Out of the box: Using gamification cards to teach ideation to engineering students

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Abstract. This paper reports on innovative teaching interventions in the frame of Internet of Things (IoT) design ideation classes. A card-based gamification approach has been applied in two different engineering masters courses. The participating students had already a good understanding of IoT technologies and they were asked to produce innovative designs by using them. We examine here the produced design ideas and the students' perception of the collaborative design process and tools. The paper discusses broader issues relating to applicability of design- and ideation-focused gamification methods in the context of engineering education and the effect they have on collaborative design and innovation.

Keywords: Internet of Things · ideation method · card-based design.

1 Introduction

The general goal of engineering courses in Internet of Things (IoT) is to establish a clear view of the technological landscape of the Internet of Things. The range of technologies that students need to understand, from low-power embedded devices, low-power and long-range wireless networking, up to cloud environments, is vast. Engineering education should address the need for skills such as flexibility and ability to work in a broader multi-disciplinary perspective, which are recognized as key skills for the 4th industrial revolution [3]. Towards addressing this need, the University of Patras and the Sapienza University of Rome introduced design methods for ideation in different IoT classes, as part of course workshops. The aim was to investigate what engineering students gain from such design methods, and assess the weaknesses and strong points of such interventions in teaching design ideation. The workshops produced some interesting findings in terms of the applicability and usefulness of such methods, with a particular perspective in the generation of innovative ideas, i.e. aiming to assess if this approach allows for 'out-of-the-box' design thinking. Design cards

have been used extensively to guide the processes of ideation and negotiation, allowing introduction of new and different perspectives [4, 2].

2 User studies

The Tiles IoT Toolkit[5] (version 0.6) was used in the interventions presented here. The Toolkit contains 21 design *missions* cards, centered on human needs and desires, 25 *things* cards for connected and interactive technological artifacts, 9 cards on *human actions* and 9 on *feedback*, describing how people can interact with things, *services* (25 cards), with popular apps and online services for IoT communication, and finally 10 evaluation *criteria* cards. The rules were adapted in each intervention in order for the ideation activity to be constrained within the time limits of the workshop and to give a more playful character by introducing turn taking, and roles of defender and attacker of cards, as discussed next.

Fig. 1. A typical design session with the Tiles IoT Toolkit.

The Tiles IoT Tookit was used in design workshops in three separate occasions. Two of the workshops were organized in the frame of the graduate course 'Design of Interactive Systems' of the Combined Master's in Electrical and Computer Engineering of the University of Patras (UPatras), in two consecutive years, in the spring of 2017 and 2018 respectively [1]. In April 2018, a third IoT design workshop was organized in the frame of the 'Master's degree course in Pervasive Systems' in the Department of Computer, Control, and Management Engineering at Sapienza University of Rome (UniRoma). The use of the ideation toolkit and the design tasks differed in the two cases, as discussed next.

In the University of Patras, in total, 30 final year students participated in the workshops (ages 24-26). The first cohort (2017) had 12 students, in 3 groups of 4, while the second cohort (2018) provided data by 18 students, arranged in 4 groups of 4 or 5 students each. The design workshops had a duration of approximately 2 hours.

The UniRoma workshop consisted of 31 (ages 22-30) students, split into 13 project groups. The workshop was organized in two sessions. Only data from the

first session is included here, since the second session was focused on presenting and criticizing the designs of the teams.

Design task: The UPatras students were given the task of designing an innovative cultural heritage application or device. The 2017 cohort was asked to support visitors of an unspecified museum, without further specifying the type of device, or the characteristics of the museum. The 2018 cohort was asked to design an IoT application for the visitors of the archaeological site of Pompeii in Italy.

In the UniRoma workshop, unlike the UPatras workshops, each team individually determined its design task at the beginning phase of the workshop, however the students were more constrained in the use of the Tiles IoT Toolkit.

Procedure: In the UPatras workshops, each group used a full deck of Tiles cards and board (Figure 1). The sessions were organized in phases: For every phase, each team member drew cards in turn, and when the player found one she thought was relevant, she argued defending it, while the rest argued for rejecting it. Teams were instructed to agree on 2-3 cards in each phase. In the first phase (50 min duration) they drew from the 21 *mission* cards in order to investigate possible design missions, then followed by 25 *thing* cards. Next, they used the *human actions* cards and corresponding *feedback* cards. Having selected the cards, they had to proceed with defining some scenarios of use for their design.

In the final phase of the workshop they had to use *criteria* cards for evaluating their proposal. Finally, they had to photograph the material and reflect individually on their design and prepare an individual report, to be handed in a week later. They were also asked to evaluate the tools and the group activity.

In the UniRoma workshop, the students were split in groups of 2-3 people. After an introductory discussion, the workshop facilitator handed to each group one or two *mission* cards, to reflect on context and to describe the subject area of the missions and what it can include (5-7 minutes duration). The workshop facilitator moved between them to stir ideas when they seemed stuck.

Next, each group presented the subject of their design task. As the presentations progressed, the facilitator wrote keyword-clouds on the board, linking different subject areas. Similarities between the groups emerged, on the basis of which, ten larger teams were formed. Next, selected *things* and *human action* cards were handed to the new teams. They were asked to continue brainstorming, with a more concrete scenario on their design task, to solve real problems with IoT application suggestions. The facilitator helped teams that seemed stuck by asking prompt questions. After 15 minutes of team brainstorm, they quickly presented their results to the other groups, aiming to cross-fertilize their ideas.

After the presentations, near the end of the two-hour session, the students were asked to individually evaluate the process and put their thoughts about the Tiles cards process in writing. These comments, along with the reports submitted by the UPatras cohorts, form the basis of the following analysis.

3 Designs

The UPatras groups produced the following design ideas: (a) A tablet and stylus device, through which the visitor can pick up the colour of a real object and use it to draw shapes on the tablet, inspired by the exhibit. (b) A smartwatch and headphones for a personalized guide in the museum. (c) An augmented reality glasses guide of the museum, that allows watching videos related to exhibits. (d) An immersive virtual reality application at various VR stations, providing experience of the site as it used to be augmented with avatars of current visitors. (e) Smart glasses presenting images of the exhibits, as they used to be, augmented with audio and text. (f) A head-mounted display and glass in a special room, providing virtual reality experiences of the site as it used to be. (g) An augmented reality application that allows the visitor to see the place as it used to be.

As one can observe, the produced designs lack in innovation and are mostly variations of the same idea, reflecting current trends and applications in museums and archaeological sites with virtual and augmented reality components.

The URoma groups produced the following design ideas: (a) Innovative authentication process using user's hardware and cloud resources. (b) A smart luggage that automatically checks its content and provides suggestions of what to pack and a reminder of when to pack. (c) A smart aquarium that can feed the fish and monitor their well-being. (d) Smart contact lenses that provide information about the emotional state of people around the user. (e) A smart bracelet that contains personal identification documents such as identity card, passport, credit card etc. (f) A device to record and manage track training exercise. (g) A neural computer-to-human interface that enhances human cognitive abilities. (h) An in-car sensing system for road pothole detection and reporting. (i) A bed with mechanical alarm that does not allow oversleeping. (j) A general architecture to integrate IoT hardware through a single interface. In the UniRoma case we have wider diversity as the task was not constraint by a specific problem, however some of the produced designs were either inspired by science fiction (e.g. neural-computer interface to augment human intellect) or smart devices (luggage, aquarium, bracelet) that sense the world and react to it, implementing more typical IoT applications.

The more diverse designs produced by UniRoma students reflect the fact that they were faced with an open design task.

4 Analysis

The students' comments were further analyzed following a structural coding approach [6], that allows the exploratory investigation of the participants' responses. After reviewing the students' feedback, an initial code list was developed, and used to code the responses. Subsequently, in two iterations, the code list was evaluated, revised and re-applied. The resulting list contains sixteen codes, ten of which express positive attitudes and six negative ones (Table 1).

Table 1. Coded responses of the 55 participants of the workshops (UniRoma N=27, UPatras N=28). Plus or minus signs denote positive or negative attitude respectively.

#	**Code**	**All**	**UniRoma**	**UPatras**
1	Fast ideation and rapid brainstorming (+)	36 (65%)	19 (70%)	17 (61%)
2	Brainstorming in teams was effective (+)	17 (31%)	8 (30%)	9 (32%)
3	The framework was limiting (-)	13 (24%)	3 (11%)	10 (36%)
4	Structured idea generation process (+)	11 (20%)	3 (11%)	8 (29%)
5	It is a useful tool to stimulate discussion (+)	9 (16%)	5 19%)	4 (14%)
6	Tiles Toolkit provides flexible starting points (+)	9 (16%)	4 (15%)	5 (18%)
7	It has been an enjoyable experience (+)	9 (16%)	5 (19%)	4 (14%)
8	The Tiles concepts are unfeasibile or unrealistic (-)	5 (9%)	5 (19%)	0 (0%)
9	Tiles cards do not lead to a design idea easily (-)	5 (9%)	3 (11%)	2 (7%)
10	Hones teamwork skills (+)	5 (9%)	5 (19%)	0 (0%)
11	The Toolkit promotes speculative thinking regardless of technical limitations (+)	4 (7%)	2 (7%)	2 (7%)
12	Not enough time available for idea generation (-)	4 (7%)	0 (0%)	4 (14%)
13	Vague ideas, unfeasible or not realizable (-)	4 (7%)	2 (7%)	2 (7%)
14	Concrete ideas, feasible and realizable (+)	3 (5%)	1 (4%)	2 (7%)
15	Hones presentation skills (+)	2 (4%)	2 (7%)	0 (0%)
16	Brainstorming in teams was not effective (-)	1 (2%)	1 (4%)	0 (0%)

The students made 137 comments (2.5 comments per student), 77% of which were positive, distributed uniformly across the two student groups (UniRoma 79% and UPatras 76% positive comments respectively).

Both groups agree on items 1 and 2, namely that the Toolkit supports fast ideation (65%) and that team brainstorming was perceived as effective (31%). Most of the comments are similarly distributed between the two groups.

A negative comment, made by 24% of the students was that the framework was limiting (item 3). This was more pronounced in the UPatras group, whose design task was set by the workshop facilitators.

5 Discussion

Feedback from the students, indicates a positive view for both the approach used and the process of collaborative design. They commented that the tool supports fast development of new ideas, structures ideation, supports exploration of new design spaces, facilitates collaborative brainstorming. On the other hand, frustration was expressed on the time constraints and the feasibility of some of the mission cards allocated to them, in particular by students of UniRoma. Some explicitly mention in their comments that, because of training as engineers, they have not been taught rapid ideation in a team environment. Similarly, another student notes that, the real problem is that "we are engineers and it is very tough to be speculative." The complaints about time restrictions reflect the fact that engineering students are used to focusing on technical aspects of possible design solutions and not so much to exploring a design space horizontally. The

produced design solutions were not very innovative, but were based mostly on existing applications. In particular the UPatras workshop designs were repetitive and of low innovativeness. This may be attributed in some degree to the fact that the students were not introduced to the requirements of the domain of cultural heritage, so ownership of the problem was low. There seems to be a contradiction between the positive view of the students on the tools and the process and the results of the workshops. Questions are thus raised regarding the motivation and ability of engineering students to use broad techniques and design ideation methods effectively, and, specifically, how they should ideally be trained in order to cope with broader thinking and adoption of multidisciplinary approaches.

Starting from specific mission cards may be the reason that the UniRoma students provided a wider diversity of scenaria. Indeed, 16% of the responses allude to the opportunities that the wide range of mission cards offer.

Broader issues are raised by these observations, as per the effectiveness of the educational curricula within which they are used, and on how engineering students are trained to utilize design methods effectively [1]. As the facilitators observed first-hand, and the students explicitly noted in their comments, background skills are missing from their (formal or informal) curricula, constraining their abilities to approach design problems from different perspectives, address the broader issues involved, and generate ideas from different starting points, an issue that needs to be further investigated.

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