Online distributed prototyping through a university-makerspace collaboration

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Abstract

Distance based design education is limited in its ability to support learners' exploration of tangible aspects of design processes. However this mode of learning trains students in working in online environments. Makerspaces offer training in physical aspects of making and designing but with a focus on informal teaching of instrumental skills. We have investigated the feasibility of bridging these environments to offer a more rounded educational experience that could prepare students for future employment in emerging redistributed manufacturing industries.

Our pilot study paired design students at The Open University with maker learners at MAKLab, a community makerspace. Teams communicated via an online environment, to evolve design concepts from sketches and CAD models to fabrication of a full scale prototype chair, repeated in three iterations. Participants experienced challenges in cross disciplinary communication and collaboration across the different learning cultures mediated solely by the internet, but learners noted they had gained insight into a range of processes, and the pilot showed potential as a model for future university-makerspace collaborations.

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Author Keywords

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Introduction

The UK government has identified that manufacturing is changing, and that this will affect the workforce skills that will be needed in design and manufacturing industries [3]. Emerging distributed production processes and digitised manufacturing chains will require future employees to be competent not only in a range of technical skills (e.g. computer-aided design and digital manufacture), but they will also be expected to have the relevant soft skills associated with online mediated, knowledge based work (e.g. negotiation, cross-disciplinary communication, project management).

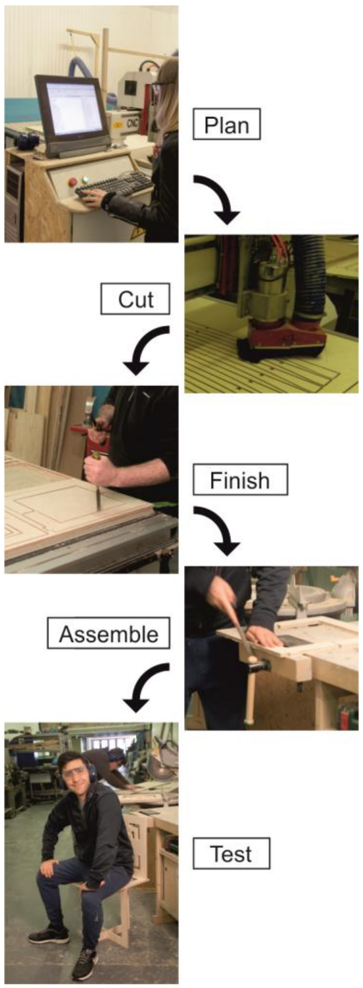
The research reported in this paper investigated the extent to which the challenge of training designers and makers of the future could be addressed through a collaboration between universities and community makerspaces. A collaborative learning model was tested via a feasibility study which included a distance based design education provider, The Open University (OU) in the UK, and a makerspace, MAKLab Limited (http://www.maklab.co.uk), based in Glasgow.

Each of these partners has strengths but also challenges: the OU provides high quality blended distance design education, but is limited in its capacity to support students in material aspects of design, e.g. making physical prototypes; whereas MAKLab provides personalised, informal face to face tuition to develop specific making skills, but have expressed an interest in offering longer term design-focussed challenges to trainees and engagement with online collaboration practices. Through the feasibility study, we explored to what extent learners in the two organisations would benefit from collaborating in a distributed 'summer school'. The participants' objective was to produce physical prototypes from a design brief, communicating solely via an online space, whilst learning vital soft skills that would be applicable in future professional workspaces.

Background

Manufacturing industries are changing. The emergence of online technologies has revolutionised production processes and manufacturing chains, for example, it is now common for a designer to collaborate with a fabricator working anywhere on the planet, with communication supported solely via the internet. New ways of working are developing and new skills are required: a 'business as usual' approach to training will not provide the workforce of the future [3].

Figure 1: The making process (MAKLab, Glasgow)



Design education has traditionally focussed on providing students with both theoretical frameworks and a range of experiences that enable them to develop understanding of shape and form [9] and hence prepare them for design problem solving in the workplace. Active engagement with materials, tools and processes emphasising "learning while doing" [11] is central to the studio focussed, long established model of training provided in higher education, often seen as the "signature pedagogy" for design education [2]. A central activity is the creation of physical models, the creation of which raises design issues that are difficult to identify via alternative representations such as sketches and software models [14]. But providing this experience via a distance based education can be challenging: "making of three-dimensional models has always proved difficult to support" [8] and it has long been recognised that online collaborative design projects bring challenges [12].

Online learning means "a certain level of digital literacy is necessary simply to study" [4] and active approaches are taken to support students' digital training and skills development, recognizing that ICTs have moved learners to "interactive learning participants" and repositioned teachers' identities and roles [8]. 'Virtual design studios' have enabled the social component of studio based education to be approximated and explored in online learning environments [7].

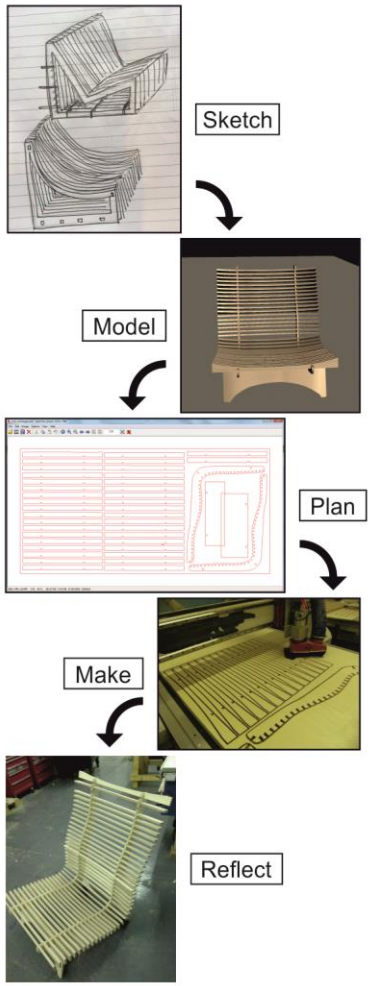
The emergence of the makerspace movement might provide a complimentary partnership to distance learning universities, and enable the provision of a broader curriculum. Makerspaces are community based work spaces, with an emphasis on peer learning, idea sharing and making, offering the opportunity for trainee designers and fabricators to engage in the physical and tangible aspects of designing and making, as well as developing soft skills [5]. However, such informal education can be too instrumental, focussed around particular tasks or specific situations, with too little theoretical or conceptual underpinning [6].

We therefore propose a collaborative model of education that combines the distinct pedagogical approaches of these two types of organisations (makerspaces and universities), taking a less instrumental and more informal, studio-based semi-structured approach to learning. As well as overcoming the challenges indicated above, by bridging formal and informal learning environments and devising a learning activity that required learners to work with partners from outside their own institution, we created a more 'authentic' learning experience [13] that closely replicated a real-world distributed designer-maker relationship, and enabled us to carry out development research into design-and-making focussed online collaborative learning [10].

The Summer School

In 2015, we designed and ran a 12 week activity that randomly paired OU second level undergraduate design student volunteers (located around the UK), with members of MAKLab (Glasgow), recruited from the local community. Participants (7 female, 9 male) were from varied backgrounds with differing experiences of designing and making. The pairs were given a design brief to design and fabricate three iterations of a full sized prototype chair, to be constructed of 12mm plywood, and to be assembled using no adhesives or fixings (e.g. screws or nails). The chair had to be designed for easy assembly and transportation, and

Figure 2: The summer school prototyping cycle



fabricated using a CNC (computer numerical control) router (for the making process, see Figure 1). These parameters were intended to focus learners' attention on range of design and making challenges, and require them to develop expertise in a variety of industry applicable skills. Pairs were allocated the roles of *designer* (the OU students) and *maker* (the MAKLab members), and all communications between pairs were via an online forum (built using standard Wordpress modules), simulating a distributed manufacturing scenario they were likely to encounter in future workplaces. The designers responded to the brief originating sketches and CAD models of designs, shared via the forum and discussed with their maker partner to ensure their intentions were clear. The makers then responded to the designers' ideas and helped them move towards a finalised 2D CAD software model ready for cutting, providing technical advice where required, for example on appropriate joining techniques, or the performance of the material. Once agreed, the design was cut on a CNC router in MAKLab, and the components for the chair posted back to the designer (the prototyping cycle is illustrated in Figure 2). This was then used by the designer to inform the next iteration of the design-make-analyse-reflect cycle, enabling evolution of design concepts (see Figure 3).

The online forum was monitored by OU and MAKLab staff, and a tutor was allocated for each group: an online OU tutor to help support design processes, and a tutor at MAKLab to support the makers with fabrication of the physical prototypes to provide expertise in response to technical questions.

Data was collected via surveys before the start of the summer school to capture participants' existing knowledge of design and making, feedback surveys were completed at the end of each iteration of prototyping, and semi-structured interviews were carried out either face to face or via Skype on completion of the project. Content and volume of forum posts were also analysed.

Outcomes

Seven out of eight pairs of learners completed the summer school. In total 1355 contributions were made to the forum by the participants, and tutors contributed 279 additional posts. 18 full scale chair prototypes were successfully fabricated, and a diversity of working and communication approaches was noted amongst the designer-maker pairs, with a number of key themes emerging: challenges around technical competencies, engaging with materiality of design, communication and collaboration, and issues resulting from working within a lightly structured learning model. In this paper, we will focus on two of these: materiality; and the learning model; and illustrate these through the challenges experienced by a designer and a maker.

Experiences: engaging with materiality of design
A key goal of the summer school was to enable learners to engage with the tangible, physical aspects of design and making. All participants noted their enthusiasm for this aspect (e.g. one of the designers provided the feedback *"Seeing the actual chair helped me to realise how it really presents itself"*).

However, a range of challenges were encountered across the design and fabrication cycle, from conceptualisation through to production. Designer X, originally from a banking background, illustrates the range of challenges we observed. This participant did

Figure 3: Three iteration of prototypes

not have previous design experience, so had to develop a range of skills while engaging with the project. In common with many of the designers, Designer X struggled initially with the instrumental skill of converting their idea from a sketch into a formal CAD model ("*thanks for pointing out the 'back and legs will be at different heights from the floor' issue"*) and also with understanding basic principles of design-for-assembly (*"I have been thinking about the joints again… ..I'm hoping that the maker can guide me here"*). Like many of the learners, Designer X was highly self-motivated and engaged with the material aspect of the activity (*"[I got] a piece of plywood for myself. I thought it was a good idea to hold it and touch it, to try and understand the material a little more*"). This designer struggled in the first cycle and a decision was made to send a small scale model to help communicate the shortfalls in the submitted CAD model. The physical reality of this mini-prototype helped move their understanding forwards ("*I have been kindly sent a mini laser cut version of my chair. Immediately I put it together and could see the errors of my design*"). Through active engagement with their designer-partner, and aided by tutorials shared by the design-tutor, this learner steadily improved their skills and successfully completed the second and third prototypes (see Figure 4). On completion, Designer X reported that they had utilised the skills they had developed during the project to design a bench for a local barber, and they reported "*I have learnt to design with manufacturing in mind*".

Experiences: managing a lightly structured approach to learning

A second key theme that emerged was the pedagogical approach, and how learners managed within the lightly structured, instead of a closely guided framework. The intention was for participants to benefit from the studio-learning model that typifies traditional design education, while also experiencing a more authentic distributed manufacturing scenario where professionals negotiate their own vision towards successfully completing a brief, working within multi-disciplinary and geographically distributed teams. (e.g. [10]).

Undergraduate students at The Open University follow highly structured learning pathways, intended to ensure parity of experience for a highly diverse and geographically disparate student cohort. Training in makerspaces can be focussed around specific, short term instrumental tasks, rather than longer duration, larger scale learning activities, so we expected this to be challenging but hopefully rewarding for both sets of learners.

Maker Y came from a design background so had some familiarity with design processes but was a novice maker, and typifies some of the challenges learners had to address. Like many of the makers, this participant was paired with a designer who had limited experience of making, so needed to provide the kind of feedback that might be expected from a tutor in a more formal, structured learning environment ("*My initial feedback is that your joints are quite complicated … I think the simpler the joint the better*").

Maker Y was proactive in supporting the designer, and suggested resources beyond those provided to develop their partner's knowledge: *"Have a look at some of the [online] plans for the designs here for inspiration*". The maker found that they had to make some of the design decisions in order to progress the work ("*We had to*

Figure 4: Engaging with the materiality of design

make a few decisions at our end as the sketch-up file didn't have all of the information we needed"), but this more open collaborative approach was seen as positive by their designer-partner *("The maker had to take some decisions for me, [… e.g.] chang[ing] slightly the shape of dowels, and they are working much better than the ones I've designed"*).

Maker Y reflected on how much of the process they should own, and how much support they should give, but recognised that this was moving the learning experience towards an authentic workplace scenario ("*I wasn't sure on how much input should I have, because in the real world is a manufacturer actually going to tell them they were wrong, or are they just going to make it and send it to them?*").

As an experienced designer, Maker Y was familiar with taking part in the designer-maker conversation, but this experience provided valuable insight into the issues that arise from the perspective of the maker.

Discussion

The summer school showed that this constructivist, distributed approach, focussing on collaborative production of full scale prototypes holds promise for future development, but also identified a number of challenges.

Running a learning activity around the progression of design ideas to fabrication of full-sized prototypes in multiple iterations was valued by participants, but was also seen as highly challenging. We had overestimated the expertise of the participants, and as a result tutors had to provide more ongoing support, and improvise additional supporting materials (e.g. guidance in using the CAD software). For future presentations, we would envisage providing more learning materials and guidance for the participants, with the aim to provide a better scaffold for the learning. We also underestimated the amount of time participants would need to dedicate to the project, and this resulted in a tight schedule of designing and making. In future summer schools, the timing of the design-make cycles would be revised to allow participants more time to mature their design concepts through reflection and research. Despite these limitations in our planning, learners were highly engaged, particularly in the materiality aspects of the tasks. This resulted in an active online community that at times began to resemble an online studio, with designers and makers sharing resources, ideas, and feedback. For example, one maker started a gallery space within the forum for participants to post their prototypes as they completed them. This allowed participants to comment on each others' work and learn from mistakes.

Specific technical challenges around the internet mediated communication were noted (confirming prior research by e.g. [12]): while the OU students were familiar with work-based dialogue in online spaces, this was a new skill for some of the makers, and the chosen software platform had its limitations. No notification was given when a new post was made by a learner-partner, which meant pairs were unsure of how often to check the online space, leading to frustration, increasing pressure to move towards independent decision making, and potentially reducing collaboration.

While a key goal of the summer school was to emphasise the remote working aspect of the distributed design and fabrication process, a number of the participants indicated a preference for an initial face-to-face group meeting to establish relationships. This might have led to richer interactions, though we were also aware that in practice this would be difficult if we were to continue with national or even international paired collaborations, and with greater numbers of participants. If such a meeting could be held in the makerspace then this could have the additional benefit of allowing the designers to gain further insight into the making process, insight that could help improve initial design concepts as well as communication with makers about fabrication issues.

The level of provision of support for learners was debated before, and throughout the summer school. We were keen to give learners as much autonomy as we could, encouraging an environment where “meaning is created by the learner” [1], monitoring the conversations in the online platform and only joining when an issue was not being resolved, and likewise encouraging independence in the fabrication process after initial training, where safe to do so. The challenges manifested themselves in two distinct aspects: first, how much tutor support should be offered, and second, guiding the makers in how much support they should offer the designers.

The first issue was resolved through a team decision, though dynamic responses were required as technical challenges were encountered, or inexperienced learner required additional personal support. With a group of mature and responsible maker participants apparently managing the majority of designer issues independently and referring problems to staff only occasionally, the second issue was less visible, but became more apparent through post summer school debrief interviews. Makers in their support of designers recognised that this was a learning scenario, not a true industry scenario, so harsh responses (e.g. going ahead and cutting plywood from an obviously faulty design file even though failure would occur) were avoided and allowances made. However makers reported further clarity would have been preferred from the research team about what responses were appropriate. In future, it is clear that more careful structuring will be required to manage this mode of learning.

Associated with this, we encountered different cultures of learning between the two different organisations. This was expected and dialogue around bridging approaches was one of the hoped-for outcomes of the summer school. However, this difference did cause practical challenges, for example with the OU participants characterised as performing as if responding to university course deadlines, often working until the last minute and not allowing the makers sufficient preparation time. MAKLAB learners, on the other hand could only gain limited access to the machines so had to work to tight deadlines at specific times which limited flexibility, and were in some cases less accustomed to the longer term broader style of learning activity.

Conclusion

Overall, this proved to be a successful pilot. The majority of the full scale prototypes were made, and participants noted their satisfaction: both in terms of learning gains and the effectiveness of the summer school in providing an authentic distributed manufacturing scenario. It has enabled the OU and MAKLab to explore an extended collaborative learning activity around distributed and remote prototyping between a makerspace and a distance-learning university, testing a set of design guidelines [10] that may offer a model for future similar partnerships. We are considering extending the collaboration to include an industry partner to further emphasise professional as well as academic development towards employment, exploring how this pilot might be scaled to a larger cohort, and investigating the development of a 'Maker MOOC' which will teach design thinking and include a fabrication task.

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References

[1] Biggs, J. *Teaching for quality learning at university: what the student does*. Open University Press, Buckingham, UK, 1999.

[2] Crowther, P. Understanding the signature pedagogy of the design studio and the opportunities for its technological enhancement, *Journal of Learning Design 6*, 3 (2013), 18–28.

[3] Foresight. *The Future of manufacturing: A new era of opportunity and challenge for the UK Summary Report.* The Government Office for Science, London, UK, 2013.

[4] Hall, M., Nix, I. and Baker, K. Student experiences and perceptions of digital literacy skills development: engaging learners by design? *Electronic Journal of e-Learning 11*, 3 (2013), 207–225.

[5] Halverson, E. R. and Sheridan, K. The maker movement in education. *Harvard Educational Review*, *84,* 4 (2014), 495-504.

[6] Jowers, I., Gaved, M., Elliott-Cirigottis, G., Dallison, D., Rochead, A., and Craig, M. Communication is not collaboration: observations from a case study in collaborative learning. In *DRS2016* (forthcoming).

[7] Lotz, N., Jones, D., and Holden, G. Social engagement in online design pedagogies. In *Proc. 3rd Int. Conf. for Design Education Researchers,* Aalto University (2015), 1645–1668.

[8] Park, J.Y. Design education online: learning delivery and evaluation. *International Journal of Art & Design Education, 30,* 2 (2011), 176–187.

[9] Prats, M., and Garner, S. Making meaning: developing an understanding of form in distance design education. In *DeSForM2009*, (2009), 196-203.

[10] Reeves, T., Herrington, J. and Oliver, R.A development research agenda for online collaborative learning. *Educational Technology Research and Development 52,* 4 (2011), 53-65.

[11] Schön, D. *The reflective practitioner: how professionals think in action*. Temple Smith, London, UK, 1983.

[12] Sclater, N., Grierson, H., Ion, W., and MacGregor, S. Online collaborative design projects: overcoming barriers to communication. *International Journal of Engineering Education, 17,* 2 (2001), 189-196.

[13] Stein, S. J., Isaacs, G., Andrews, T. Incorporating authentic learning experiences within a university course. *Studies in Higher Education 29*, 2 (2004), 239-258.

[14] Yang, M. A study of prototypes, design activity, and design outcome. *Design Studies, 26*, 6 (2005), 649-669.