Leveraging prototypes to Support Self-directed Social learning in Makerspaces

Jaskiewicz, Tomasz; Mulder, Ingrid; Verburg, Samuel; Verheij, Bob

Publication date
2018

Document Version
Final published version

Published in
DS 93: Proceedings of the 20th International Conference on Engineering and Product Design Education (E&PDE 2018)

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
6 & 7 SEPTEMBER 2018, DYSON SCHOOL OF DESIGN ENGINEERING, IMPERIAL COLLEGE, LONDON, UNITED KINGDOM

LEVERAGING PROTOTYPES TO SUPPORT SELF-DIRECTED SOCIAL LEARNING IN MAKERSPACES

Tomasz JASKIEWICZ, Ingrid MULDER, Samuel VERBURG and Bob VERHEIJ
Faculty of Industrial Design Engineering, Delft University of Technology

ABSTRACT
The “Maker Movement” signifies emergence of a cultural model of a society where anyone can become a creative maker. As part of this movement, various kinds of “Makerspaces” provide physical and social infrastructures that help unleash people’s intrinsic abilities to make, create, and innovate. In this way, makerspaces become loci where maker communities develop as communities of interest and communities of practice. In such communities, participants acquire skills and knowledge through self-directed peer-learning and learning-by-doing, while leveraging each other’s practical expertise, individual motivations and enthusiasm. The presented work elaborates upon how maker communities within academic design engineering education and everyday-life contexts could better support their participants’ self-directed learning. Throughout two independent researches through design case studies, we investigated how these learning processes could be improved. Both cases involved the iterative development and assessment of service platforms for supporting the social learning processes of makers. One platform focused on documenting and sharing skills of makers, the other on documenting and sharing the making processes leading to a given artefact. Reflecting on the two platforms revealed two distinct aspects of encountered learning. The first aspect involves deepening and mutually encouraging development of individual expert skills. The second aspect involves multidisciplinary alignment during collaborations and peer-learning within a maker community, performed in teams encompassing complementary skills. The lessons learnt lead to proposing a conceptual framework, which aims to provide a support structure to improve self-directed social learning processes in makerspaces.

Keywords: Learning-by-Making, Makerspaces, Peer-learning, Prototyping, Research-through-Design

1 INTRODUCTION

The Maker Movement [8] signifies an ongoing transition towards a global culture where anyone can be a maker. Makerspaces are loci [18] where maker communities develop as communities of interest [7] and communities of practice [20]. In such communities, participants may acquire practical, craft-related skills and knowledge in a self-directed and unmoderated fashion. Additionally, Makerspaces frequently organise various kinds of tutorials, workshops, exhibitions or other events that support knowledge sharing, trigger inspiration and enable community building. The learning processes occurring in Makerspaces involve aspects of social learning [3], peer-learning [4], learning-by-making [15] and project-based-learning [11]. During their self-directed learning processes, makers leverage each other’s practical expertise, individual motivations and enthusiasm. They do so by working on concrete, typically self-motivated, “projects”, which incorporate implicit learning goals, inspire acquisition of new knowledge and skills, and verify and enforce newly acquired knowledge and skills through their immediate application to creation of concrete, physical or virtual (e.g. programming code, 3D computer model) artefacts. The making activity is typically part of some form of a creative design process. Artefacts which are the subject of making, are often not the main goals of the process, but are made in order to be learned from. In such context, these artefacts take the role of prototypes, which, according to Lim et al. [12] function both as “filters” for acquired or generated knowledge, and as “manifestations” of that knowledge. In both of these roles, prototypes may also serve as “boundary objects” [17], which are objects supporting communication and knowledge exchange within and towards the outside of the maker community and the Makerspace were hosting it. Just like there is no single definition of a prototype, there is also no single definition of what is a Makerspace. However, Makerspaces can be differentiated from other kinds of workshops, labs or classrooms by an ambition to provide the highest possible range of making facilities to the highest possible diversity of people, where FabLabs, Techshops or Hackerspaces are specific types of Makerspaces [5]. From this perspective, a community centre, a university or a company can be a viable host of a Makerspace, and maker communities may respectively be composed of citizens, students or employees. Indeed, Makerspaces proliferate around the world in public, educational [9] [13] and commercial [2] contexts, while providing tools and infrastructures to unleash people's intrinsic abilities to make, create and innovate [18].

2 CASES AND METHODS

Even though, Makerspaces and maker communities offer unique learning opportunities to their participants, there are also multiple factors inhibiting the learning processes of makers. In the presented work, we investigate these factors and we explore how involved learning processes can be improved with help of digital services. We chose two contexts for performing this investigation, as summarised in table 1 and figure 1. The first case is a typical not-for-profit Makerspace called "Maakbaar", situated in the historic centre of Delft, the Netherlands. Maakbaar mainly caters to spare-time, often casual, making activities of citizens and has a growing community of approximately 200 makers. The second case is a large workshop called "Practicum Modelbouw en Bewerkingen" (PMB), which is part of the Industrial Design Engineering faculty of TU Delft, located on the university campus, on the edge of Delft. PMB caters to approximately 2000 industrial design students and staff. PMB also qualifies as a Makerspace, because it offers a large variety of making facilities, and it caters to students and staff having very different making skills, interests and goals. The two chosen cases offered us an opportunity to compare the learning processes occurring in Makerspaces that share the same geographical context, but differ in their scale, organisational models and motivations of their members.

Figure 1.Maakbaar, on the left, accommodates casual makers, while PMB, on the right, is embedded in university education and caters to makers of varying expertise and interests through a wide range of machines and workshops

Table 1. The two investigated service design cases encountered two different sets of problems in respective maker communities and makerspaces

	Case 1 / Maakbaar / Makefolio	**Case 2 / PMB / Make-the-Cut**
Makerspace	Not-for-profit	University-based
Makerspace users	Citizens-makers	Design and engineering students and staff
Number of members	200 (approximate)	2000 (approximate)
Purpose of making	Hobby and DIY projects	Prototypes for education and research
Design goal	Supporting peer-learning and team-forming	Supporting acquisition of expert skills
Design and research methods	Interviews, observations, paper prototype and digital prototype usability studies, surveys, focus groups, concept testing, iterative design	
Designed platform purpose	Matchmaking of makers	Deepening making skills with focus on laser cutting as an example

Each Makerspace was addressed in a separate case study project following the principles of research through design (RtD), involving “gaining actionable understanding of a complex situation, framing and reframing it, and iteratively developing prototypes that address it” [16]. Each of the two cases was executed by one designer-researcher as part of a Master of Science graduation project in industrial design. Both designer-researchers are also co-authoring this paper. Designers-researchers selected the context and investigated problems and challenges faced by the encountered makers. The initial investigations were supported by literature studies, observations and interviews with makers engaged in the studied contexts. In later stages, prototypes of varying fidelity were designed, built and employed in a range of generative and evaluative research activities, as listed in Table 1 and exemplified in Figure 2. This approach allowed to incrementally collect insights regarding learning processes of encountered makers, while adjusting the scope and direction of addressed research questions.

Figure 2. Iterative design processes involved such activities as testing paper versions of designed service with makers (left), or organising and assessing a skill-building workshop and documenting its outputs (right) to verify design assumptions and generate new insights

3 CASE 1 OUTCOME - “MAKEFOLIO”

The first case converged on the problem of finding the right peers in the maker community to work with or learn from, which was a pressing concern of makers at Maakbaar. Casual makers constituting Maakbaar’s community do not regularly attend the Makerspace, and resort to social media, including a dedicated Facebook group and WhatsApp chats, in order to find other makers for join projects and peer-learning activities. In answer to this problem, the service and app called “Makefolio” (Figure 3) was designed as a tool for improved matchmaking between makers, based of their project needs and own skills.

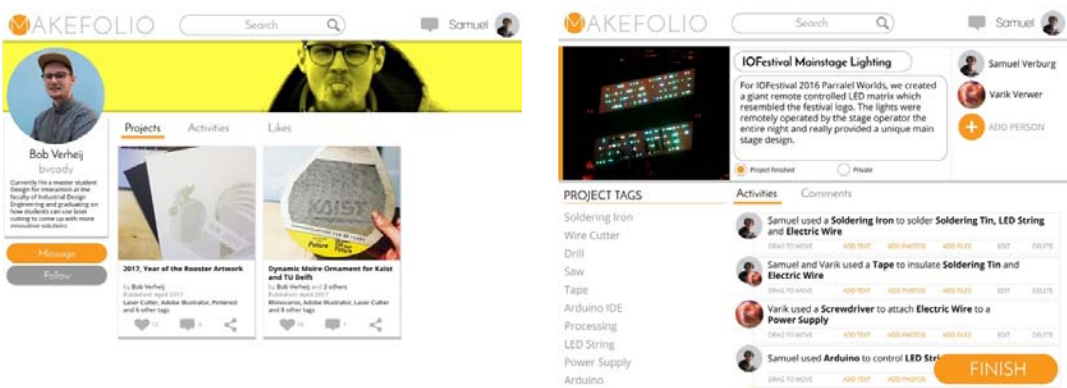

Figure 3. The designed “Makefolio” platform enables makers to document and share their skills while intuitively documenting the making processes of featured prototypes

Makefolio is both a concept and a prototype of an online service platform, which could be described as a social network platform for makers. The core functionality of Makefolio is documentation of tasks performed by one or multiple makers working in a project towards creating a specific prototype. Makers can use the platform to document their activities by using a simple sentence format with auto fill suggestions, based on principles of task analysis [1]. The sentences created in the platform include references to tools and materials used in the makerspace and are, in this way, made interoperable. Research performed throughout the design process has shown that this way of documenting enables makers to articulate their otherwise tacit or latent skills and know-how. Once skills of individuals are articulated, they can be found by others seeking help and project partnerships. Browsing of skills can be achieved in several ways. They can be accessed through the personal profile of a maker, through the project profile featuring the prototype, or by searching for a specific tool or material. In this way, a maker looking for either a new project partner with relevant skills, for someone to help in learning a particular skill (including the use of a specific tool or material), or ways to recreate parts of someone else's prototype, can find the needed person in the community.

4 CASE 2 OUTCOME "MAKE-THE-CUT"

The second case converged on the problem of the lack of support that makers at the PMB experienced when seeking new creative applications for Makerspace facilities. Here, the knowledge was typically obtained and shared through global platforms such as Instructables, YouTube videos or Pinterest boards. However, in this way, the sharing mechanisms lacked local specificity and relation to the social and physical locus of the PMB. To answer this problem, the design in the second case was aimed to support aggregation and exchange of expert skills in a community of makers. The case focused on laser-cutting as an example of a Makerspace technique, leading to the design of the "Make-the-Cut" platform.

Make-the-Cut is a concept and prototype of an online service platform and app, as illustrated in Figure 4. The platform could be described as a tool for documenting unique making techniques based on prototypes they were applied to. Unlike Makefolio, which is intended to connect makers to each other, the premise of Make-the-Cut was to help makers in developing a specific making expertise in a self-directed manner, while creatively exploring intriguing results and making processes. The platform has been specifically designed for supporting laser cutting. However, it was envisioned to be equally applicable to other facilities and skills commonly encountered in Makerspaces.

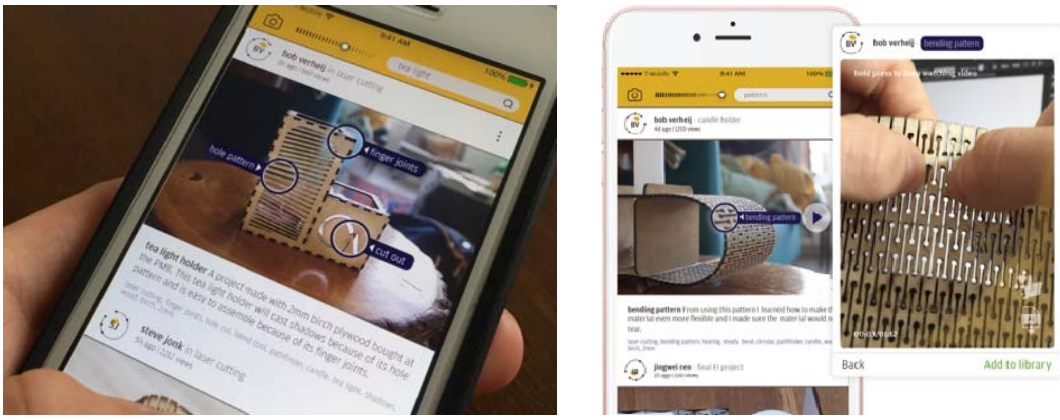

Figure 4. Make-the-Cut app allows browsing prototypes built in the makerspace, and selecting their parts to reveal detailed making instructions and tips

Make-the-Cut's functionality has been organised around browsing a catalogue of prototypes, and zooming in on their details to access videos and textual descriptions explaining how they were created. The app reduces the threshold required to make documentation of prototypes, amongst others, by supporting making video documentation with the Smartphone and providing a prescribed format for tips and instructions. The platform also allows generation and scanning of fiducially markers embedded in prototypes, turning exploration of real-world prototype exhibitions into browsing and searching for relevant in-app content.

5 DISCUSSION

Throughout both iterative RtD processes, multiple insights were generated around the two complimentary sets of challenges encountered in maker communities. On the one hand, we found that peer learning success depends on the ability to find the right peers to learn from and to learn with, which turned out to be a serious obstacle for makers at Maakbaar. On the other hand, deepening makers' individual areas of expertise, as well as accumulation and growth of expertise across the maker community have been the major learning obstacles encountered in the PMB. While the two designs attempt to provide solutions to these two sets of problems, they also, in combination, provide a lens for a broader reflection on the nature of the occurring learning processes.

The main similarity between Makefolio and Make-the-Cut lies in the strategy of leveraging prototypes as a scaffold supporting removal of encountered self-directed learning obstacles. In the Makefolio design, prototypes were used to structure and organise the making activities of individual makers. By describing activities performed in the process of making a prototype, the prototype becomes a point of reference towards which these activities converge. It allows a tangible exemplification of one's skills and abilities, provides a way to articulate these skills and abilities, and enables a natural way for other makers to discover and relate to them. In the Make-the-cut design, prototypes became a way to structure the expert know-how, including documenting unique making techniques. Here, the prototypes have a different role than in Makefolio. They serve as exemplifications of expert know-how and skills, which are otherwise difficult to grasp, communicate and share. The designed platform amplified this role by providing a link between the prototypes and detailed documentation of the skills and knowledge required to build them. By doing so, it served the two complementary driving forces of a maker community: it helped the makers, who were sharing and the makers who were learning. Makers willing to share were provided with a set of tools that allowed them to easily document their work and reflect on it. Makers keen to learn were provided with a way to instantly obtain the specific skills and needed know-how. Ability to learn faster allowed makers to progress quicker with their project and reach the stage of developing additional know-how and skills that they in turn could share back with the community, stimulating the turnover of learning and sharing activities.

Reflecting on both designed platforms allowed us to explicitly articulate two aspects of the learning process occurring in the makerspaces. This reflection can be translated into an elaboration on the way of describing professionals and their skills using a T-profile [10], and its pi-shaped and comb-shaped extensions [6]. As shown in Figure 5, on the left, in such profiles the long vertical bar represents the core expertise of a given maker, and the shorter vertical bar optionally represents one of many other possible expertise areas that maker may have. The vertical bars can be imagined to grow in the process of one's specialisation. The horizontal bar represents maker's "disposition for collaboration across disciplines" [10], requiring him or her to understand and empathise with other participants of the maker community. From the perspective of the occurring learning, we can refer to the involved process as a "collaborative learning alignment" between involved individuals. Juxtaposing hypothetical T-profiles of a number of makers, as shown on the right-hand side of Figure 5, shows that the individual expertise areas of makers are complementary, meaning that where one maker can be an expert, the other can entirely lack or have partial expertise and vice versa. At the same time, makers' general overview of all making practices and possibilities in a makerspace should ideally match, such that they can find project partners and be able to direct their individual learning processes.

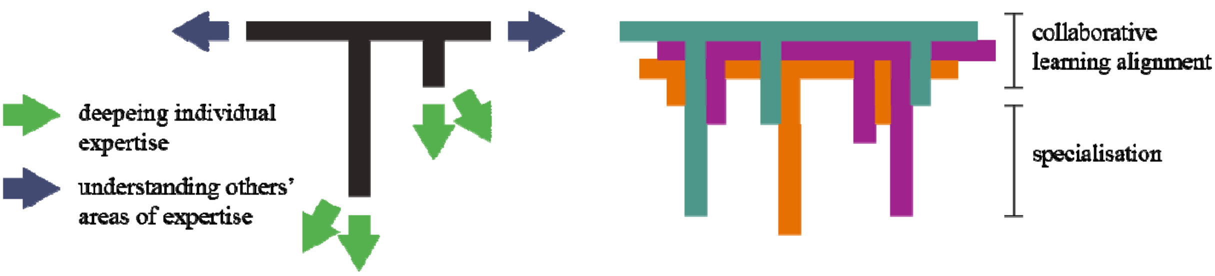

Figure 5. Comparison of the two designs revealed two distinct types of collective learning encountered in makerspaces, being collaborative learning alignment and specialisation

The two design cases which have led us to above reflections might have initially appeared to pursue two different sets of problems that the makers in these studied communities were directly facing. However, the joint reflection on both cases provided us with a pedagogical perspective to see the challenges of collaborative learning alignment and specialisation as complementary ingredients of the involved learning processes. This enables further investigation into the opportunities of combining the two platform designs, while using prototypes as the connecting element for documenting and sharing the personal skills of individual makers, as well as for transferring know-how between makers.

Eventually, we can also speculate whether the nature of the observed learning processes is exclusive to craft-related making skills, as presumed in this work, or whether it can be also applied to other domains of knowledge acquisition. For example, we might imagine that skills such as performing user research, or developing a business model could be added to enhance the scope of involved learning-by-making processes.

6 CONCLUSIONS

In keeping with the RtD approach promoted in the students' work, the presented paper elaborated upon two service design cases performed for two different makerspace contexts as instruments of enquiry on the nature of learning taking place in maker communities. The resulting framing distinguishes collaborative learning alignment and specialisation as two complementary types of learning activities of makers. Based on the insights generated from the *research through* the designed platforms, we infer that facilitated documentation of prototypes and prototyping activities can serve as a catalyst for reflective and collaborative learning processes in maker communities. Earlier work [14] showed how hard it is to organise and assess collaborative and reflective learning processes. The presented research shows that leveraging documentation of prototypes and prototyping can be instrumental in embedding these informal learning processes in design engineering curricula.

REFERENCES

[1] Annett, J. and Stanton, Task analysis. 2000.
[2] Autodesk Pier-9, Available: https://www.autodesk.com/pier-9 [Accessed on 2018, 5 March].
[3] Bandura A. Social learning theory, 1971.
[4] Boud D, Cohen R, Sampson J. Peer learning in higher education: Learning from and with each other, 2014.
[5] Cavalcanti, G. Is it a Hackerspace, Makerspace, TechShop, or FabLab. In *Make*, May 22, 2013.
[6] Classon I. Stupid Question 218: What are T-shaped, Pi-shaped and Comb-shaped skills, and which one should I aim for? Available: http://irisclasson.com/2013/07/08/stupid-question-218-what-are-t-shaped-pi-shaped-and-comb-shaped-skills-and-which-one-should-i-aim-for/ [Accessed on 2018, 5 March], 2013.
[7] Cortes C, Pregibon D, Volinsky C. Communities of interest. In *International Symposium on Intelligent Data Analysis,* 2001, pp. 105-114.
[8] Dougherty D. The maker movement. In *Innovations: Technology, Governance, Globalization,* 7(3) 2012, pp.11-4.
[9] Halverson, E.R. and Sheridan, K. The maker movement in education. In *Harvard Educational Review*, 84(4), 2014, pp.495-504.
[10] Hansen M. IDEO CEO Tim Brown: T-Shaped Stars: The Backbone of IDEO's Collaborative Culture. Available: https://chiefexecutive.net/ideo-ceo-tim-brown-t-shaped-stars-the-backbone-of-ideoaes-collaborative-culture__trashed [Accessed on 2018, 5 March], 2010.
[11] Krajcik J.S., Blumenfeld P.C. Project-based learning, 2006.
[12] Lim, Y.K., Stolterman, E., Tenenberg, J. The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas. In *ACM Transactions on Computer-Human Interaction (TOCHI)*, 15(2), 2008, p.7.
[13] Mostert-van der Sar, M., Mulder, I., Remijn, L., and Troxler, P. FabLabs in Design Education. In *Proceedings of E&PDE*, 2013, pp. 629-634.
[14] Mulder, I., Swaak, J., and Kessels, J. In search of reflective behavior and shared understanding in ad hoc expert teams. *CyberPsychology & Behavior, 7*(2), 2004, pp. 141-154.
[15] Papert S., Harel I. Situating constructionism. In *Constructionism*, 36(2), 1991.
[16] Stappers P. and Giaccardi, E. Research through Design. In *The Encyclopaedia of Human-Computer Interaction, 2nd Ed.*, 2017.
[17] Star, S.L. and Griesemer, J.R. Institutional ecology, translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *In Social studies of science*, 19(3), 1989, pp.387-420.
[18] Von Hippel E. "Sticky information" and the locus of problem solving: implications for innovation. In *Management science* 40, no. 4, 1994, pp.429-439.
[19] Walter-Herrmann, J. and Büching, C. FabLabs: Of Machines, Makers and Inventors. 2013.
[20] Wenger E. Communities of practice: A brief introduction, 2011.