Having or Using a 3D Printer in Experiential Learning

William Lavatelli Kempton[1]

Abstract

Digital fabrication technology, 3D printing in particular, has evolved from industrial use and is entering different social and cultural contexts, such as schools, FabLabs, libraries and universities. As it enters schools and educative facilities, some of the challenges related to this pedagogically are time, availability, guidance and creative permission.

With 3D printing, the convergence between analogue and digital, imaginary and physical, allows for a wider range of students to conceptualise and visualise their ideas. However, the process of making with 3D printing involves more than just fabricating artefacts. From a design point of view, I consider the process of making to include several phases. An initial idea is conceived, designed and processed by the 3D printer, before a physical artefact is outputted. All these stages may require new skills and learning, ranging from ideation and digital drawing in CAD, to the actual fabrication process.

The argument of this paper is that 3D printing is a valuable tool to facilitate experienced-based knowledge, although it is not necessary for educators to have the technology locally present. Through the context of use in design education at The Oslo School of Architecture and Design, I discuss the various advantages and disadvantages of having remote and local access to the 3D printer.

1. Introduction and Background

As a potentially socially transformative technology, digital fabrication is entering many different social and cultural settings, including universities, schools, FabLabs and libraries. Although the technology has had a longstanding role in an industrial setting [1], since 2007 digital fabrication technologies and 3D printing in particular, have experienced a surge in popular media and popular imagination [2]. Visions of future applications of 3D printing are conveyed as manifold, and novel uses of it, in fashion, in the sports world [3] and in high-tech industries [4] appear to support some of these projections.

As a place for people to learn and be involved in making personal fabrication, FabLabs and makerspaces have particularly been adopting 3D printing and other digital fabrication technologies (laser-cutters, waterjet and CNC mills) with open arms, to unexpected outcomes. In 1998 Neil Gershenfeld [5] created the ‘How To Make (Almost) Anything” class at MIT for the first time. While the course initially taught students different tools to use in their research, the now famous FabLab concept has since turned into a place that is “inventing a new physical notion of literacy.” [5, p. 7]. We begin to understand that the 3D printer has different roles depending on the social context.

The premise of my discussion in this paper is that technology itself does not have an agenda, but is propelled forward by the relevant social groups that use them [6]. As 3D printing trickles into new settings such as education, challenges occur. 3D printing is a powerful tool, but it requires its own learning curve.

My hypothesis is that fabricating with the 3D printer is useful in education, but it is not necessary to have it present to foster new experiences. Having the 3D printer locally present as opposed to using it remotely creates different kinds of knowledge, which I will discuss later in this paper. Before that I will explain the premise and challenges of 3D printing from a design and experiential learning perspective.

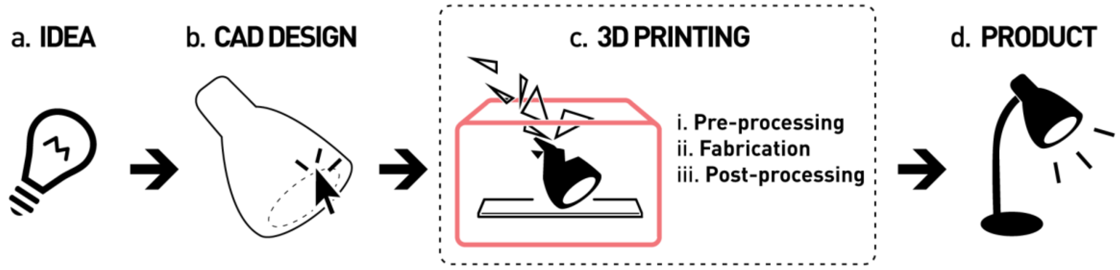

Fig.1 – The process of making with 3D printing involves more than just fabrication

[1] The Oslo School of Architecture and Design, Norway

As shown in Figure 1, the act of 3D printing (c) relies on having ideas and making them tangible. From design education we know that the idea phase (a), CAD design phase (b) and the possession of physical outputs (d) are important factors for fostering new experiences. Both phases happen mostly locally, that is where the actor is situated. The 3D printing (c) process itself involves several stages: a digital input from a CAD design application, pre-processing of the design, the actual fabrication process, as well as necessary post-processing of the artefact (cutting, sanding, gluing, painting). Both the fabrication process and CAD drawing tools were once restricted to 'experts', as they were expensive and required a steep learning curve. However, as the popularity of 3D printing has increased, so has the availability.

2. Making, 3D printing and learning

2.1 Digital fabrication in an educative environment

3D printing in the setting of education can be considered relevant for its engagement in competencies such as maths or engineering [7]. However, it is important to point out that digital fabrication needn't just happen in the classroom, nor does it need to relate to such specific competencies. Interests, capacities and the "day-to-day culture of children" are valid reasons to incorporate 3D printing in education, as we are arguably in an "early phase of a wide-scale revolution in tangible creation"[8, p.1].

There are several barriers and possibilities when facilitating the use of 3D printers by a young audience. The 3D printing process comprises different tools, from drawing to fabricating. As these tools become more widespread among non-experts, we can imagine they become simpler to learn and use.

2.2 Initial challenges for digital fabrication in education

To shine a light on some of the challenges of 3D printing in education, preliminary interviews and discussions were held with museums and individuals who are early adopters of digital fabrication in young (age 12+) learning environments. Representatives from the Teknisk Museum (tekniskmuseum.no) in Oslo, Norway, point to many issues relating to personal 3D fabrication and children. A challenge that often surfaces is the issue of time. Quick demonstrations are often done as opposed to hands-on-practise.

Since 2015 the museum has operated its own maker space, open to all its paying audience. The audience constitutes a mostly young public, from elementary school children to university students. The lab, equipped with a variety of tools spanning from electronic prototyping boards to 3D printers, allows children to participate in the making of things. Museum representatives state the desired age group as 12 years and upwards. In reality the people who visit the lab are anything from children to young grownups. Guidance can therefore not be too generic, so that different age-groups will be motivated to participate.

In the museum lab there are currently two Ultimaker 3D printers, in addition to an industrial laser cutter. While museum representatives would like to have their young visitors use, understand and freely make things with the tools, there are apparent challenges. The tools are complex and require the knowledge of several sub-systems, digital and physical, as well as understanding the overarching principles of digital fabrication. The visitors in the lab are seldom present for more than 60 minutes, and often arrive in groups of 30 pupils. The resources, of both tools and personnel, are often too few for groups of school children to learn and use the digital fabrication tools. The use is therefore restricted to those working at the lab. Personnel demonstrate the technology rather than allowing it to be used by the younger audience.

In his discussion of digital fabrication in education, Blikstein [9] further points out challenges related to the introduction of digital fabrication tools. Among some of the lessons learned from his practice, Blikstein discusses the "keychain syndrome". Students in his experiment were introduced to a digital fabrication technology (laser cutting), and given the task to make a simple, personal keychain. Rather than seeing the tools as valuable for exploring new ideas and iterating upon them, students in his experiment quickly saw the opportunity to stick to what they knew and re-produce their simple creations, revealing the triviality of the (keychain) product. From this the author stresses the importance of veering away from quick, simple and admirable projects, and push towards complex tasks in an attempt to explore new knowledge.

There are challenges regarding the introduction of 3D printing in education. Specifically, when introducing 3D printing to new learners, how should resources be applied, and how can it facilitate new learning experiences? More importantly, is it about learning *of* or *with* 3D printing? In order to clarify this, we turn to theories of Experiential learning, before arriving at our own experiences using the 3D printing in Design education at The Oslo School of Architecture and Design (AHO).

2.3 Experiential learning

In order to understand the rationale for making in education, we may refer to John Dewey and his concern with education and experiential learning. His criticism of past and contemporary education was that it built on existing knowledge, custom and established routines, imposed on a new generation of learners [10]. In an ever-changing society, he remarked, the transmitting of static knowledge is itself problematic.

Dewey argued that there are different forms of experiences, agreeable and disagreeable, which naturally effect later experiences. Implicit in Dewey's experiential learning is its link to real world objects, not bound by the organisation of subject-matter in the way much current natural science (STEM) education does.

Building on Dewey experiential philosophy, Kolb [11] formalised a learning cycle around four distinct modes: *Concrete Experience*, *Reflective Observation*, *Abstract Conceptualization* and *Active Experimentation* (Fig.2.B). Central to his idea is that learning, and thereby knowing, requires the figurative representation of an experience, followed by a transformation of that representation. It is possible to enter at any stage, but necessary to complete the cycle in order to get a feedback loop.

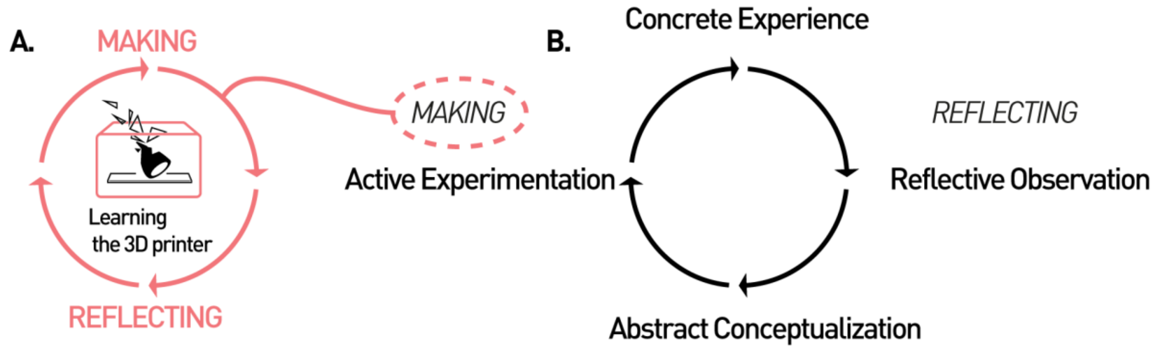

Figure 2 – Learning the 3D printer is a sub-system of experiential learning. Figure B based on Kolb's Experiential Learning process

The 3D printer is a powerful tool for *making*, but relies on a surrounding structure, such as *reflecting*, to facilitate experiential learning. However, the 3D printer has its own learning cycle (Fig.2.A), as there are many sub-systems involved. Considering the results from the environmental scan, optimal experiential learning with 3D printing is difficult to achieve, as learning the tool itself, and learning how to use it, go hand in hand.

2.4 3D printing in design education

As stated earlier, 3D printing has caught the attention of popular imagination. However, in Design education at AHO it has had a relatively long history. Bearing resemblance with mainframe computers of the 1960s, the 3D printers at AHO were initially remote 'black boxed' services. Students delivered CAD designs, and got them back as tangible artefacts. While being able to produce high-quality, precise designs, students were abstracted to phases of the 3D printing process. With the emergence of desktop 3D printing, the 'black boxed' services have since been complemented with the presence of portable, easily maintainable Ultimaker 3D printers. While not being as capable and precise as the remote fabrication services, the local 3D printer complements with its own set of tangible, present and adaptable qualities (Fig.3).

Placed in the students' studios, the local Ultimaker 3D printer can be seen ordering organic PLA-material to exact X, Y to Z coordinates, making true to the world a CAD design that was inserted though the SD card just moments earlier. The creators flock around to see the extruder-head move in speeds of 50 mm/s, printing in 0.2mm layer intervals. The parameters are deliberate, allowing details to reveal the creators' intentions. Once taken out of the machine, the design is set to the test. Is the piece to big? Too small? Does it appear the same as on the screen? Only trials can tell.

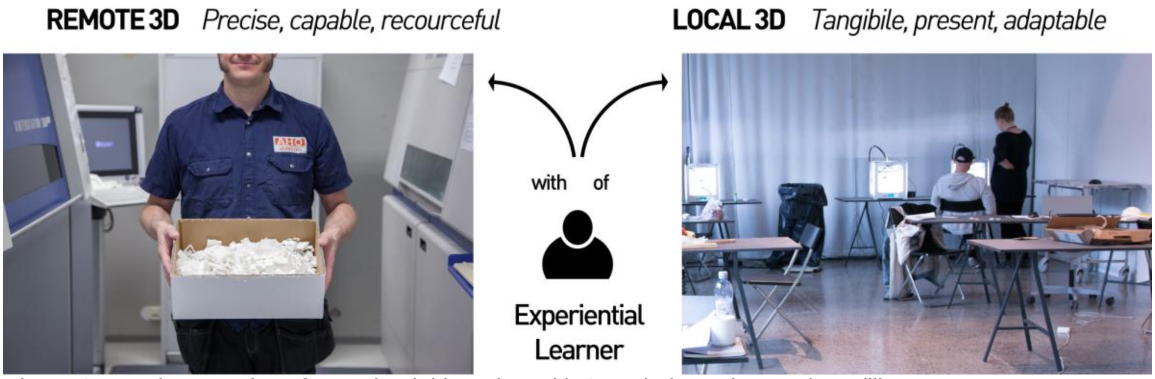

Figure 3 – Various modes of experiential learning with 3D printing. Pictures by William Kempton

The 3D printing phases (Fig.1.c) are introduced to students for the first time in their 2nd year. The students learn to operate, experience and explore the 3D printer through a series of 3-week projects. While having a basic CAD proficiency (the students primarily use Solidworks) from earlier semesters, their skills rapidly develop as they see for themselves the results.
Figure 4 shows artefacts from the iterative design process of a veneered computer mouse. In the process, several 3D printed tools for moulding the veneer were created, in addition to the main body of the mouse. The designer had both local and remote access to the 3D printer, and adapted the making workflow according to the available tools.


Figure 4 – Artefacts, tools and materials in the process of designing. Designs by Hans-Martin Erlandsen

3. Conclusion and Discussion

Digital fabrication is a tool with the capacity to facilitate experiential learning. Through the literature we see that 3D printing in education is being used in many different age levels, and especially so in design, from pre-teens to students in universities, both in and out of the classroom. However, digital fabrication brings with it many sub-systems, creating new challenges for facilitators of the learning process. My position is that having a 3D printer is not necessary in an experiential learning process, even if 3D printing is an integrated part. I argue that *local* and *remote* access to the fabrication tool will provide different learning outcomes. Local access facilitates learning *of* the tool, as opposed to *with* the tool.
Once in action, the local 3D printer gives the user a visual impression on how the process works. The models may not have the desired material strength, finish or scale, but it provides the user with representations, which may be quickly iterated on. The tool may be slow, but it is immediately available. Those who own a personal 3D printer will know that it requires continuous attention, as there are many moving parts. It also requires the knowledge of several tools to use it.
Remote 3D printing services are found on the internet as services (shapeways.com), but they may also be in your immediate vicinity. The point is that you don't own the tool, you get to fabricate artefacts through it. The act of 3D printing becomes abstracted from the making and learning process, with attention being focused on the experiential learning process.

I have now discussed aspects of 3D printing in an educational setting. However, further research is needed in the facilitation of making with 3D printing as a pedagogical tool, both in and out of the context of education.

References

[1] N. Hopkinson, R. Hague, and P. Dickens, *Rapid Manufacturing: An Industrial Revolution for the Digital Age*. John Wiley & Sons, 2006.

[2] Gartner Inc, 'Gartner's 2015 Hype Cycle for Emerging Technologies Identifies the Computing Innovations That Organizations Should Monitor'. [Online]. Available: http://www.gartner.com/newsroom/id/3114217 . [Accessed: 04-Apr-2016].

[3] Andrew Zaleski, 'New Balance, Adidas, Nike: Who's Winning the 3D-Printed Shoe Race? - Fortune'. [Online]. Available: http://fortune.com/2015/12/15/3d-printed-shoe-race/. [Accessed: 04-Apr-2016].

[4] Madeinspace, 'Projects | Made In Space'. [Online]. Available: http://www.madeinspace.us/projects/ . [Accessed: 04-Apr-2016].

[5] N. Gershenfeld, *Fab: the coming revolution on your desktop–from personal computers to personal fabrication*. Basic Books, 2008.

[6] W. Bijker, *Of Bicycles, Bakelites, and Bulbs : Toward a Theory of Sociotechnical Change*, New edition edition. Cambridge, Mass.: MIT Press, 1997.

[7] R. Q. Berry, G. Bull, C. Browning, C. Thomas, K. Starkweather, and J. H. Aylor, 'Preliminary considerations regarding use of digital fabrication to incorporate engineering design principles in elementary mathematics education', *Contemp. Issues Technol. Teach. Educ.*, 2010.

[8] M. Eisenberg, '3D printing for children: What to build next?', *Int. J. Child-Comput. Interact.*, vol. 1, no. 1, pp. 7–13, 2013.

[9] P. Blikstein, 'Digital fabrication and "making"in education: The democratization of invention', *FabLabs Mach. Mak. Invent.*, pp. 1–21, 2013.

[10] J. Dewey, *Experience And Education*, Reprint edition. New York: Free Press, 1997.

[11] David A. Kolb, *Experiential learning: experience as the source of learning and development*. Prentice-Hall, 1984.