RP OR NOT RP, THAT IS THE CO-CREATION QUESTION.

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ABSTRACT
Rapid prototyping has been growing in complexity, capability and user-friendliness. 3D printers have been dropping in price as rapidly as modern mobile devices with touch screens. From schools to consultancies, local businesses to global manufacturers, everybody recognises the unique contribution of RP in the design development process and the savings in time and money it can deliver. This demand has been fuelling the phenomenal growth in investment in the technology and its uses. Many academic institutions like Bournemouth University are conducting research into the uses and developments of RP technology.
However, as the cost of the technology has dropped a whole new conversation about the effects of RP in design education has arisen. Just as most technological developments have both positive and negative implications, many questions have been raised, such as:

- Can the technology handicap the development of other essential skills required in design and engineering (D&E)
- Does RP encourage D&E students to think that simply being able to visualise a product digitally is enough?
- Does RP give students unrealistic expectations of the real design and manufacturing environment?
- How can RP be used to stimulate creativity without sacrificing design integrity
- What view does the design industry take on these questions.

Drawing on the experiences of Bournemouth University's BA/BSc Product Design students and industry professionals, this paper discusses how RP affects the traditional design education approach, and explores the concept of co-creation through the combination of both traditional physical fabrication and rapid prototyping.

Keywords: rapid prototyping, RP, traditional prototyping, teaching prototyping, design prototyping

1 INTRODUCTION

"So many of the designers that we interview don't know how to make stuff, because workshops in design schools are expensive and computers are cheaper. That's just tragic, that you can spend four years of your life studying the design of three dimensional objects and not make one." [1]
These words were spoken by Apple's head designer Jonathan Ive at London's Design Museum in November 2014. Remarkably for a senior vice president of the world's biggest technology company, Ive bemoaned the reliance on digital tools over practical skills. Ive's words highlight a crisis within current product design education.
Since the conception of stereolithography in the early 1980s, the role of rapid prototyping (RP) has grown with gathering pace within industry. RP's ability to produce models with arbitrary shapes more quickly, and at a lower cost, than traditional prototyping techniques has driven its popularity in the production of evaluation aids, concept models, and master patterns. More recently RP – as RM (rapid manufacture) - has increasingly adapted to the ability to replace traditional manufacturing processes in applications where a relatively small number of parts are required. Across the additive manufacturing industry worldwide sales topped $2.2 billion in 2013 and are predicted to reach $6 billion by 2017 [2].
RP's growing prevalence within industry - where time constraints and cost are dominant – is understandable. Desrosier's requirement for industry tools that expedite response to changing market

conditions - whether to exploit rising opportunity, to seize competitive advantage, or to defend business [3] - appears to be effectively fulfilled by RP .
Within the consumer market, the popularity of low-cost, desktop “3D printers” such as Makerbot’s Replicator shows no sign of slowing, with sales forecast to accelerate to one million machines per year by 2018 [4]. Schools have also embraced the new technology. Makerbot’s stated aim to place a 3D printer in every US school, and Ultimaker’s intention to do the same in the UK, will produce a generation familiar with .stl files and build envelopes.
Given this background, it would seem inevitable that higher education (HE) establishments should be replacing lathes with printers – and many are. Anyone who has visited London’s New Designers Exhibition over the past few years – a showcase for the UK’s brightest new graduate designers – will have noted the gradual demise of the hand-made prototype. Bucks New University, Portsmouth and Falmouth are just three of the universities to announce workshop closures in 2014 [5][6][7].
The authors of this paper have viewed these developments with increasing concern. The ethos of all the design and engineering courses at ? University (?U) has been based on a holistic approach within the remit of each course. A common factor has always been that the final product must be designed for manufacture, hence - with the exception of Industrial Design - every course has had access to the design and engineering workshops, and the teaching of practical skills has been a core requirement.
As educators and facilitators with many years’ experience in both industry practice and teaching across a wide range of design and engineering sectors, the authors feel that the role of RP requires serious investigation, now more than ever. To that end this paper will deliver new research which aims to uncover some of the true attitudes of students and practitioners to 3D printing and workshops, and present a discussion of the issues surrounding the topic.

2 METHODOLOGY

In order to understand design practitioners’ and design students’ views of rapid prototyping verses traditional prototyping and inform further discussion a data collection activity was conducted. A basic qualitative and quantitative questionnaire delivered by Survey Monkey™ was determined to be the most suitable form of tool for data collection.
Data collection was solicited from three sources: final year BSc and BA Product Design students studying at Bournemouth University, all of whom had completed an industrial placement; Product Design academics at ? University; and design professionals currently employed in design management or design training at Dyson Ltd.
The participants were invited to answer a series of questions regarding their own views and experiences of RP versus traditional prototyping in education and practice.

3 FINDINGS

There were 40 responses in total: 27 from undergraduate ?U Product Design students, seven from ?U Product Design academics and six from design professionals employed at Dyson Ltd.
It is apparent that the majority of respondents (95%) has or intends to use rapid prototyping in their professional practice (Figure 1). The uses were wide-ranging but by far the most common use of 3D printing was for prototyping (Figure 2). The majority of design professionals used rapid prototyping across all activities within the design process.

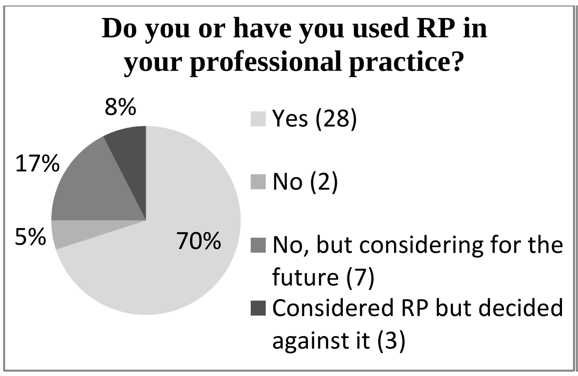
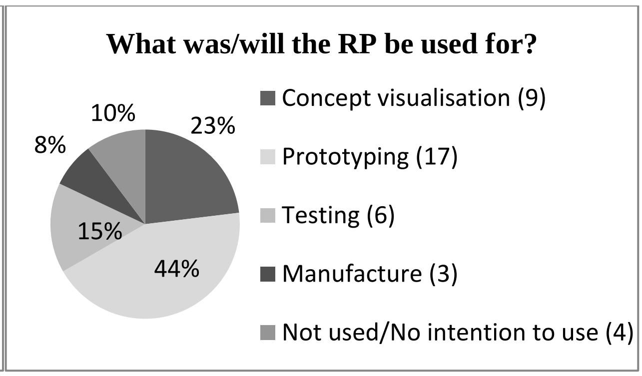


Figure 1



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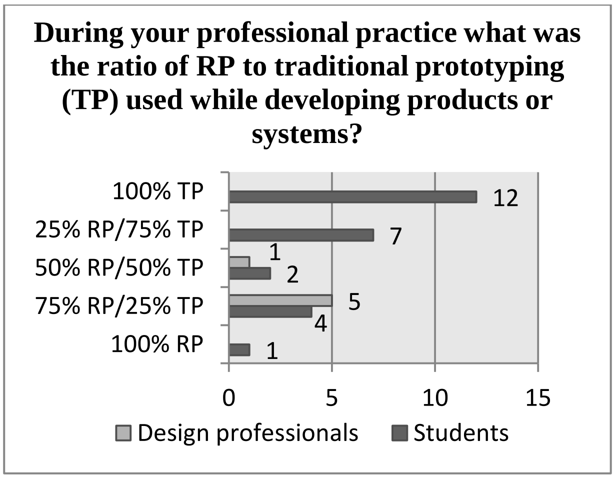

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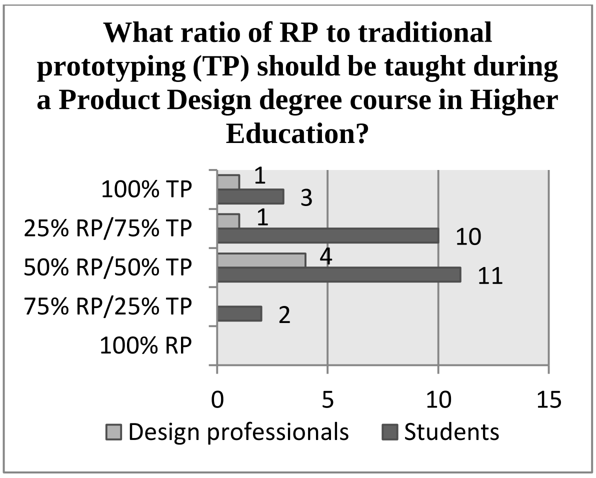
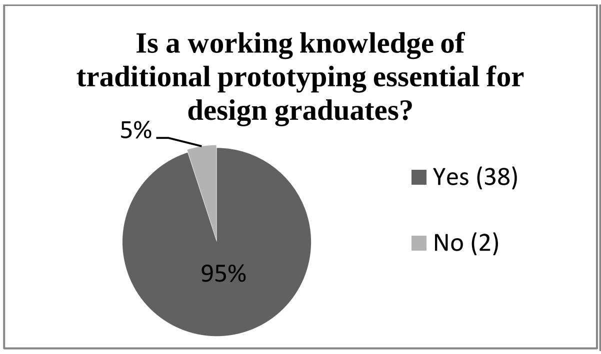


Figure 4

When asked what the percentage ratio of use between rapid prototyping and traditional prototyping the majority of student respondents (around 72%) had used 75-100% traditional prototyping during their professional practice (Figure 3). This is in contrast to the design professionals of whom the majority (around 83%) utilised 75% or more rapid prototyping during their professional practice. This may be due to specific research and development practices used by Dyson Ltd, but are in all likelihood an indicator of what progressive product design and manufacture companies are doing.
When it comes to thoughts on what should be taught during a typical Product Design degree course most respondents agreed that the split should be around 50% - 75% traditional prototyping skills to 50% - 25% rapid prototyping skills (Figure 4). Interestingly the Head of Design at Dyson qualified his view that only traditional prototyping skills should be taught in HE with the observation that RP skills could easily be learnt when working in industry.
In addition 95% of respondents indicated that a working knowledge of traditional prototyping was essential for design graduates (Figure 5) whilst only 75% indicated that a working knowledge of RP was essential (Figure 6).



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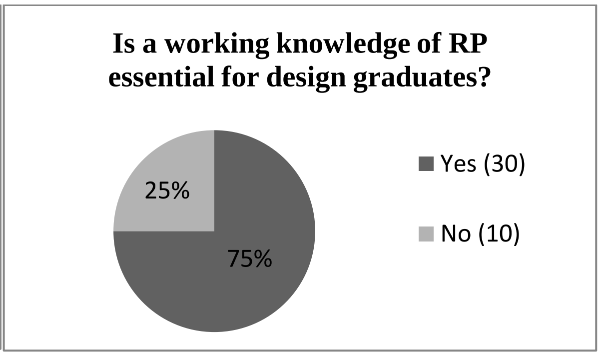

Figure 6

When asked to give their qualitative views on the subject the majority of students and professionals agreed that traditional prototyping skills are an essential element, particularly in the earlier stages of the design process. The following comment from a design professional is typical:
"We see graduates that are now too quick to CAD something up and then RP it rather than go to the workshop and cobble something together to test the basic principles first. It wastes time and money doing it. That approach is fine once you have done some rudimentary work beforehand."
Students related similar experiences with traditional methods during their professional placements:
"When you work in a design consultancy, for example, CAD and RP are the last stages of the design process. The way the designers communicate is through sketches and crude model making. This is where the most important discoveries in the design process are made. It is this creative, fast paced and dynamic way of thinking that produces innovative ideas and the unique selling points which will determine the success of your product."

The value of traditional skills in encouraging empathy for materials and manufacturing methods was also stressed. Another Dyson professional commented:

“Machining, CNC, lay-ups, mouldings, etc all have deep roots in manufacturing methods which give designers good empathy for how a design could be manufactured. It's manufacturing empathy that's lacking as a result of too much RP emphasis in HE.”

It is interesting to note that even though Dyson Ltd utilise a high percentage of RP work compared to traditional prototyping, the design managers have very strong opinions on the importance of teaching traditional prototyping skills in higher education.

It was generally acknowledged that appreciation of RP was important but should be taught as a compliment to the design process rather than a direct replacement of traditional prototyping. Concern was also expressed that alternative RP processes should not be side-lined:

“Design education should also make sure students know what RP processes are available and under which circumstances they should be used. I've found some universities have a strong focus on FDM machines when in practice I've found SLA to be most essential (apart from very early spacial models, in which SLS works very well).”

4 DISCUSSION: RP IN EDUCATION

The pragmatic and economic advantages of utilising RP have been the primary driving force behind its adoption in HE. As in industry, the expense of installing new equipment has been rewarded by savings in workshop manpower and space. Prototype build times have been reduced, and the burden of health and safety requirements significantly lightened. Though material costs and limitations have been problematic in the past, the introduction of cheap plastic filaments and a wide range of revolutionary printing materials – including even carbon-fibre and Kevlar – have largely dissipated these criticisms. Even full-colour 3D printing has become a reality.

While these practical arguments are compelling – and apparently conclusive in their support for RP - the educational case is less clear-cut, and it is this area that concerns the authors of this paper. The research findings highlighted particular issues with the use of RP during early design development and these deserve further discussion.

The benefits of using traditional methods and materials (such as Styrofoam, card and modelling clay) during these early stages are well-documented, and no CAD-based system can provide the level of instant scalar and tactile feedback provided by hands-on modelling. Moreover, while CAD encourages students to create finished designs with precise dimensions and geometric shapes, traditional modelling produces a more “fuzzy” approach to early modelling, the significance of which has been widely established by previous research [8][9][10]. CAD modelling is also much less likely to produce the happy design “accident” – those occasional but significant instances when a design can take a major turn due to a chance discovery or the shape of an offcut of material [11].

Many researchers, such as Gerber & Carroll [8], accentuate the importance of quick design iterations with a high failure rate, in order to increase confidence in the validity of the final design; in the words of Craig Sampson, to “measure success by the height of the trash pile” [10]. While methods like foam modelling can produce a larger number of different models in a short time compared to 3D printing, students can often be reticent to undertake multiple design revisions due to the effort required: each model needs to be started from scratch, whereas a CAD model can be edited and reprinted with ease [12][13].

Undoubtedly, design development can be hampered by the practicalities of modelling with traditional methods. This may be due to the limitations of the materials or processes or due to the skill level of the student themselves [14]. Many design students will find traditional modelling frustrating and outdated. Wilgeroth and Gill [15] claim that RP relieves students from the “burden” of learning model making skills. The authors regard this observation as short-sighted in the extreme. Although the process of making models by hand is arguably more difficult, costly and time-consuming, the educational benefits to the students are vital. An understanding of the behaviour and characteristics of materials is perhaps the greatest benefit, and it is the disconnect between material and form that particularly worries Jonathan Ive:

“"One of the things that drives me potty is this idea that you can have a random shape, and then you think let's make this bit in wood and that bit in plastic….You can't make those decisions, you can't read about it, you gain that experience by making.”[1]

The authors' research findings support the belief that consideration for manufacturing processes and specifications are also best learnt through practical, hands-on experience. Ironically, although the health and safety benefits of 3D printing have been championed in comparison to workshops, ?U believes that exposing students to the potential dangers of the workshop and providing them with skills and knowledge to use machines safely ultimately produces safer, more confident designers.
However, Forkes [16] noted the frequent discrepancy between students' design drawings and their final models, and his argument that RP models will retain more of the designer's original vision is compelling – though this is only true if the student's CAD skills are up to the task. The phenomenon of "design for model making" was ably described by Wilgeroth and Gill in 2006 [15], where students consciously (or subconsciously) create designs that they know they can create in the workshop. Although their assertion that RP eliminates this issue is debatable, it is certainly true that designing within the digital realm can enthuse students, motivating them to produce more complex and extravagant forms [17][18][19]. While this does not necessarily ultimately produce "better" designs – and some students (and possibly educators) may be guilty of confusing higher quality models with better design - it does broaden the possibilities, and levels the playing field for students of differing modelling abilities [14].
The broadening of possibilities raises the issue of design for manufacture. In 2012 Campbell, Bourell and Gibson [20] embraced RP's capability for allowing students to be "encouraged to ignore the design-for-manufacture limitations they have been used to", while Helbling & Traub [12] welcomed designs "no longer hindered by manufacturing difficulty". These comments assume that today's product design and engineering graduates have no need to understand the limitations imposed by traditional manufacturing methods. In the opinion of the authors, this is a severely misguided view. As one of the main aims of the design educator is to prepare the students for their professional life in the industry, it has always been deemed necessary to use industry-standard processes. Despite the increasing popularity of rapid manufacture, the expense and practical limitations of the current RM technology and materials have ensured that it still occupies a niche position within the manufacturing industry. In removing the requirement for such staples of design as draft angles and tooling standards, RP discourages students from engaging with the eventual method of manufacture and gives them a false sense of what may or may not be economically or practically viable.
However, as stressed in the authors' research, educators are equally guilty of leaving students ill-equipped if insufficient attention is given to RM. Undoubtedly the proliferation of printed products will only escalate. 3D printers offer students a valuable insight into the current and future possibilities of RM, and a sobering reminder to treat media hype with a pinch of salt. The number of different forms of RP is increasing rapidly, each with their own specific design-for-manufacture considerations, and all of these should be taught alongside traditional manufacturing. In the words of Ford & Dean [17]: "Teaching should not be restricted to innovative practice in the application of new technology but all appropriate methods, old and new."

5 CONCLUSION

? University's practical workshop facilities have received much praise in recent years from external examiners – for example from Dr John McCardle of Loughborough University in 2013: "Bournemouth is clearly delivering a modern and a pragmatic approach to product design, supporting extensive CAD use and elements of digital prototyping, but importantly also encouraging a hands-on approach in workshop practices." The importance of teaching traditional model making skills was similarly reinforced by the vast majority of respondents to the authors' own research – both student and professional. This appears to support the concerns of Jonathan Ive, and highlights the folly of closing workshop facilities. By neglecting the teaching of practical skills, design educators may well be damaging their students' employability, as noted by one of Dyson's design managers:
"As far as I am aware ? University seems to still place a great deal of importance on traditional prototyping and I feel this is very beneficial in providing students with practical skills that some, but not all, employers may look for. I think it more likely that an employer would pick someone with practical workshop experience over RP experience as there is more "skill" involved in traditional prototyping. This probably greatly depends on the employer however."
However, the authors' research also revealed some dissatisfaction amongst students with regard to the lack of emphasis placed on RP at ?U, and this may be of equal concern. If product design educators are to take note of what students and industry are telling them, they must aim to strike a balance of true co-

creation between technology and tradition: "RP is merely a process that enables certain parts to be made to work alongside TP. Both are necessary and should be taught to complement each other, giving students the knowledge to know when and why one may be used over the other is essential."

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