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CHALLENGES OF 3D PRINTING FOR HOME USERS

Russell WADE, Nigel GARLAND and Gary UNDERWOOD
Bournemouth University

ABSTRACT
3D printing is described as the next industrial revolution bringing manufacturing to the home. However, it's attraction to the home or non-technical user is frustrated by the difficulty in deploying the software and the technology which both need professional understanding and training.
Research and innovation in this area has concentrated on technology, not users and usability. Home users can access simple design software tools, best described as good for one task only.
Software such as Microsoft word and Excel have been the subject of development for enabling most people to use computers without the need for training or the ability to program. However research in the home users of 3-D printing is very limited. This literature review is concerned is an investigation into home/non-technical use of 3-D printers, their needs and limitations, in order to facilitate the development of effective tools and manuals.
An investigation of literature and a survey supported by a focus group of 42 university students aims to understand the way home/non-technical users currently use designs, and how they can to adapt/change their designs for effective use of 3-D printing. This will identify the tools/'apps' needed for accessible understanding and deployment of the technology.

Keywords: 3D Printing, Home Fabrication, Home Design, Sustainable Future.

1 INTRODUCTION

Home fabrication/3D printing is described as revolutionary by many. It has the ability to bring design and manufacturing to the home for a significant section of society, and change the process of manufacturing. Additive manufacturing at source reduces waste when compared to current subtractive methods and supports the worlds move towards a sustainable future. The technology is often compared to the early stages of computing where early developers tinkered with emerging technology in garages. The history of computing for home, non-technical users to its current stage can easily be traced. However home 3D printing does not solely rely on one technology and it is here the comparison ends. This paper discussed a literature review with support from a focus group of 42 Undergraduate students being introduced to 3D printing.

2 RESULTS AND DISCUSSION

Product innovation has been seen by economists and policy makers as a producer activity, with consumers simply selecting among offerings the market provides [1]. Traditionally, professional designers at companies were exclusively responsible for designing products for the consumer marketplace. However, recently, various industries have developed many new products that were not developed by designers working at firms but rather by the users themselves [2]. For example, a recent survey of a representative sample of U.K. consumers revealed that 6%, or almost 3 million consumers, innovated in the domain of household products, and annual product development expenditures of users has been found to be 1.4 times larger than the respective expenditure invested by all U.K. firms combined [1]. This demonstrates the importance consumers play in developing designs for production but more importantly how numerous consumers that are acting as designers. This work is limited to research in design innovation by the users and not on whether the innovations were taken further for realisation. The discussion concentrated on how these innovations were evaluated, produced and converted by industry for the mass market, still due to increasingly sophisticated customers intensifying competition, companies are paying a growing attention to mass customization [3].

The paradigm of mass customisation emerged in the late 1980's as demand for product variety increased [4]. The number of varieties offered by consumer product manufacturers has increased significantly since then [5] and while mass customisation provides a high variety for consumers to choose from, such high variety also introduces manufacturing complexity in the assembly systems [6]. These systems limit consumers to choosing module combinations which are not always able to produce exactly what is desired. Hu [5] Discusses how the presence of the internet, computing and the emergence of 3D printing is truly meeting consumer customisation, presenting opportunities for a new paradigm of product creation. Consumers can create innovative products and realise value by collaborating with manufacturers and other consumers. A consequence for businesses is how the Internet has increased user participation in the production process. Increased participation has been very visible since the birth of Web 2.0 technologies. Some successful Web 2.0 outlets such as Facebook, Instagram, Flickr, and Twitter have the content provided by user's accounts for most of the value of the service. This participation has blurred the line between consumption and production activities [7], users can now consume and produce content. Users are no longer pure consumers but have become producer/consumers or 'prosumers'. This role is more noticeable when one considers their involvement in the production of physical objects. Consumer-owned printers, for instance, are one of the many means of production that firms can use within a co-creation activity [8].

This revolution has enabled the consumer to take an ever increasing part in production processes, Rayna et al details how 3D printing is the 'last piece of the puzzle' enabling consumers to intervene at any stage in the production process, from initial idea to fully manufactured product, even carry out most (if not all) of this process. Hence, understanding the changes online 3D printing can bring to the innovative processes requires users to fully understand the nature of co-creation activities and the changing role of consumers in the production process. For individuals' to carry out all of this production process will require more than just the 3D printer, Rayna et al 2015 omits discussing technical skill or tools required to produce and test designs that can be printed. Addressing how consumers will manage this process without cooperation of industry or education is missed within the discussion.

For most, it is difficult to see 3D printing technology operated by any person who is not an engineer or technically inclined; even so this technology is following a pattern similar to that of personal computing which over the past 40 years removed the need of specialist skills to operate them as a tool that almost every person in society uses or interacts with [9]. Like the early computer, 3D printing suffers from limitations [10], Nevertheless, the last few years have seen the capabilities of 3d printing increasing and costs decreasing. In 2001 the cheapest 3D printer available in the market was priced at $45,000, today a personal 3D printer costs between $1000 and $10,000, making it accessible to individuals and small organizations [9], placing this technology within the reach of schools, small businesses and local production shops. However, these new low cost consumer based 3D printers can prove frustrating for those non-technical, with their lower print quality, and complicated build techniques when compared to more expensive industrial printers; this view is supported by Easton (2009) saying that as things stand today, home 3D printers are at about the same level of capability, user-friendliness, and price as personal computers in the mid-1970s. Further, Neagle [11] discusses how 3D printing will struggle in consumer markets because of the education needed to use the devices. Consumers will need to use CAD or other 3D design software if they are to design an item for a 3D printer. Furthermore when a user has learned how to use software, the intricacies of 3D printing will be difficult to master for beginners, Basiliere says "Once you have that, now you still have to print it out, and depending upon the consumer's skill set, it could be a very difficult process of trial-and-error getting the printer to produce the part that they envisioned," he says. "Not that the printer is incapable, but there may be need for support structures and other elements in the design that, if the consumer isn't proficient with the software, it leads to a bad print."

Shewbridge et al., 2014 confirm this, discussing individuals' experiences when considering everyday design. They realised that a design idea was often quite difficult, as an individual with an idea to create or modify an object, but may lack the skills to fabricate such an object. However they noted that the adoption of fabrication tools such as 3D printers may lower the barriers to creating a physical representation of an idea.

A Shapeways, Ponoko and Fabbaloo Survey [12] furthers this with 358 respondents establishing the demographic of 3D printing as male dominated with the average age of 35. This survey group had a high level of education with 56 percent having at least a bachelor level degree [13]. However when

participants were asked “What is the most wanted feature you are waiting for to develop further or to emerge?” and given a predefined list of options: Multi-coloured printing; Metal material printing; Glass material printing; Speed; Object quality; Ease of use; Ethernet connected printers; Better printer integration to CAD (or other similar) modelling software; Cheaper printer price; Cheaper material prices; and, Other, the most prevalent answers were:

1. Object quality (166)
2. Speed (119)
3. Cheaper material prices (115)
4. Metal material printing (108)
5. Cheaper printer price (106)

This survey does not show whether those surveyed are employed within the design industry and have relevant knowledge of 3D printing and its techniques but does highlight usability as a non-priority leaving industry to focus on the technology as a priority. The Technology at the high end sees 3D printers with micrometre resolution that can combine flexible, rigid, and transparent materials whilst consumer level systems have output quality similar to machines that cost tens of thousands of dollars just a few years ago [14].

The lowering of cost is making 3D printing more accessible to home users, however there is a need for software that lets them create. This software does exist in the form of professional CAD software but cost and complexity of this software is beyond the average user’s ability. Simple software has been created for novice designers and aimed at specific tasks. Shapeways Creator tools (www.shapeways.com/create) lets unskilled users create customized 3D ring models for printing, although With the Custom ring app, users need only type in their initials and pick a font. The Ring Creator takes a grey scale image as input, wraps it around a ring template, and extrudes a ring. This workflow lets novices use familiar image-editing tools to create unique 3D objects [14].

The easily available software tends to do one thing, and does it well, focusing on solving a single design problem. This approach is useful with inexperienced 3D designers. However these inexperienced designers inevitably master any given task-specific tool and begin demanding more expressive capability. Unfortunately, scaling these simple tools to more complex design tasks is difficult and many online discussions begin with the question “How do I do X?” and end with the suggestion that the user look into Blender or SolidWorks, extra ordinarily complex professional tools [14].

Shewbridge et al., 2014 took a different approach to their research describing it as to the best of their knowledge, the first study consisted of 28 individuals and their uses for 3D printing over 4 weeks at home. The theme of this study was driven by subject experience with only one having used a 3d printer. The study encouraged participants to identify 3D objects to print for everyday use. Most users created items to replace objects that were broken or missing, duplicating objects that they wanted more of, or alter existing objects. Users saw the 3D printer as a useful appliance in as much as they thought it a creative tool. This experience runs counter to the current representation of 3D printers in advertisements and the popular press, which often highlights how these technologies are used to create art or to prototype new inventions. Fortunately, it seems clear that their participants did not see the 3D printer solely as a utilitarian device, and used it for many creative purposes, including creating gifts, decorations, and toys [15]. Just as inkjet printers are used to print airline boarding passes and drafts of one’s novel, people should accept and support both utilitarian and creative uses of 3D printing in the home.

In many respects, the notion of everyday designers is not entirely new. People have been redesigning designs all along [16]. Louridas’s (1999) discusses the concept of the designer as a bricoleur, making do with resources available to them and exploring situations through actions for new uses and connections. Everyday design systems evolve to be unique, and this requires not thinking of technology applications in a generic sense and deeply radicalising the idea of customisation [16].

Most of the recipient requirements in the Shewbridge study could be met using repositories of printable 3D objects such as Thingiverse. Thingiverse offers a catalogue of open source and printable 3D models designed by members of its community. For example, participants suggested toothbrush holders as responses to five design prompts and Thingiverse currently has 98 designs for 3D printed toothbrush holders. However, an object library could not satisfy all of participants’ requests; many requests involved customised or altered objects [15] . This suggests that there is a need for 3D design and customization tools that are not traditional CAD tools. Of note in this study were a number of

requests that began with an existing object, but requested a version of that object that was larger, smaller, or different in some other way. Design tools that enable users to scan an existing object and adapt it offer a promising path for end user design. A key feature of the study was not burdening participants with new technology and actual 3D printers and It established that improvements were needed for design tools, although how this was established was not clear as participants only used paper to write down ideas and a camera to take pictures of objects they wanted to create or modify; no design tools were involved. Schmidt and Ratto 2013 describe these design tools as having important ramifications. Get the tool chain right; easy to learn, scalable in complexity, and accessible and digital fabrication could spur widespread engagement in creative making. Get it wrong—hard to learn, limited in capability, and focused on restricted social groups and digital fabrication could become just another mechanism for delivering products to consumers.

Cano 2011 [17] compares 3D printing with the infancy of computing in the 1970's and its garage based computer designers and how we cannot think about 3D printing as we think about the mature computing systems of today but to compare the future of 3D printing with the first PC killer applications: What are going to be the equivalents of spreadsheet and word processing software in the 3D printing field? These killer applications described by Cano are the authors speculation, the statement has no research attributed to it in the paper. Cano's comparison to spreadsheet and word processing software appears narrow simply because these applications took mechanical processes from typewriters and applied them in exactly the same form digitally; however it drove people to adopt digital technology. A killer app today is Photoshop, the de facto photo editing software dominating the market. Photoshop digitally manipulates images in hundreds of ways but over complicates and frustrates average users and is now dominated by professional users with training. An intuitive balance between these may encourage users towards 3D printing but research is lacking in this area.

A recent study by one of the authors G Underwood [18], using focus groups with 42 second year university design students tasked with designing a computer mouse found skill levels made a difference when 3D printing, and interestingly led to divergent design trajectories with students' with lower skill levels keeping designs simple. These students had completed 10, 2 hour sessions of CAD tuition as well as other workshop and design studies underpinning the course. Although some students expressed frustration with the restrictions on creativity imposed by the SolidWorks software, it seems likely that many of these frustrations were related to an insufficient level of skill rather than an inherent fault of the process. This reinforces the case that the ability of a home user will be frustrated when designing to 3D print with little or no knowledge of design techniques and lead to the compromising of their designs to meet simplicity and ability. Comments were made on disconnect between software and printer. This was explained as the processes required in moving a CAD model to a printer. This involved converting files to a printer a friendly format before opening it in the printer software, followed by further processing in this vendor specific software and again converting into a another format for the printer itself.

3 CONCLUSION AND RECOMMENDATIONS

Home users of 3D printing seem largely ignored by software and hardware designers. Instead it is concentrated on the partially skilled and industrial users. Clear evidence of little research into how home users will use this technology has been shown. The small amount of research shows user needs may be met through online libraries, however these cannot always be met, leaving users frustrated with how to modify or create their own products. Easily accessible software is limited to simple tasks or design processes that leaves them wanting. The software that can meet their needs such as solidworks is prohibitively expensive and over complicated for novice designers, requiring professional tuition to understand and use. The "killer app" has been described to bring 3D printing to the home similar to those in computing, e.g. the Microsoft office suite that is now used by all for office functions, however this "killer App" is merely a mention. It is this killer app and how it works that needs research. Research has concentrated on what people want to print and modify not how they want to print and the tools required, it is here this killer app will have influence by providing a user friendly approach to this technology for novices. In creating this killer app research needs to work closely with its users and avoid over complication and alienation of users. This happens when developers create the ultimate app to meet every need such as photoshop, an app that has ballooned in size to the point professional training is required.

Researchers need to investigate what the non-engineer home users require, in terms of skills and tools, in order to develop their full design from product concept to realisation, without the need for specialised engineering/CAD software or hardware. This will result in the development and supply of tools, be it pater based or software. This approach has so far been overlooked.

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