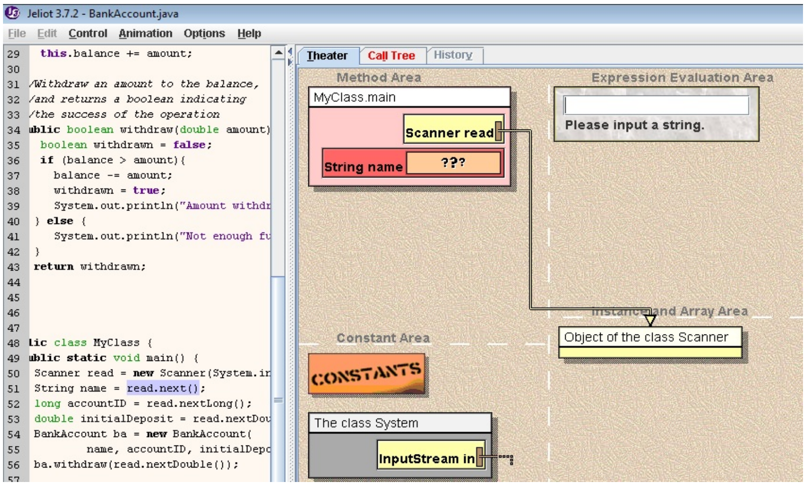


Fig. 1. A snapshot of exploratory prototype used at Participatory workshops

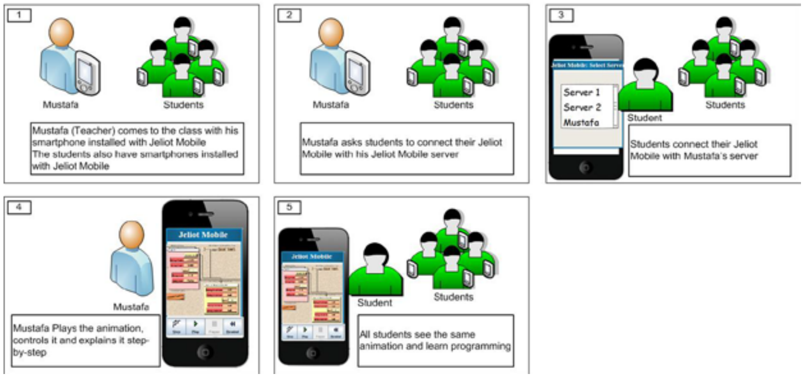


Fig. 2. One of the Storyboards used at Participatory Workshops (Collaborative Learning)

3.2.2. Participatory Evaluation Stage

The participatory evaluation stage comprised of two workshops, E1 and E2, both attended by all 58 participants of the evaluators group. The workshop E1 trained the participants individually—groups were not formed yet—for upcoming evaluation activity in workshop E2. Table 2 details the protocol used at workshop E1. The workshop E2's time was largely used for evaluations. The workshop opened with introduction and subgroup formation, followed by priming and understanding, and evaluations. Table 3 shows the protocol used at workshop E2.

The evaluation activity took two sessions, first with 145 minutes, and then with 90 minutes. The activity was divided because the facilitators felt that the participants were not able to concentrate and work any longer. All 15 subgroups, evaluated all design ideas (of PA, PB, and PC) for novelty and meaningfulness on a Likert type scale, as illustrated in Fig. 3. The questionnaire was an electronic document, and the participants used their computers to fill in the data. They returned filled-in questionnaire to the facilitators once the activity was completed.

3.2.3. Analysis Stage: Variables and Measurements

The independent variable was categorical. It defined three levels of intervention, namely 1) exploratory prototype with use scenarios, 2) storyboards and 3) exploratory prototype with storyboards coded PA, PB and PC respectively.

The dependent variable, namely Absolute Innovation Score (*AIS*), was created by summation of the ratings given to each design idea by 13 evaluator subgroups on a 5-anchors unipolar Likert type response format. The response anchors included extremely meaningful (*em*), highly meaningful (*hm*), Meaningful (*m*), somewhat meaningful (*sm*), and not meaningful (*nm*). Responses of two evaluator subgroups were not included into the analysis. One subgroup was excluded because it had only one participant. The other excluded groups' responses were found to be inconsistent.

Table 1. Participatory Protocol Used at Participatory Innovation Workshops

Activity	Procedure	Duration (min)
Probing: Start of the workshop	Introduction of participants/facilitators	10
	Briefing about the upcoming activity and Jeliot	
Priming: employing interventions to preparing for workshop	Applying Design Aid Interventions	30
	Break	20
Understanding: To assess the impact of interventions and to remove any ambiguities	Facilitators ask questions to assess the participants	10
	Participants ask questions to resolve any ambiguities	15
Generating: To generate innovative design ideas	Brainstorming	30
	Design Ideas generation	85
	Total Duration	200

Table 2. Participatory Protocol Used at Participatory Evaluation Workshop E1

Activity	Procedure	Duration (min)
Probing: To assess the participants' current state of knowledge and expertise	Introduction	10
	Q/A activity about Design Tools, Participatory Design, and Participatory Innovation	
Priming: To prepare the participants for the workshop by employing interventions	Explaining the purpose of the activity, participatory design and participatory evaluation	15
	Culturally situated innovation design activity (hands-on exercise)	35
	Introducing Jeliot and Jeliot Mobile	5
Understanding: To assess the impact of interventions in priming stage on participants' understanding	Facilitators ask questions to assess the participants	10
	Participants ask questions to resolve any ambiguities	
	Total Duration	75

Table 3. Participatory Protocol Used at Participatory Evaluation Workshop E2

Activity	Procedure	Duration (min)
Probing: To set the protocol and familiarize with the environment	Introduction of participants, facilitators, and the activity	10
	Formation of groups	
Priming: To prepare the participants for participatory evaluation	Presentation of Jeliot Mobile design artefacts	15
	Explaining participatory assessment and meaningfulness	
Understanding: To assess if the participants have developed the understanding	Facilitators ask questions to assess the participants	10
	Participants ask questions to resolve any ambiguities	
Assessing: To assess the design ideas produced by the productive group in earlier participatory design workshops. The stage was divided into two sessions	Brainstorming	145 + 90
	Assessing Jeliot Mobile conception for innovation in a participatory fashion	
	Documenting the assessed level of participatory innovation	
	Submitting the results of evaluation	
		270

The authors did not include negative anchor points, because they believed that a product/idea could not be negatively innovative/creative with respect to meaningfulness to the target community, though it can have zero or no meaningfulness in the opinion of a user. The measure of meaningfulness, if exists, varies in positive degrees, as in the case of most of the psychological measurements [14].

Once, all 15 evaluator groups responded on each Likert type item, the authors calculated *AIS* of each design idea (Likert-type item) using the formula given in (1). Consider idea A2-4 (fourth idea generated by productive Subgroup

A2), for example. Two evaluator groups thought it was not meaningful at all, one took it as somewhat meaningful, two group thought it was meaningful, five groups rated it to be highly meaningful, and only one group believed it was extremely meaningful. Using (1), the said idea received an *AIS* of 28, as demonstrated in Table 4.

$$AIS_i = \sum_{j=0}^{4} (\mathcal{T}(p)_j \times nr_j) \tag{1}$$

Where, AIS_i = Absolute Innovation Score of design idea i,
$\mathcal{T}(p)_j$ = scale weight of anchor point j, and
nr_j = no of responses anchored to point j

Table 4. The Score received by and the sum calculated for an example Likert type item (design idea)

Id	em	hm	m	sm	nm	Absolute Innovation Score (*AIS*)
A2-4	1	5	4	1	2	(4 x 1) + (3 x 5) + (2 x 4) + (1 x 1) + (0 x 2) = 28

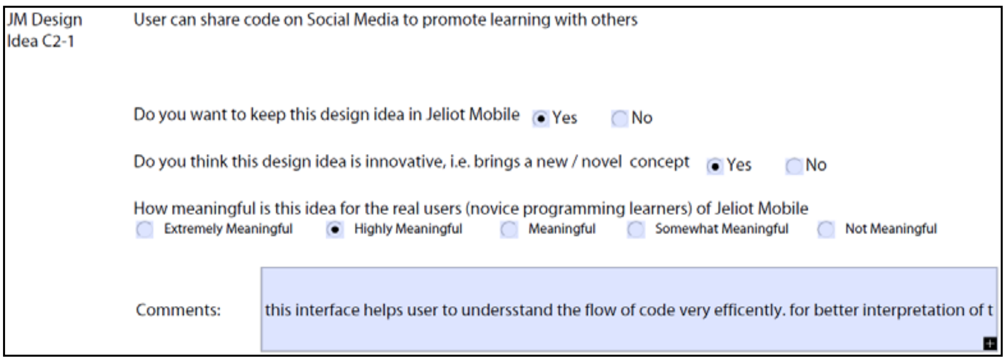
The *AIS* produced three distributions, PA, PB, and PC each representing the respective productive group. The authors then compared distributions means for between-group differences with an omnibus F-Test, i.e. with a one-way parametric analysis of variance (ANOVA).

4. Analysis and Results

The descriptive statistics showed that the distributions were slightly kurtotic and skewed. The assumption of normality was not tenable in some distributions ($n_{PA} = 67$, $n_{PB} = 55$, $n_{PC} = 50$). PB was skewed (skewness = -.72, *SE* = .32, *z* = -2.22) and kurtotic (kurtosis = .98, *SE* = .63, *z* = 1.54). PC slightly approached non-normality [(skewness = -.31, *SE* = .34, *z* = -.93), (kurtosis = -1.02, *SE* = .66, *z* = -1.53)]. PA was approximately normal [(skewness = -.17, *SE* = .29, *z* = -.59), (kurtosis = .07, *SE* = .58, *z* = .12)]. The assumption of homoscedasticity was tenable, confirmed with Levene's test (p = .23). The smallest to largest variance ratio was 1.33—[PA: (*M* = 28.79, *SD* = 6.94, *SE* = .85), PB: (*M* = 26.44, *SD* = 6.81, *SE* = .92), PC: (*M* = 31.18, *SD* = 7.84, *SE* = 1.11). ANOVA results showed a statistically significant difference between groups [$F(2, 169) = 5.74$, $p = .004$, $\alpha = .05$] with moderate effect size ($\eta^2 = .064$, $\omega^2 = .052$).

Since the assumption of normality was not tenable, the authors crosschecked ANOVA with Kruskal-Wallis H test. The H test produced similar results and showed a statistically significant difference between treatment groups [$\chi^2(2)$= 10.43, $p = .005$, $R_{PA} = 87.05$, $R_{PB} = 71.22$, $R_{PC} = 102.57$].

The authors analyzed the pairwise comparison of effect size with Common Language (*CL*) effect size statistic. The *CL* calculations showed the probabilistic inferiority of the group PB to other groups. There were 64% chances that a randomly drawn sample from PB had lower *AIS* than a randomly drawn sample from (*PA* U *PC*). The group PC performed generally better than other groups with 64% probability of observing superior *AIS* in PC than in (*PA* U



JM Design Idea C2-1 | User can share code on Social Media to promote learning with others

Do you want to keep this design idea in Jeliot Mobile ◉ Yes ○ No

Do you think this design idea is innovative, i.e. brings a new / novel concept ◉ Yes ○ No

How meaningful is this idea for the real users (novice programming learners) of Jeliot Mobile
○ Extremely Meaningful ◉ Highly Meaningful ○ Meaningful ○ Somewhat Meaningful ○ Not Meaningful

Comments: this interface helps user to understand the flow of code very efficently. for better interpretation of t

Fig. 3. Snapshot of the Questionnaire used for evaluation

PB). The pairwise probabilities of superiority were $p(PC > PA) = 59\%$, $p(PC > PB) = 68\%$, $p(PA > PB) = 60\%$. These *CL* results corresponded consistently with η^2, as checked against the correspondence of η^2 and CL provided by [15].

The consistency of parametric and non-parametric statistics provided evidence that the model developed for study was valid. Both parametric and non-parametric analysis failed to accept the null hypothesis that the groups were equivalent with respect to *AIS*, i.e. failed to accept that all three design aids influenced participants' creativity/innovation in a similar way. This implied that some design aids worked better than others with respect to participants' creativity/innovation.

The magnitude of positive influence was speculatively moderate ($\eta^2 = .064$). The same medium effect was exhibited by ω^2, however with a smaller number since it adjusted for any bias effect in population. Similarly, all pairwise comparisons between groups aggregated into a 62% stochastic heterogeneity. That implied a medium effect size explained by the choice of a particular design aid [16]. Further analysis revealed that the group with design aid composed of exploratory prototype and storyboards of the future system (PC) performed the best, the group with storyboards (PB) stood in middle, and the group having design aid composed of exploratory prototype and use scenarios (PB) performed the worst.

5. Discussion and Implications

Every single design aid has its own dynamics. Some tools are abstract, and hence promote a wider search space. However, the resulting ideas may be far from solutions, infeasible to implement, or simply out of the scope of the target system. Other tools are best at defining system boundaries, however guide the participants' creativity, and hence keep the person's creative process bound to a narrower solution space. The perfection of a design aid is to keep the bias minimum and trigger the creativity maximum. Using a single instrument, this balance seems difficult to achieve. For example, storyboards/scenarios provide good triggers to initiate broader thinking process, however unable to inform participants of the system boundaries/limits. Similarly, interactive illustrations/exploratory prototypes inform participants of the system concept, however, unable to initiate a divergent process sometimes. Moreover, not all tools are created equal, for example, both use scenarios and storyboard have intrinsic abstraction, but their impact was seemingly different on the participants.

The abstraction of storyboards required participants to spend more time in discovery than exploratory prototype. The authors understand that it was because they had to fill in missing gaps by themselves to create a big picture of the target domain. However, the boundaries of the target domain were still unclear, because everyone relied upon their own interpretation. Nonetheless, once primed, the participants asked fewer questions as compared to other groups. They were able to diverge and produce design ideas that were considered innovative both by the evaluator group and by the authors. However, this group sometimes generated ideas which seemed too futuristic, infeasible or unrealistic. The authors attributed this diversity to the abstraction of the storyboards

The exploratory prototype worked better for delivering the domain knowledge. The participants were able to understand about the problem domain. However, it brought strong and concrete visual cues binding the participants to a limited search space. The facilitators observed during the workshops that the participants were not sure what they were required to do or how they were expected to generate design ideas. Once exposed to exploratory prototypes, they mostly tried to correct any perceived problems, or considered ideas similar to that presented. This behavior showed that their thought process did not diverge.

Since, exploratory prototype did not help much in triggering divergent thinking process, the group PA and PC were given use scenarios and storyboards respectively as the second part of their design aid. The facilitators did not note any differences in the behavior of the two groups, like clarity/confusion, questions asked etc., i.e. they developed a similar level of understanding. However, the creative thinking process was influenced differently as exhibited by the difference in output of both groups. The authors attribute it to the medium of presentation. Nonetheless, the storyboards and the use scenarios offered the same story, however with different medium. The storyboards were pictorial and the use scenarios were verbal.

6. Conclusions

The authors conclude that it is beneficial for end-user designers that they are given polymorphic design aids. First, they shall be primed for the target domain, and then they shall be given triggers to push start the divergent thinking process. A clue on scope and feasibility boundary shall accompany as well.

The authors also conclude that it is important to evaluate ideas generated in PIN/PD contexts. The end-user designers may produce design ideas that are infeasible to implement, too-futuristic, confined to a particular sub-group, or meaningless to the target community on the whole. Hence, evaluation of design ideas for their meaningfulness is utmost important. Nonetheless, a non-user cannot decide which ideas to pick/drop from user-generated output, which will turn the whole exercise from being user-centric to designer-centric. Thus, a user-centric participatory approach to establish the usefulness and meaningfulness of design ideas must be deployed to refine the target ideation.

In summary, the design aids shall serve at least three distinct purposes for PIN/PD contexts. First, they shall provide domain/design knowledge to the participants. Second, they shall trigger participants' creative process. Third, they shall provide clues on scope/feasibility boundaries. When designing with experts in non-PD/PIN contexts, the participants usually come with some amount of domain knowledge, adequate amount of design knowledge, and are aware of scope/feasibility boundaries. Thus, developing design aids in such contexts does not demand separating, detailing, designing and implementing these three aspects. The importance of carefully designing these aspects for user-designers in PIN/PD is, however, immense. The application is not limited to one particular field, ranging from healthcare to education, and from industry to government, designing innovation in participation can benefits from this strategy.

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