

# **EMBEDDING IMMERSIVE TECHNOLOGIES INTO PRODUCT DESIGN EDUCATION: STUDENTS' AWARENESS OF VIRTUAL REALITY AS A TOOL TO SUPPORT THE DEVELOPMENT OF DESIGN SOLUTIONS**

**Laila AL JAHWARI, Vanja GARAJ and David HARRISON**  
Brunel University, London, United Kingdom

## **ABSTRACT**

Using new and emerging technologies in education can increase student engagement and support teaching methods. However, using any technological tool requires prior knowledge and understanding, especially in education. An online survey was used to gather data on product design students' knowledge of Virtual Reality (VR) technology. As a case study, this survey will examine how the use of Virtual Reality technology can impact the product design development process and design thinking. A questionnaire was distributed to product design students as part of a mixed method approach. Students' views on common design solution development practices and Virtual Reality technology were quantified and analysed through open-ended and closed-ended questions. The survey revealed students' preferred modelling and rendering software, sketching methods, level of detail in sketches, prototyping materials and tools, assessment modes and aspects. The questionnaire also assessed students' knowledge of VR and their perceptions of its utility in product design. In product/industrial design education, high student awareness of technology indicates a bright future.

*Keywords: Virtual reality, product design, higher education, design thinking, product development*

## **1 INTRODUCTION**

The use of Virtual Reality (VR) in product design education is revolutionary. Several impediments make implementation difficult. Obstacles can be related to the technology, the end users (educators and students), or their interaction with the technology. To overcome these hurdles, researchers must identify real-world problems that VR can solve, and demonstrate its educational value. A better approach is to investigate the current process, identify the challenges and barriers that prevent end-users from achieving good outcomes, and finally test potential solutions without forcing the latest technological trends. This study used mixed methods to gather data from various product design students. The survey assessed students' knowledge of VR technology and their perceptions of its use in product design. The study is part of a larger PhD research project investigating best practices for using VR to enhance product design education.

## **2 RATIONALES FOR THE STUDY**

Prior studies established the great potential that VR and related technologies have in industrial/product design education [1], [2], [3], [4], [5]. An experimental study that examined three case studies including undergraduates, postgraduates, and design research concluded that VR had progressed beyond being a tool for visualisation and decision-making and might be ready to play a critical role in all phases of the design process [6]. In the field of industrial design education, several studies examined the effectiveness of using VR to aid design learning [7], [1], another study focused on the usefulness and ease of use of VR [2]. In contrast, Hamurcu et al. (2020), analysed the efforts of using VR in industrial design in professional and educational contexts by focusing on VR as a tool to represent and communicate design ideas [4]. Roberts et al. (2020) investigated using VR to aid in the design process across various stages from early conception through usability testing [6]. Jimeno et al. (2016) narrowed the focus to using VR sketch drawing software in the design process [3]. Camba, Soler and Contero (2017), broadened the scope to using VR to facilitate multidisciplinary design education in industrial design, architecture,

and interior architecture [1]. There is little evidence in the literature of studies that have investigated the current design process followed in product/industrial design education without proposing the “technology solution” from the beginning. The objectives of the work presented here are to investigate current approaches to developing design solutions among product design students, explore product design students’ awareness and perceptions towards the integration of VR in developing design solutions, and reflect on the future of VR technology in product design education.

### **3 RESEARCH METHODS**

This study utilised a mixed methods approach that included qualitative and quantitative aspects via the distribution of a questionnaire to product design students in various levels, BSc Product Design, MSc Integrated Product Design and PhD Design in Brunel University, London. A questionnaire was identified as the most efficient means of gathering information from a large number of students [8]. The type of sampling used was random sampling, with e-mails sent to the participants that contained the SurveyMonkey URL of the survey. There was no hypothesis testing in this study since the objective was to uncover the usual practices of product design students in terms of solution creation and to elicit participants’ perspectives on incorporating VR into the product design process. The survey consisted of 28 questions divided into three main sections, A-Background of Respondent, B-Design Solution Development, and C-Experiencing Virtual Reality Technology. The survey questions were mainly multiple choice with one open-ended question. The open-ended question aimed to understand the participants thoughts about the usefulness of VR technology in developing design solutions. It was thought that the open-ended question would allow for the opportunity to gather rich and probably deeper data for the participants’ perspectives on virtual reality and its implementation in product design education [9], [8]. A three-phase pilot study was initially undertaken to test the questions, the variability of the answers, and the method of analysis.

### **4 RESULTS AND DISCUSSION**

By the end of the survey period, data had been collected from 61 students.

#### **4.1 Research objective one: Investigate the current approaches to developing a design solution among product design students**

This research objective was established to give insights into product design students’ existing practices when working on their design projects specifically when designing a solution. The findings add to information about duration, techniques, tools, and preferred software/hardware. The sequence and the flow of the questions were structured carefully according to the process of developing a solution in product design education starting from drafting concepts to prototyping the final design solution. For each phase, specific questions about duration, techniques, tools and software/hardware were asked. When constructing the survey, the *item-order effect* was applied to ensure that respondents would interpret later questions properly. According to Price et al. (2017), “One item can change how participants interpret a later item or change the information that they retrieve to respond to later items” [10]. Therefore, Section B [Design Solution Development] was initiated with a question which aimed to produce a cognitive attachment for the respondents on how to retrieve the later questions. The question was: “What is the overall expected time you need to re-create the following 3D CAD models?” Three different images of simple construction items, (a cup, a chair and a goblet) were provided. In this way the respondents would keep the provided images in mind when answering later questions. The results of this survey will be discussed in line with the findings of Noor Aldoy & Mark Evans’s (2011) survey study, which investigated design graduates’ insights into the use of conventional and digital design modelling tools in UK higher education. The findings on current approaches to developing a design solution among product design students are discussed below according to a) Time spent in each phase of solution development b) Sketching techniques used c) Level of details in sketches d) Prototyping materials and tools e) Assessment modes and f) Modelling and rendering the final concept.

##### *a) Time spent in each phase of design solution development process:*

According to the responses, the duration product design students spent in each phase increased subsequently as they progressed in the design process (Figure 1). This could be because students gradually employed digital methods in the process as they progressed in developing the design solution. The percentage of time spent on digital approaches grew dramatically as the design process continued [11].

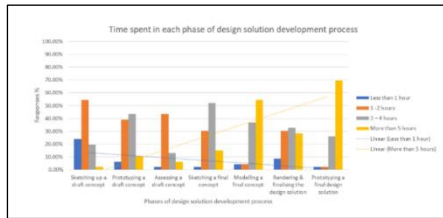


Figure 1. Time spent in each phase of design solution development process

b) Producing sketches throughout the design process

According to Pipes 2007 (as cited in [11]), the majority of designers begin by creating drawings (such as 2D side view sketches, 3D perspective sketches, investigative/exploratory sketches, and explanation sketches). Throughout the concept-generation phase, sketching is widely employed to externalise, alter, and assess concepts. From comparing the responses of the students to their sketching modes, while generating concepts and while finalizing them (Figure 2), most of the participants prefer the conventional method of pen and paper for drafting concepts. According to Henry (2012), at the outset of the design process, sketches should be spontaneous and have little detail [12]. Remarkably, the same traditional method is still in a high percentage, 39%, in drafting final concepts. Sketching using drawing tablet is ten percent higher in the later phase. These results agree with those of Noor Aldoy & Mark Evans (2011), which showed that over 90% of respondents said that they always/frequently utilised freehand paper sketching. This was also confirmed by another recent study of the same authors in 2020, which showed that students believed that traditional drawing using pen and paper was a more efficient and effective approach to communicating early thoughts, particularly during the concept creation phase when they were expected to generate a significant number of ideas [13]. Reasonably, sketching using graphics software with a mouse increased from 6% to 15% in the concept finalizing phase as digital methods are more effective to support visual representation in the later phases. Participants who selected the choice “Other” provided a variant of answers which are similar to the provided choices. For example, in drafting concepts, students provided like “digital sketching, Sketch using graphic software with iPad and Autodesk Fusion 360”. And one student said they preferred to use “Procreate” which is a raster graphics editor application for digital painting. Very similar answers were given when finalizing concepts.

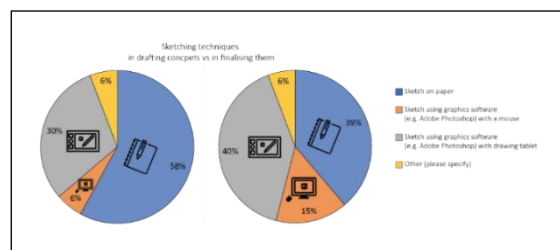


Figure 2. Sketching techniques throughout the design process

c) Level of details in sketches throughout the design process:

When comparing the degree of details in the proposed design from concept generation to final concept, it is obvious that students explore more details in the concepts such as materials and textures as they progress in the design process. As Figure 3 shows, the orange segment which represents *how thorough is the sketch of the final concept*, increases gradually from minimum details, with pencil or markers, to as many details as possible. In contrast, in the early phases of the design process students provide minor details in their concepts. These findings match those observed by Noor Aldoy & Mark Evans (2011), and they reasoned this was because product/industrial design students significantly employ more digital methods in the later stages which support increasing the level of details [11].

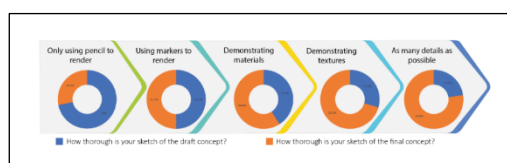


Figure 3. Level of details in sketches throughout the design process

*d) Prototyping materials and tools throughout the design process:*

The survey results suggested that workshop-based sketch models were more often utilised than digital sketch models during the early phases of design solution development. More than 80% of product design students used materials such as paper, cardboard, foam, wood, plasticine clay and a combination of multiple materials. During the late phases, students moved to employ tools such as CAD software and 3D printing as a full-size working design representation and used them to simulate some of or all the features for a proposed product. Interestingly, some product design students provided answers such as using Unity software and VR technology.

*e) Assessment modes and aspects throughout the design process:*

Communicating design concepts is a vital component of the design process, and design ideas must be expressed and communicated at each stage of the product design process, from concept design to detailed design – and must be assessed throughout the process [4]. However, assessment modes and aspects differentiate between the beginning of the process and the end. During the early phases, product design students are involved in activities such as self-assessment and peer-assessment. Being involved in these activities helps students to learn to recognise constructive collaborative behaviours by reflecting first on themselves, then on others, and lastly on a comparison of the two [14]. More than 84% of students elected self-assessment and peer-assessments as their main modes of concept testing and evaluation in the early phases. Additionally, as previously described, product/industrial design education is like a simulation of a professional design studio where teachers are the customers and students act as the designers, so assessment with the supervisor is crucial from the beginning of the process. More than half of the students selected “assess with supervisor” when drafting concepts, and this percentage increased when assessing the final concepts to be 76%. Moreover, when finalizing the design concepts, other modes of assessment appear such as user testing. Aspects of assessment started with assessing form and structure in the early phase. About 70% of students ranked those two aspects higher when answering “*What aspect of the draft concept do you usually assess?*”. On the other hand, assessing features such as usability, functionality, manufacturability, service attributes and Environmental Impact Analysis are ranked as more important when finalizing concepts.

*f) Modelling and rendering the final concept:*

Most designers begin the design process using pen and paper and then move to CAD software to model the final concept. The preferred software to model the final concept for product design students, classified from most favourite to least favourite, are Solid works, Fusion 360, Rhino, 3Ds Max, Maya, and CATIA. Renderings are sometimes referred to as ‘presentation drawings’ and ‘persuasive sketches’, for example, two-dimensional side view renderings and three-dimensional perspective renderings [11]. According to Noor Aldoy & Mark Evans (2011), computer-generated renderings created using software such as Adobe Photoshop were substantially more often employed than hand-drawn paper-based renderings [11]. This was demonstrated by the questionnaire replies, which revealed that product design students prefer to use software such as Adobe Photoshop, Adobe Illustrator, Individual rendering software and Procreate in iPad, to render the final concepts.

## **4.2 Research objective two: Explore product design students’ awareness and perceptions towards the integration of VR in developing design solutions**

*a) Experiencing Virtual Reality Technology:*

Section C of the questionnaire aimed to provide insights on product design students’ awareness about VR technology without linking it with design or design education initially. The first question is “Have you ever tried Virtual Reality technology before? And the choices provided are: “Yes, No, Not sure, I don’t know what Virtual Reality technology is”. The percentage of “Yes” and “No” answers is almost equal, with 45% of students answering “Yes” and 47% answering “No”. When comparing our results to those of Noor Aldoy & Mark Evans (2011), it must be pointed out that there is an increase in the level of awareness about VR technology among product/industrial design students in the UK. Their study reported that eighty-eight percent of students had not tried Virtual Reality in 2011. As expected, most students, about 71%, have used VR “mainly for gaming”, when asked about the purpose for using the technology. In second place came “gaming”, and finally “education”. VR technology is popular among university students for entertainment purposes, and this explains why Sony PlayStation VR is the most frequently used VR headset by participants. After that, other popular VR headsets come such as, HTC Vive, Oculus Rift, Oculus Quest and Samsung Gear VR. Due to its affordability, Google Cardboard is also popular among students.

b) *The usefulness of VR in developing design solutions:*

The Participants were asked an optional question asking: “*How useful you think Virtual Reality would be in developing design solutions?*”, aiming to investigate their insights about the usefulness of using VR in the design process. All the respondents who provided an answer for this question, have used VR before for different purposes and using different VR headsets. The most interesting findings from this question are the following:

- Unexpectedly, there is no relation between the age of the respondents and their insight into the usefulness of VR. It was expected that younger students would be more enthusiastic about the technology whereas graduates and post-graduates would be more cautious. Interestingly, the respondent insights varied and there is no link between the age of the participants and their insights about VR.
- Unlike the age variable, the industrial expertise of the students influences their insights about VR. It has been noticed that opinions of students who are in their placement year range between “Extremely useful” and “Somewhat useful”. Placement year students think that VR could be “Extremely useful” in mocking up designs, 3D modelling, testing solutions. Additionally, they think that VR features of full-scale and immersion will support the design process. Placement year helps product/industrial design students learn about the latest technologies in the product/industrial design profession and they could have the chance to test them. One of the emerging technologies which is more advanced in industry than education context is VR and its related technologies.
- Sixty percent of the participants think that VR would be “somewhat useful in developing design solutions. They think that deciding to use VR depends on the purpose of using it. According to the participants, VR could be somewhat useful for user testing of architectural designs, service design and interior design. Additionally, VR could provide a new way to interact with the product and can help in enhancing the rendering phase. On the other hand, they think that VR has limited potential in the design process and is “sometimes unnecessary”. One of the respondents said that VR is not very useful for small individual products. Other participants highlighted that Augment Reality AR technology could be more useful than VR in product design scenarios because with AR we can assess certain aspects of the product, such as form and size in shorter time without the need for rapid prototyping. One of the participants said: “*I think VR would be useful to a certain extent. We must ask ourselves what type of projects would benefit most from the technology, and not just using it for the sake of using it*”.
- A percentage of 33% of respondents think that VR would be “Extremely useful” in developing design solutions. One of the participants thinks that VR allows for a faster and more adaptable way of developing and testing design solutions within a 1:1 scale contextual environment. Another participant said: “*With the development of technology, Virtual Reality technology will gradually replace the traditional computer technology, such as hand drawing, CAD, etc. VR will become an indispensable tool for designers in the future, like computers now*”.

#### **4.3 Research objective three: Reflect on the future of VR technology in product design education**

- Studying the current design process that product design students are following and the common practices among them is extremely important in measuring the readiness of product design education and product design studio to fully employ VR technology as one of the digital design methods. Experimenting with the technology in short time and through narrow-scope sessions without investigating the end users’ needs will not help in progressing toward a full employment of the technology.
- Analysing the strengths and the weakness of the current design methods and tools will determine the right time and proper context to effectively integrate VR technology. For example, according to the findings of this study, product/industrial design students spend a considerable amount of time in the later phases of design solution development. Thus, scenarios where VR could accelerate the design process in the later phases of product design studio could be proposed.
- The majority of experimental-based previous studies compared VR or any related technology with one or more of the conventional or well-established design methods. This study suggests comparing an emerging technology with another in the product/industrial design education context. For example, a study could compare the potentials of VR with the potentials of AR in product design education, or with Mixed Reality MR.

## 5 CONCLUSION AND FUTURE WORK

The first part of this study focused on common design development practices among product design students without using VR technology. The findings revealed significant details about students' preferred modelling and rendering software, sketching methods, level of detail in each phase's sketches, prototyping materials and tools, assessment modes and aspects. The questionnaire also assessed students' knowledge of VR and their perceptions of its utility in designing products. The high level of student awareness of technology indicates a promising future for product/industrial design education. Moreover, their generally positive views on the use of VR in design solutions show a high tendency to use and accept the technology. This study may change how educators and researchers view VR in the classroom – not just as a supplementary feature, but as a valuable component that should be planned from the start. A recognised limitation of this research is the study's inability to generate generalisations owing to the limited number of participants and the fact that the data were gathered at a single design school.

## REFERENCES

- [1] Camba J., Soler J. and Contero M. Immersive Visualization Technologies to Facilitate Multidisciplinary Design Education. *Lecture Notes in Computer Science*. 2017;;3-11.
- [2] Hamurcu A. User Insights about Using Immersive Virtual Reality in Industrial Design Studio Courses. 2018 *2nd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)*. 2018;;1-8.
- [3] Jimeno-Morenilla A., Sánchez-Romero J., Mora-Mora H. and Coll-Miralles R. Using virtual reality for industrial design learning: a methodological proposal. *Behaviour & Information Technology*. 2016;35(11):897-906.
- [4] Hamurcu A., Timur Ş. and Rızvanoğlu K. An overview of virtual reality within industrial design education. *Journal of Engineering, Design and Technology*. 2020;18(6):1889-1905.
- [5] Yu-Che H. and Yi-Ru C. The Study of Virtual Reality Product Design in Education Learning. *Proceedings of the 2019 The 3rd International Conference on Digital Technology in Education*. 2019;;9-11.
- [6] Roberts S., Page R. and Richardson M. Designing in virtual environments: The integration of virtual reality tools into industrial design research and education. *DRS2020: Synergy*. 2020;.
- [7] Lee A., Liang Y. and Liu S. A Study on Design-oriented Demands of VR via ZMET-QFD Model for Industrial Design Education and Students' Learning. *EURASIA Journal of Mathematics, Science and Technology Education*. 2016;12(5).
- [8] Kiernan L. and Ledwith A. Is Design Education Preparing Product Designers for the Real World? A Study of Product Design Graduates in Ireland. *The Design Journal*. 2014;17(2):218-237.
- [9] Baxter G. and Hainey T. Student perceptions of virtual reality use in higher education. *Journal of Applied Research in Higher Education*. 2019;12(3):413-424.
- [10] Price P., Jhangiani R., Chiang I., Leighton D. and Cuttler C. RM in P 3rd ed. p. 133. *Research Methods in Psychology*. 3rd ed. 2017. 133 p.
- [11] Aldoy N. and Evans M. A Review of Digital Industrial and Product Design Methods in UK Higher Education. *The Design Journal*. 2011;14(3):343-368.
- [12] Henry K. *Drawing for Product Designers*. Laurence King Publishing; 2012. 9 p.
- [13] Aldoy N. and Evans M. An Investigation into a Digital Strategy for Industrial Design Education. *International Journal of Art & Design Education*. 2020;40(1):283-302.
- [14] Mattioli F, Ferraris S. Self-Evaluation and Peer Evaluation Tool for Design and Engineering Teams: Experiment Conducted in A Design Studio. *DS 95: Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019)*, University of Strathclyde, Glasgow 12th -13th September 2019. 2019;.