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User Experience Evaluation of a Virtual Reality Tool Used for 3D Modelling in Industrial Design Education: A Study in the Indian Context

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Abstract: Virtual reality (VR) technology has recently been adopted by educators for use in the classroom. Currently, this educational model includes not only lectures with teachers in the online classroom but also practical sessions using online platforms. Few studies have explored the potential of pedagogical approaches to implementing VR in the classroom for the purpose of design education. The focus of this paper was to study the learning experiences of the 3D visualisation of products among industrial design students through the strategic implementation of virtual reality technology. A within-subjects comparative study was conducted to measure cognitive workload and engagement and enjoyment, while a 3D modelling task was given using two different set-ups (conventional 3D software versus VR-based software). The statistical results show that the NASA-TLX score was lower in the case of the VR-based 3D modelling exercise compared to the conventional 3D software-based exercise. On the other hand, the mean values were higher for the engagement and enjoyment and usability scores, which means that the VR-based experience for 3D modelling was better than the traditional modelling experience using conventional software. Hence, there are possibilities to implement VR-based 3D modelling tools for online industrial design education for 3D visualisation in the near future.

Keywords: 3D model; experience; immersive media; industrial design; visualisation; VR

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1. Design Education in the Indian Context

Advancements in design education have occurred in India through various changes in curriculum design and pedagogical applications. The acceptance of design practices has increased. With the growth of the design industry, design education has drawn attention in recent years. The design education sector in India is expected to thrive in the near future due to favourable demographics, consciousness in terms of design thinking and technology focused on design pedagogy.

Design education was formally established under the umbrella of the National Institute of Design, as reported by Eames and Eames (1961) [1]. Since this, design education has become an aspirational magnet for young talent. As a result, there has been an organic change in policies and markets. Hands-on-based and experiential projects make design education more interactive and practical for world scenarios, as they are ideally mentored by faculty members [2]. Now, there are more than a thousand design institutes in India, but there has been a very limited exploration of the application of contemporary technologies in classrooms for educational purposes. Apart from theoretical courses, design training also includes practical courses in which students participate in the development of prototypes or models.

2. Pandemic and Design Education

The COVID-19 pandemic has led to the global adoption of online technologies for educational purposes. As a result of the pandemic, educational institutions worldwide have shut down and academic schedules have been disrupted. To continue academic activities, most institutions have shifted to online educational platforms [3]. Students have faced numerous uncertainties and challenges in learning various subjects and acquiring skills. In design education, most course curricula are skill- and practice-based. Because of this, design education suffered considerably during the pandemic. While the curriculum of knowledge and lecture-based programs has still managed to be delivered via an online medium, design faculty have faced more challenges in conducting studio-based courses [4].

Design institutes in India have also incorporated online classes into their curriculum. However, the hands-on learning approach of design education requires access to workshops and tools, and it often involves one-on-one communication between faculty and students. Despite this, both design learners and faculties have recognised the potential of conducting courses through an online medium [5].

To construct a model in a 'model-making course', students must possess an understanding of concepts such as form, shape and space. Additionally, design students need to learn how to use various hand tools to create 3D models. To construct a physical model, it is crucial for learners to comprehend the tactile qualities (i.e., texture), materials and dimensions. However, they may face challenges when it comes to understanding the three-dimensional visualisation during the digital representation of their ideas using 3D software.

Acquiring skills in an online environment can be a challenging task. As a result, educational technology researchers are continuously exploring better solutions for communicating in remote education. Immersive media, such as virtual reality (VR), seems to be a promising avenue for such tasks. VR has the potential to enhance students' understanding of specific course objectives by providing an immersive learning experience. In the context of a model-making class for design students, VR can be an effective solution for providing interactive learning experiences [6].

After COVID-19, there has been a rise in the level of acceptance of online education. Immersive technologies such as VR and AR have gained popularity, and their applications have become better understood. Many educational institutions believe that students benefit more from a hybrid mode of instruction. Even after the pandemic, online platforms will continue to be used as a teaching and mentoring medium. On the other hand, hybrid, blended and online (HBO) learning is effective when learners are not restricted to physical classrooms; rather, they can learn many things by themselves with the HBO learning mode [7].

3. Immersive Media in Design Education

The adoption of HBO education can also help design schools in India to address some of the challenges they face, such as a shortage of faculty, limited resources and outdated curricula. By leveraging technology, design schools can offer personalised and adaptive learning experiences, incorporating industry-relevant projects and collaborating with global partners to provide students with a more comprehensive and diverse education.

It is very difficult to find and recruit faculty members with a background in design education in India. In fact, the faculty–student ratio is profoundly imbalanced (i.e., fewer faculty, more students). According to the All India Council for Technical Education (AICTE), the ideal faculty-to-student ratio for design institutes should be 1:10. However, many design universities in India have a higher student-to-faculty ratio, with some institutions having ratios as high as 1:20 or more [8]. This is a key reason for the adoption of the HBO mode of teaching in design education. Hence, the application of immersive media (AR/VR) is of enormous significance in terms of design education in India. The virtual labs were developed by IIT, Guwahati, for design education, and practical classes have been arranged in virtual design studios in web app-based ecosystems [9]. Further, when students are ill or miss practical classes, they may attend the simulated virtual studio to learn 3D modelling. University students might also learn various design courses and go for knowledge and skill acquisition using virtual tools.

When immersed in a virtual reality experience, the user is given the impression that they are actually present in the setting. To simulate a real-world setting and its contents, a VR interface provides a sophisticated method for humans and computers to interact. Participants are free to explore the virtual environment, examine it from all sides, reach out and interact with objects, and even alter their appearance [10]. To create an immersive experience in three-dimensional, interactive environments, VR reconstructs reality using various graphic systems [11].

Additionally, in some cases, it may appear that the allocated time is insufficient if one is expected to acquire knowledge of the entire skill set during face-to-face instruction. Therefore, some of the inputs may be made available online, where students will be able to access them at their own pace. Karen Swan proposed that student interaction can be improved through discussions and that there are multiple factors that can contribute to successful online discussions. These include the following: instructors discussing with students, the frequency of participation required, and the length of students' responses in discussions. It is evident that these factors require further exploration. As online course discussions are crucial, examining the quality of discussion responses through qualitative analysis can produce insightful and valuable outcomes [12]. Then, they may be provided with additional time for skill development through face-to-face instruction. Thus, the hybrid mode enables the combination of skill-based and knowledge-based learning the use of project execution to improve comprehension and learning substantially. Various media and technologies, such as emerging immersive media, are gaining traction in the design field. Immersive media such as VR and AR have recently gained traction in the education sector [13].

Industrial design students are required to possess a skill set that includes 3D visualisation in model-making courses. Immersive media such as virtual reality may be useful for teaching this skill set. Some inputs can be generated online or through electronic media, allowing students to study them at their own pace. Additional advanced material can be delivered online, while the fundamental courses are delivered in person. Some advanced study material is delivered online, enabling the development of a hybrid mode of design education. It can be a separate repository of additional inputs to which students can refer at any time. While face-to-face instruction will continue to play a significant role in education for the foreseeable future, we recognise the need to develop a variety of channels to address not only extreme circumstances like a global disaster but also the more commonplace challenges that hinder efficient instruction. Hybrid classrooms have many benefits, including facilitating inclusion for students with special needs, reaching students in outlying areas, keeping students connected during extended absences, and introducing both educators and learners to cutting-edge communication tools.

Nonetheless, it was stated in a research article that a detailed theoretical framework for VR-based learning environments is required to guide future development efforts. Key factors influencing learning effectiveness in a VR-based learning environment, as well as the impact of VR technology on the psychological learning process, should not be overlooked [14].

4. VR in 3D Visualisation

Industrial design students often require visualising complex 3D concepts as part of their learning process. In this study, we aim to explore the impact of VR technology on the 3D concept visualisation experience of industrial design learners. Three-dimensional visualisation is a cognitive skill that is developed through a rigorous process, and if the process is not efficient and interesting, then students are affected, especially in further study of design. In the later stages, when these problems grow into major problems, it causes them to compromise their creative output. Hence, for design students, it is important to address this in earlier learning stages. Immersion, presence and interactivity are defined features of VR technologies.

The exploration of immersive VR is enticing for educators because of its cutting-edge visualisation and interactive capabilities. Virtual reality has been widely adopted by teachers as a means to improve students' ability to visualise difficult concepts and broaden their horizons. Typically, sensory and kinetic elements are prioritised in VR applications. To help design students get around the constraints of prototype visualisation and make better design decisions, practical lessons are increasingly incorporating the use of virtual reality devices. Immersion creates a significantly more motivating environment for students because they are active participants in the process. There has been a rise in the use of cutting-edge visualisation tools like virtual reality in recent years [15]. Researchers in the field of education have studied the tools that boost engagement and knowledge retention [16]. In recent studies, virtual reality has been used in terms of medical awareness in the context of the menstruation cycle among teenage girls, which proved to be effective [17]. The virtual 'Tilt brush' was used in expressing art intuitively. The flow of the hands makes the strokes immersive and makes the person visualise their work in a 3D space [18].

Heuristic evaluation of AR/VR concepts showed that immersive media in the classroom have been shown to enhance students' educational experiences. Furthermore, when compared to a static interface, the results of AR/VR concepts show that student involvement is higher and more beneficial to both faculties and students. Immersive media-based model making courses may offer improved learnability compared to traditional teaching methods.

According to research conducted by North and North (2016), people in virtual reality environments have a strong impression of being there [19]. According to Yıldırım et al. (2020), students' interest and motivation in the course were both boosted by the personalised learning environment provided by virtual reality [20]. According to the findings, virtual reality environments increased motivation and critical thinking skills while decreasing anxiety. Virtual reality environments increased student engagement, according to Akman and Çakır (2020), and the study concluded that virtual reality environments facilitated student learning, increased retention, provided a high sense of presence, and developed professional skills [21]. The impact of an educational virtual reality game on the achievement and engagement of primary school students in mathematics has also been studied [22]. There are several factors [23,24] that can be considered when conducting a heuristic study of VR in design education based on Nielsen heuristic principles for technology evaluation, including:

1. Usability: The ease of use of the VR system and the ability of students to navigate and manipulate the virtual environment.
2. Effectiveness: The effectiveness of VR in helping students understand complex 3D design concepts and accurately visualising design ideas.
3. Feedback: The availability of real-time feedback to students on their design decisions, allowing them to quickly iterate and improve their designs.
4. Immersion: The degree to which students are able to experience a sense of presence in the virtual environment and the impact this has on their learning.
5. Collaboration: The ability of students to work together in the virtual environment, including the ability to share and review each other's work.
6. Accessibility: The availability and ease of access to VR systems and the ability of students to use VR outside of the classroom.
7. Cost: The cost of VR systems and the associated hardware and software and the impact this has on the ability of institutions to adopt VR design as a teaching tool.

Now, the question is as follows: Are Indian students reacting to immersive environments built for design learning as reported by other researchers in some other context? Virtual reality might have great potential as a teaching tool for design students because it allows for a more engaging, collaborative, and immersive learning environment, which enables learning possibilities in a hybrid learning mode. It might also give students the freedom to study how and when they prefer.

5. Aim of the Paper

This paper aims to understand the effectiveness of immersive technologies like VR if introduced in Indian design education as an instructional medium for 3D visualisation. To achieve this goal, a comparative study was conducted by comparing the use of conventional 3D software with the use of a VR tool for creating 3D models to examine the effectiveness of a VR-based 3D modelling tool.

The VR-based 3D modelling tool is more effective for the 3D visualisation of tangible products (e.g., water bottles) than visualisation using conventional 3D modelling tools in in terms of perceived usability, engagement, and enjoyment.

6. Methodology

6.1. Participants

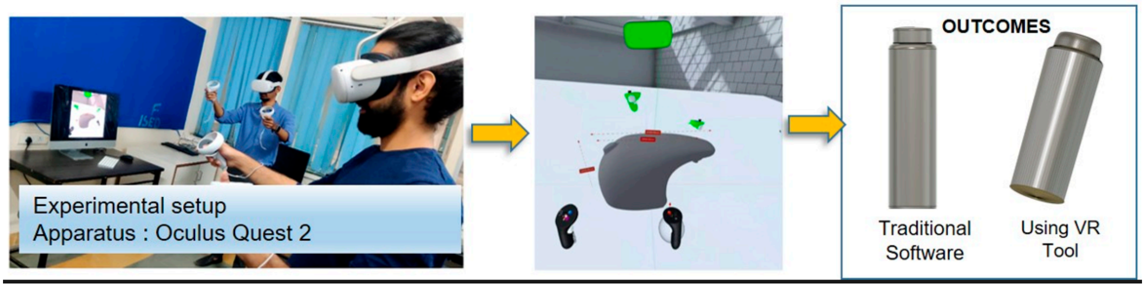
The target audience consisted of industrial design students aged 18 to 23 years from various design disciplines. Please refer to Table 1 for the demographic details of the participants. In this study, one of the perquisites was that the participants must have knowledge of any conventional 3D modelling software. All of them had a minimum of one year experience using 3D software. The workshop for VR-based modelling software has been conducted for 15 days with 34 design students to form the VR tool user group. There were two groups formed: those in Group A used traditional 3D modelling software. These were design students who had prior knowledge of traditional 3D modelling software such as Fusion, Autodesk, 3D Max, Blender, and so on (see Figure 1A, Video S1). Group B learned VR tools and attempted to create the same model using Oculus Quest 2 (see Figure 1B, Video S2). The experimental group used virtual reality headsets (Oculus Quest 2) to enhance the prototype's presentation and immerse the student in the interface (see Figure 2A).

Table 1. Demographics of experimental group participants.

Parameter	Conventional 3D Software Group	VR-Based Software Group
Usability. Engagement and Enjoyment study		
Mean Age (yrs)	20.62	20.53
Age Range(yrs)	19–23	18–23
Male: *n* (%)	15 (44.12)	15 (44.12)
Female: *n* (%)	19 (55.88)	19 (55.88)
n	34	34
Cognitive Workload Study		
Mean Age (yrs)	20.21	20.21
Age Range (yrs)	18–21	18–21
Male: *n* (%)	5 (35.71)	5 (35.71)
Female: *n* (%)	9 (64.29)	9 (64.29)
n	14	13

(**A**) (**B**) (**C**)

Figure 1. (**A**) Student creating water bottle task using Conventional 3D software; and, (**B**,**C**) students trying to create water bottle using VR Oculus 2.



(**A**) (**B**) (**C**)

Figure 2. (**A**) Student trying hands-on VR using Oculus Quest 2 'Collab' option; (**B**) showing the interface inside VR; (**C**) water bottle models.

6.2. Design Manipulation Check (Conventional 3D Software vs. VR-Based Software)

The study investigated the potential of a collaborative VR application for 3D modelling, in which users can access a menu bar and utilise sketch tools and other options. Figure 2B shows the interface of the proposed VR-based 3D modelling tool. The collaboration option can be used to enable interactions between the students and faculty simultaneously, and the steps involved in the process have been outlined in a flowchart (refer to Figure 3).

To initiate the process, students accessed the website's home page and logged in using their existing ID or created a new user account. Once logged in, students could upload pre-created 3D models/images in the OBJ format and proceed to create a virtual room. Faculty members could then be invited to join the room, and the landing page provided the option to import the same 3D objects into the VR setup.

Collab Option

- Students can import their drawing sketch and obj file of their 3D model, which they have made in 3D software.
- The faculty can use the pen tool in VR to mark overlays on the models and provide corrections by drawing directly on top of the model. They can assess the shape of the model by rotating and moving it virtually, identifying any necessary corrections in terms of sides, curves, and other aspects. This will help the student to understand the corrections instantly.
- The student can snap the 3D model onto the real image to view it in the proper 1:1 scale, and 3D model files from other software's like Blender, CAD, Rhino, etc., can be imported into this VR tool and users can create a multiple-user collaboration lobby to discuss and work on that file.
- Using the tools, faculty members can easily point out and correct student mistakes, and both can draw and interact with the object and also have liberty to scale it up or down to a 1:1 ratio to understand its real proportions. This is especially helpful when physical interaction is not feasible, which can affect the learning curve of students and create a communication gap.

Students' abilities to learn could be evaluated using a variety of criteria, including the clarity with which they can visualise models, their geometric analysis skills, their precision, and their familiarity with dimensions. Scale and proportion can be better understood through 3D environments. Students will have access to sufficient visual cues from the VR-based instructions to learn and correct themselves.

A research review conducted by Mohammad and Pedersen [25] emphasised that the effectiveness of heuristics evaluation methods used in previous studies relies on several factors. These factors include the experience and characteristics of the evaluators, the tools, techniques, and application settings utilised. The objective of their study was to evaluate an existing VR application, design a new one, or establish new heuristics. The literature review identified five crucial concepts essential for creating a positive user experience in VR learning environments: embodiment, empathy, flow, immersion, and presence. On the same basis, the following comparative study was undertaken [25]. In Table 2, the comparative inferences between conventional and VR-based modelling software are shown.

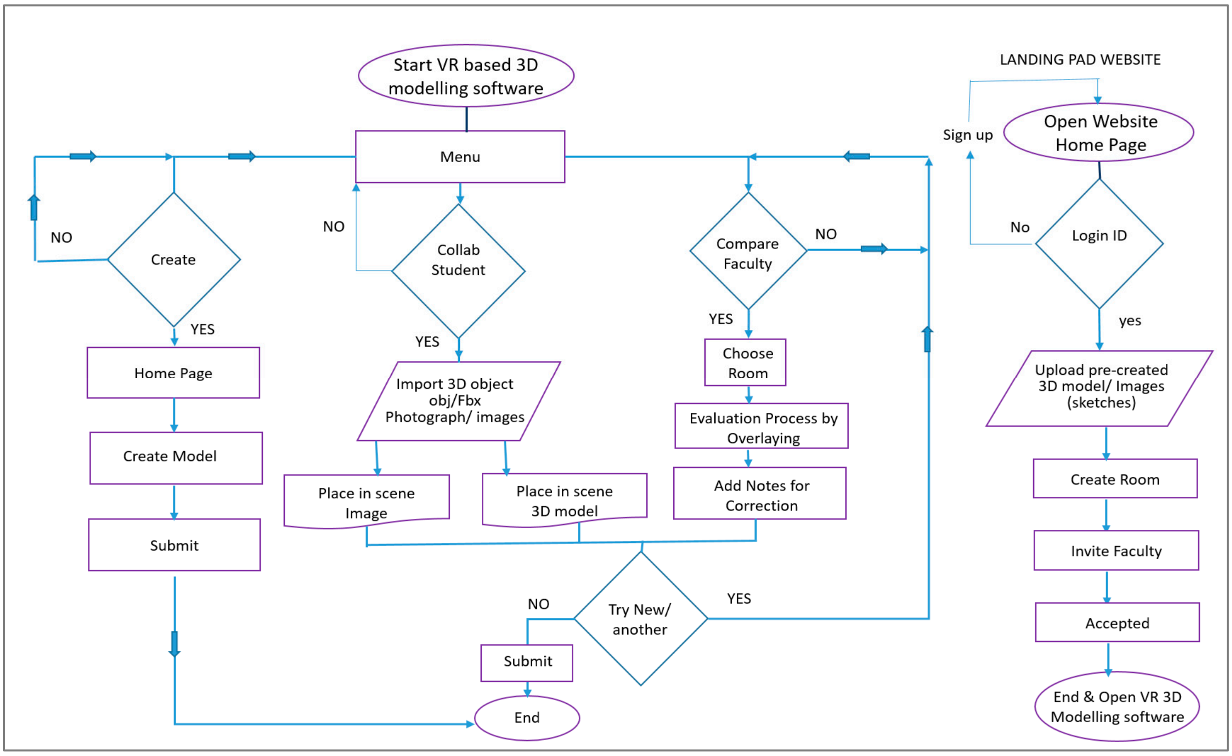


Figure 3. Activity flow chart for proposed VR tool with collaboration feature, where students can interact and receive feedback from faculty.

6.3. Working Definitions

- Ease of use means how comfortably one can use the software.
- Presence is the feeling of realism in a computer-generated environment or world.
- Accessibility is how one can reveal the desired information based on ethnicity (culture, language barrier, gender, and race) and ease.
- Interaction style is the way people how people will interact with the system.
- Visual appeal relates to the attractiveness of the interface.
- Precision is how accurately one can create 3D models with appropriate dimensions.
- Online Collaboration is the way multiple people work together using online platforms for 3D software.
- Error Notification is the way of presenting error messages to reduce human errors in human interaction.
- Natural Human Interaction refers to what they do while interacting among themselves.

- User Control and Freedom include achieving the same task through different processes.
- Implementation of Muscle Computer Interface (muICI): The muscle–computer interface is defined as interacting with computers using the electrical activity of muscles [26].

Table 2. Comparative study of the inferences of conventional and VR-based modelling software.

Sl No.	Parameter	Conventional	VR-Based 3D Modelling Software	Inferences
1	Ease of use	There are concealed commands within menus and submenus.	It has more ease of use because of hand gestures.	VR-based software is more convenient for 3D model making
2	Immersion	Negligible immersive quality (presence)	Users can seamlessly interact with the working 3D model (zoom, rotate, scale) view in different angles to get the feel of presence.	VR-based software is more immersive in creating 3D models
3	Accessibility	Voice commands are included	Voice commands and hand gestures are included	VR-based software has more accessibility for inclusive design
4	Interaction style	Input devices: using mouse and keyboard, touch-based interaction if touch-based monitor used	Using hand gestures, VR hand controller and wearable device (Microsoft MYO)	VR-based software is more intuitive to use
5	Visual appeal	Elaborated interface has been used	Visually delight interface	Visually pleasant in terms of UI interfaces in Conventional 3D software as well as in VR-based software.
6	Precision	More precise 3D models could be created in Conventional 3D software.	Lack of precision in the 3D output models	Conventional 3D modelling software can provide greater precision. However, VR-based modelling software can achieve precision if the created model is exported in a compatible format and edited in conventional 3D software.
7	Online collaboration	Limited collaborative opportunities	All type of collaboration is possible.	The VR-based system allows for collaboration between users, allowing them to interact with the intended model simultaneously.
8	Error notification	Present	More lively and feedback notification	VR-based software has better error notifications
9	Natural interaction	Absent	Hand gestural interaction Voice-based interaction (VOI)	VR-based software has a very visceral way of using hand gestures
10	User control and freedom	Present	Present	Both are good in terms of user control freedom
11	Implementation of Muscle–Computer Interface (muICI)	Limited possibilities	Enormous possibilities	In VR-based system Muscle–Computer Interface (mulCI) can be incorporated.

6.4. Study Design

A between-subjects study design was applied. The study was conducted among industrial design students in two scenarios, wherein the same water bottle model (see Figure 2C) was created using traditional 3D software by one group and the other student group created the bottle using VR-based software. The VR tool user (students) group were exposed to both 3D modelling and collaboration options for 15 days before they participated in the experiment. Both student groups were asked to create 3D water bottle models, as presented in Figure 2C. Oculus Quest 2 has been used as a VR tool in this study, as displayed in Figure 2A. To test the effectiveness of the proposed VR-based 3D modelling tool, the study subjects were randomly assigned.

A pre-test questionnaire was used to understand the student's background (demographics, 3D software skills, gender, etc.) After that, the 3D bottle making assignment was conducted in a controlled study environment. A post-task questionnaire was used to compare usability, engagement and enjoyment and acceptability between conventional 3D model-making software and VR-based 3D model-making software. To measure cognitive workload, a separate experiment was conducted using the same study set up as mentioned above. The cognitive workload was measured using NASA-TLX questionnaire to find out differences in mental workload during the 3D bottle model making task between conventional 3D model-making software and VR-based 3D model-making software [27].

6.5. Measures

Usability, engagement, enjoyment, and cognitive workload were measured using psychometric scales. The usability scale was adopted from Chowdhury A. (2019) [28]. The engagement and enjoyment scales were adopted from Thomas, Tuteja and Chowdhury (2021) [29]. The cognitive workload was measured using the NASA-TLX questionnaire.

6.6. Statistical Tools Used in this Study

Statistical analysis was performed using SPSS 20.0 software, as outlined by Field, A (2013) [30]. Mann–Whitney U-test was used to evaluate significant differences in usability, engagement and enjoyment, and acceptability for 3D model creation between conventional and VR tools [31]. In addition, significant differences in cognitive load were determined using an independent sample *t*-test.

7. Results

7.1. Perceived Usability

The perceived usability mean for conventional 3D modelling software was 3.857, and the mean for VR-based software was 3.381. The result showed that the perceived usability when using 3D conventional modelling software is significantly higher than VR-based 3D software [Mann–Whitney U = 414.50, Z (67) = −2.040; $p = 0.04$]. This kind of result is probably due to the prior knowledge of learners who participated in the 3D conventional group, as they are more familiar with 3D conventional tools than VR-based 3D model-making software. Although we have provided three initial trials for VR tools, there would be a learning curve in becoming more comfortable with the same tool. The systematic review by Kyaw et al. concludes that virtual reality (VR) improves the knowledge and skill outcomes of healthcare professionals more than any other form of digital education, including video and web-based teaching and even traditional educational methods like textbooks, 2D images, and lectures. Given its emerging and adaptable nature, VR has the capability to revolutionise education in health professions. Post-intervention knowledge and skills may be enhanced through the use of VR technology [32].

7.2. Engagement

The perceived engagement mean for conventional 3D modelling software was 3.881, and for VR-based software it was 3.523. There is no significant difference in engagement between 3D modelling software and VR-based software [Mann–Whitney U = 561.50, Z (67) = −0.206; $p = 0.837$]. Therefore, both mediums are engaging, as both mean values are more than 3.5 on a 5-point scale. Refer to Figure 4 for the usability, engagement, enjoyment and acceptability comparison results for conventional 3D software and VR-based software.

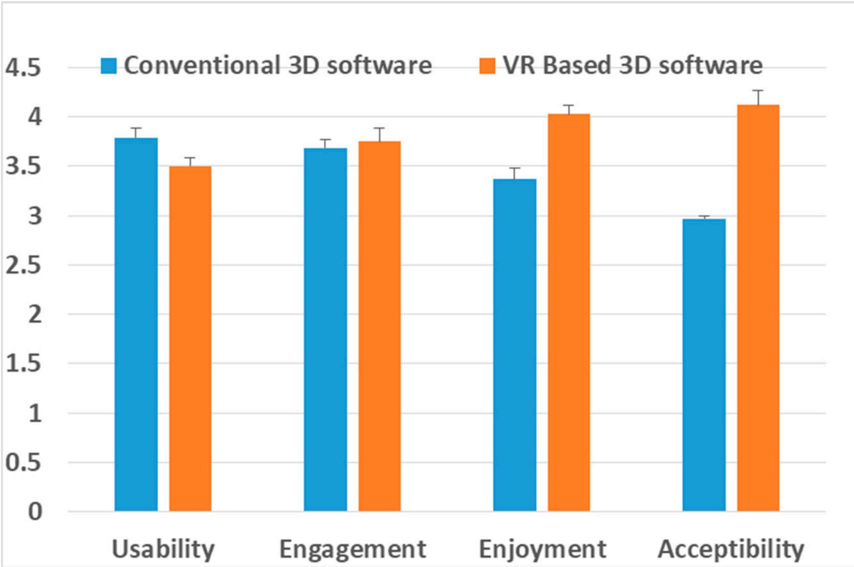


Figure 4. Comparative results between conventional 3D software and VR-Based 3D software.

Using immersive learning and practical VR tools, Guan et al. proposed a VR-based pottery making approach for a technology course, which led to increased student creativity and cognitive engagement. This research improved knowledge of virtual reality's potential for inspiring student innovation and participation in K-12 classrooms [33]. In their 2018 study, scholars investigated the use of VR tools as an alternative to traditional textbook-style learning. The results suggest that VR has the potential to be a viable substitute, with comparable performance levels, increased engagement and positive reception. These benefits may also have a lasting impact on learning, resulting in improved outcomes beyond the initial experience [34].

7.3. Enjoyment

The perceived enjoyment mean for conventional 3D modelling software was 3.5, and for VR-based software it was 4.190. The test showed there is a significant difference in enjoyment factor between 3D modelling software and the VR-based system [Mann–Whitney U = 246.00, Z (67) = −4.248; $p = 0.000$]. Hence, learners enjoyed the VR-based modelling technique more compared to conventional 3D modelling software. According to a recent study, the utilisation of gamification and quest-based techniques within a 3D social VR setting presents exciting opportunities for inter-institutional and interdisciplinary collaboration, which can enhance and differentiate conventional methods of open and distance learning in institutions of higher learning. By incorporating gamified elements, students are more inclined to engage critically and display interest, motivation, and autonomy [35]. It was observed that engaging students with low levels of academic engagement in mathematics through activities using virtual reality can enhance their academic achievement in school. They also found that incorporating virtual reality in education is highly beneficial, as it is more enjoyable, interesting, and fun for students [21].

7.4. Time Consumption

The average time consumed to complete the task using conventional 3D software was 21.12 min whereas for the 3D modelling task using VR-based software it was 18.15 min [Mann–Whitney U = 538.00, Z (67) = −0.493); $p < 0.001$]. We also found significant difference in creating the 3D model between conventional software and VR-based software. Hence, the VR-based system is efficient.

7.5. Acceptance Rating

The mean acceptance rating for conventional 3D modelling software was 2.971, which is lower than VR-based software (4.118). The result showed there is a significant difference in average acceptance rating between 3D modelling software and VR-based software [Mann–Whitney U = 149.500, $Z(67) = -5.840$; $p = 0.001$]. Hence, the VR-based system has more potential than conventional 3D software, as seen in Figure 5 below.

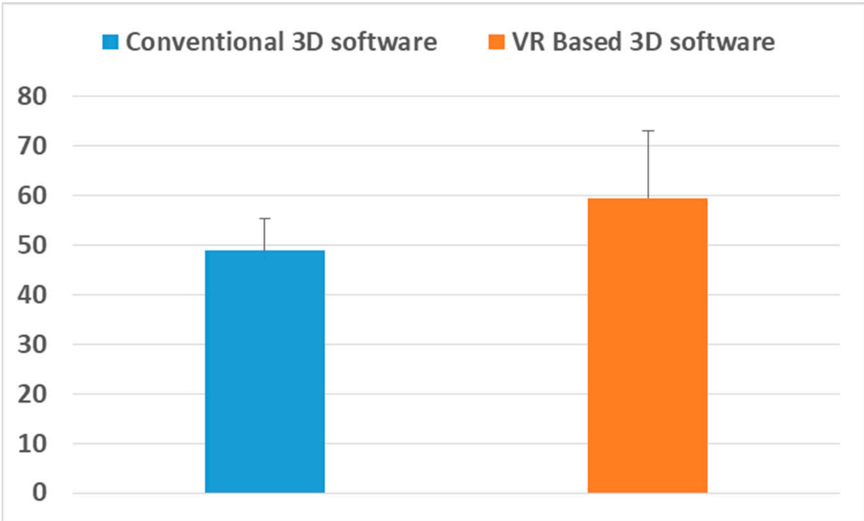


Figure 5. Comparative acceptance rating between conventional 3D software and VR-based software.

Recent research sheds new light on the effect of virtual reality applications on the training and continuing education of nursing personnel. Their study highlighted that individual acceptance determines how far VR applications should be integrated into nursing education [36]. Similarly, in this study, it was found that most of the design students rated higher on the acceptance rating scale. Therefore, they have positive attitude toward the use of VR technology for design learning. Hence, there is a possibility to implement the proposed VR-based 3D modelling tool for design education.

7.6. NASA-TLX Study

There is no statistically significant difference in data between tasks performed in conventional software and tasks performed in VR-based software. [$t(25) = -1.374$; $p = 0.18$]. The mean of the weighted rating of conventional 3D software (48.885) is a little lower than the mean of the average weighted rating of VR-based software (59.453). This shows that the VR-based software is more engaging as the cognitive load was higher [37].

In conclusion, heuristics can provide valuable insights into the application of virtual reality in design education by assessing the effectiveness and efficiency of this approach in assisting students to understand and visualise complex 3D design concepts. The NASA–TLX results indicated that the students perceived that they performed similarly to the experimental group, utilising the same mental and physical abilities [38]. At the end of the experiment, the students in the test group expressed a positive attitude towards the use of VR applications for 3D visualisation. The students ranked the VR tool as highly effective and stated that it has the potential to revolutionise traditional classroom practices.

8. Discussion

The study showed that VR-based 3D modelling software has more engagement and enjoyment and acceptability when compared to conventional 3D software. Few scholars looked into how students could benefit from combining virtual reality (VR) with conventional laboratory work in engineering. They have suggested that VR-based learning environments are beneficial for engineering students. Similarly, we have found in our research that VR-based 3D model-making software will be beneficial for industrial design students and design education [39]. Researchers have looked into the feasibility of incorporating 3D and VR models into Civil Engineering curricula. They discovered an academic study that led to the creation of a virtual reality model for controlling building lighting systems. This model facilitates the visual and interactive dissemination of data regarding the temporal physical behaviour of elements. Thus, students may be persuaded to consider CAD and VR expertise essential to their professional development if they are exposed to these tools in the classroom. Additionally, the research showed how virtual reality can be used to make instructional materials for construction methods [40].

Natural interaction is one of the key features that make a VR-based 3D modelling tool user-friendly and enjoyable. Natural interaction refers to the use of gestures and body movements to manipulate 3D models in a way that feels intuitive and natural. Zhang et al. (2020) have concluded that natural interaction can improve the user experience of 3D modelling tools and reduce cognitive load on users [41]. In the study, the enjoyment level was significantly higher in the case of VR-based tools, as there were more gesture-based and natural interactions implemented in the interface. Hand gestures are an important feature in VR-based 3D modelling tools. They enable learners to interact with the software in a more natural way and can improve the overall user experience. According to a study by Choi et al. (2018), hand gestures can help learners better understand 3D geometry and enhance their spatial perception [42].

An intuitive user interface is crucial for any software application, and VR-based 3D modelling tools are no exception. The interface should be easy to use and should not require learners to spend too much time figuring out how to operate the software. According to a study conducted by Ali et al. (2022), an intuitive user interface in VR-based 3D modelling tools can significantly improve user satisfaction and reduce cognitive load [43]. However, in our study, we obtained opposing results, as the proposed VR-based 3D modelling software had a significantly lower mean ease of use value than traditional 3D modelling software. These kinds of result might be due to lack of awareness concerning the use of the VR-based tool among Indian industrial design students.

Collaboration refers to the capability of multiple users simultaneously working on the same 3D model. Collaboration can improve the user experience by providing users with a more social and interactive experience. In their research, scholars investigated collaborative scenarios in both collocated and distributed settings involving two or more users utilising a virtual reality setup. Their findings indicate that paired users who shared a view outperformed the control group of single users in completing a series of sense-making tasks. The study provides valuable insights for designing collaborative visualisations in a virtual reality environment. It has been concluded that collaboration improved the user experience and reduced cognitive load in VR-based 3D modelling. In the study conducted using VR tools, collaboration has been enhanced [44]. These tools should enable learners to collaborate with each other in real time and share their designs with others. In addition, classical cognitive workload theory says that if there is a higher cognitive load for gamified software usage, there is the possibility of better user experience, and thus, the acceptability of the system [45,46]. The cognitive load of working with basic design objectives in the real world was reduced, and students' engagement with the problem space was increased in a responsive way when using VR, according to a recent study. Additionally, the learning process was made easy, concrete, and enjoyable in the virtual world [47].

In this study, the NASA-TLX score for the VR-based tool was slightly higher because VR-based software is more convenient for 3D model making in terms of ease of use and the fact that it is more immersive, more accessible, more intuitive and has a more natural interaction style. All of these heuristic features made the VR-based 3D modelling software more engaging. The higher engagement level is closely related with higher cognitive load, as reflected in this study. This means that the VR-based system is more engaging. During data analysis, we found that engagement level and cognitive workload are higher in the case of VR-based 3D modelling tools; therefore, it is better when compared to traditional 3D modelling tools. Moreover, in a recent study, it was observed that the users perceived the software as more usable when there is a greater level of physical interaction. Further, the VR medium is multisensory in nature, through which it is possible to achieve better instructional experiences [48]. Researchers looked into what makes 3D modelling in VR easy to use. It is important to investigate the usability, accessibility, and ergonomics of virtual reality 3D modelling for industrial design. For virtual reality to be as effective and efficient as possible, good usability design is crucial. The research pointed to interactivity, dynamic compatibility, and flow effects as the three most important usability factors for 3D modelling in VR [49].

9. Conclusions

In conclusion, conventional 3D software applications and VR-based prototyping tools offer different approaches to 3D visualisation. Conventional 3D software applications provide a wide range of features and functionalities but require significantly more training than the adaptation of VR-based 3D modelling tools. On the other hand, VR-based modelling tools may not provide the same level of precision as traditional 3D modelling software. The 3D VR tool offers an intuitive and immersive way of creating 3D models and visualisations, which can be especially useful for designers and artists who want to quickly create prototypes and concepts. As VR technology continues to evolve, it will be interesting to see how it impacts the field of 3D visualisation and which approach becomes more dominant. A study was conducted to demonstrate that the incorporation of immersive virtual reality in industrial design courses could enhance presentations and simulations. The study aimed to examine the perceptions of students and instructors towards VR technology in industrial design education and concluded that integrating VR into the curriculum could simulate professional practice and revolutionise the design process. These results indicate that VR has significant potential to revolutionise industrial design project processes [50]. Our results also support the possibilities of the application of immersive media for learning of 3D product modelling. Virtual reality in 3D visualisation can help design students overcome the limitations of prototype visualisation and make better design decisions before creating the final physical model. By using virtual reality, students can be certain of the shape and form before creating the final physical model, which results in less material waste and promotes sustainability. In turn, this approach helps to ensure the long-term viability and environmental friendliness of industrial design education. Collaborative features of immersive media extend the concept of receiving feedback beyond geographical boundaries, allowing students from all over the world to connect with faculty members from any location.

The current study explores whether Indian students are reacting to immersive environments for design education in a similar manner as reported by other researchers. We found that virtual reality (VR) has great potential as a teaching tool for the design students because it allows for a more engaging, collaborative, and immersive learning environment, which enables learning possibilities in the hybrid learning mode. It also gives students the freedom to study how and when they prefer. The study design reported here had not been carried out before in a design education context, especially in India.

The outcomes of the water bottle modelling exercise were similar, as presented in Figure 1C. However, we found dimension-assignment-related issues in the case of the VR-based 3D modelling tool, which could be achieved through importing the CAD model (.obj format) into conventional 3D modelling software. More precision dimensioning of the 3D model could be achieved for the proposed tool in the near future.

The cognitive workload was studied with comparatively fewer students due to the limited timeframe of the research project. However, we obtained the correct trend of data as per the literature on cognitive workload theory. The design education in the hybrid online blended mode would give more opportunities to the learners and design faculties. The same study could be conducted further with industrial design faculties. If students use the VR-based 3D modelling software for longer periods at a time, then there is a chance of dizziness [51] and eye-related issues [52], as reported in other studies. These human factors and VR sickness issues could be studied for the proposed VR-based 3D modelling tool in the near future.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/designs7050105/s1, Video S1: Using Conventional 3D Software-Creating Water Bottle-Lowres, Video S2: Using Oculus Quest2 Vr 3D Software-Creating A Water Bottle-Lowres.

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