Developing a VR Tool to Support Repeat Pattern Design Learning

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Abstract. Virtual Reality (VR) applications have been progressively adopted in design industry and education, and are often associated with increased engagement, creativity, and spatial awareness skills. This study investigates the development and use of a bespoke VR application in textiles and fashion design education, designed to support the teaching and learning of repeat pattern design principles and techniques, transposing the limitations of traditional monitor displays and image editor software. Aiming at identifying potential benefits for students and educators, we have surveyed and observed students who explored the application to visualize their design outputs, applying their pattern designs onto real-size virtual objects and environments. Our findings suggests that VR tools have a positive effect in both learning and design process, allowing students to identify design shortcomings and technical issues, as well as fostering self-evaluation and reflection on their work. Moreover, although findings on spatial awareness are inconclusive, they indicate that the use of the VR application to estimate final dimensions of repeat patterns allows students to identify and correct patterns that have been inaccurately designed.

Keywords: XR and Immersive learning · Textiles design · Virtual reality · Higher education

1 Introduction

Immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR) are increasingly being applied to education, training, research, and industry. Potential benefits of visual and spatial capabilities of VR for presenting, representing and simulating have been anticipated for decades as a major transformation in teaching [1]. More recently, the adoption of such technologies in educational settings has been facilitated by a decrease in prices of VR equipment [2], providing benefits such as lower risk levels, lower costs, and accelerated learning within a safe environment where it is possible to experiment and learn through simulation.

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The use of Virtual Reality (VR) in education has been associated with higher level of engagement from students in both STEM and humanities subjects [3,4]. In the case of the School of Design at the University of Leeds, we have identified textile design for interiors and fashion as a potential field of application in which to support students. Although a confident engagement can be readily recognized with Computer Aided Design (CAD), students' understanding of technical space, scale and physical dimensions is often confused by seemingly infinite digital options, particularly for the design challenge of creating repeat pattern. VR is successfully used in diverse sectors of textile and fashion industry [5–7]. With that in mind, this study aims at improving the learning of repeat pattern design through the design and development of a VR tool (Fig. 1) that allows students to preview and apply design outcomes to virtual canvases, objects, and environments before physical prototyping, supporting decision-making in the digital design domain. Our research questions are:

Q1: How does VR visualization impact students' understanding of repeat pattern design principles and technical challenges?
Q2: How do students, educator, and researchers perceive the VR tool in terms of its functionalities and usefulness?
Q3: What are the challenges associated with the in-house development of a VR tool to support pattern design learning?

The remaining of this article is structured as follows: *Background* contextualizes the development and application of the study; *Experiment* describes methods, participants, and stimuli; *Findings and discussion* presents findings and data collected, reflecting on how they addresses our research questions. Finally, *Conclusion* summarizes the study and presents suggestions for further research.

Fig. 1. VR tool in use.

2 Background

Despite the relatively recent emergence of VR as consumer products and increased adoption in the classroom, the exploration of such technologies in textiles and fashion design can be traced back to almost three decades ago [8], and has since then approached a variety of applications, ranging from haptics for sensing textiles textures [9], to cloth simulation for virtual fitting [10], e-commerce and retail [11], and real-size visualization [12]. In architectural design education, VR tools have been associated with better performance and enjoyment from students solving architectural design problems [13]. In fashion design education, they have been used in collaborative creative processes, leading to design outcomes that differ from those obtained from traditional processes [14]. A distinguishing ability for textile designers, and hence a focus of the teaching for the module for which the VR tool was developed, is the ability to create original pattern layouts that work in-repeat for continuous fabric printing. A desirable characteristic for textile products, be they for fashion apparel or Interior soft-furnishing and wallcovering, are that they are designed so the visual effect of the collective pattern elements flow seamlessly without any obvious disruption that might cause an undesired blocky effect, disrupting the intended balance and harmony of the overall composition. Whilst there are numerous textiles design *genera* and infinite aesthetic styles the important taught design principles for repeat layout are primarily locate in scale and color manipulation. A consistent theme in the design-led VR research [15–17] is a positive relationship between immersive technologies and creativity and imagination. Bourdot et al. [18] specifically relate the spatial-awareness students experience in VR with a greater attention to functional appropriateness, while Joundi et al. [19] identify the value Fashion students found in using VR interactive characters compared to real-life static mannequins, as well as an opportunity for an accurate assessment of scale. Lee et al. [20] provide further research to support the advantages of VR design tools in better activating greater physical and perceptual understanding, when compared with 2-D design spaces. Digital design is well-established as an environment for accelerating student experiential learning, the collective aims of the questions in this work are to balance the creative opportunities in VR with purposeful design decision-making. An initial motivation for the present study is, then, providing a tool for students to preview their creations in VR, in a similar way to architectural visualizations VR solutions, aiming at improving their sense of scale and spatial awareness. Regardless of the fact that design patterns are often applied in dimensions as large as 64 cm^2, students often generate image files of their patterns using image editors such as Adobe Photoshop and specialized software such as Nedgraphics, visualized in monitors as small as 13-inch display laptops, therefore usually lacking the means to see them in real size before print. Traditionally, students would produce mock-ups using image editor Adobe Photoshop to preview the application of the patterns they create. In that case, our study aims at providing practice and learning experiences similar to those described by the literature of reference, but having in mind the particular challenges of repeat pattern design.

3 Experiment

Throughout a semester, we invited students from Levels 2 and 3 to preview their design outcomes in a custom-made VR application, collecting information via observation and questionnaires about their interaction with the application, their design outcomes, as well as their attitudes and perceptions towards the application and their own work. Participation was optional and completely voluntary. Results were also informed by the observations from two of the investigators, respectively the instructor for the module and the developer of the application, on their own perceptions about the experiment. The study proposal was approved by the University's Ethics Committee (Ethics reference LTDESN-121). In total, 17 students (Level 2 = 7, Level 3 = 10) out of a total of 24 (Level 2 = 13, Level 3 = 11) participated in at least one of five VR sessions. Methods for data collection included:

1. Pre-visualization questionnaire for collecting students' image files (for patterns and mock-ups); students' satisfaction with mock-ups; verbal description of pattern; suggestions for features in VR tool.
2. Post-visualization questionnaire for collecting dimensions applied to pattern by student in VR visualization; students' satisfaction with pattern; confidence in estimating size and meeting of expectations; reflection on visualized outcome and ideas for improvement; VR tool's comfort, ease of use and learning;
3. Observation on students' use of, and attitudes on, the VR tool; participation in class.

As the experiment took place during the Covid-19 pandemic, all participants received individual silicon face covers for use with the VR headset. Controllers were sanitized with antibacterial wipes before each use.

3.1 The VR Tool

The *VR Patterns* application was developed by one of the researchers, who had previous experience developing games and VR applications, with games engine Unreal Engine 4 (UE4), supported by development sample files provided by Epic Games and Oculus VR headset manufacturer. The tool was compiled as a Windows executable file, and run on a PC linked by USB cable to an Oculus Quest 2 headset.

The application consists of a virtual environment designed as a room measuring 5.2 m × 8 m, featuring the following elements on which students could apply pattern designs: (a) 5.2 m w × 2.6 m h wall; (b) lamp shade; (c) short-sleeved t-shirt; (d) curtains; (e) double bed cover. Those were included to allow students to see their patterns applied to a variety of possible applications (Fig. 2).

Furniture items were created with 3D modeling software Blender, taking in consideration dimensions from real-world products; the t-shirt was exported from fashion modeling software Clo3D; and the wall was created directly in UE4, as part of the virtual environment. All items were texture mapped, either

Fig. 2. Objects and surfaces for pattern application.

manually or programmatically, taking in consideration industry's standard size of patterns for application in textiles. 3D materials were collected or adapted from materials library Quixel and UE4's sample files. Aiming at a natural setting and at minimizing interference with pattern's colors and brightness, the virtual environment's lighting was set to simulate daylight, and to be as uniform as possible across the room.

Interaction with the virtual environment is done through Oculus Quest 2 controller, allowing users to perform the following actions: (a) navigating through the environment using the thumb stick to teleport; (b) opening and closing menu for pattern selection and adjustment using the 'A' button; (c) selecting and applying pattern onto objects, as well as adjusting its dimensions, using the front trigger button to interact with user interface components; (d) capturing high-resolution screenshots using the 'B' button (a functionality added to the prototype throughout the experiment).

Finally, the selection of student-created image files has been facilitated by the use of a repository hosted at Github, where to storage image files, retrievable from within the VR environment through a web browser embedded into the user interface. Image files (in either .jpg or .png format) were collected through the same online forms used for the pre-visualization questionnaire, through which students could upload up to ten image files. Those files were checked, re-formatted if needed, and uploaded to the repository by one of the researchers. Image dimensions were kept at 2048×2048 pixels to increase the efficiency of the application, should it be deployed as a stand-alone Android-based application for the Oculus platform.

3.2 Teaching Space and Schedule

On the days when *VR Pattern* was used in class, teaching sessions were structured as follows: one hour for use of the VR tool in the morning, followed by two hours of studio practice. In the afternoon, the VR tool would be available for an additional hour. VR equipment and computer running the application were located in a room adjacent to the studio where studio practice took place.

4 Findings and Discussion

Despite limited scope and duration of the experiment, study findings provided valuable insight on research questions proposed. Throughout the next subsections, we present and reflect on those findings, and how they might inform subsequent studies, experiments, and further development of the VR tool.

4.1 Impact on Learning

Three main aspects of the learning experience seemed to have been supported and reinforced by the use of the VR tool. First, educators have noticed an *increased awareness of design principles*, as students who had used the VR tool have later demonstrated a higher degree of awareness regarding repeat and scale in class, actively asking about design principles and industry standards for repeat pattern design. Post-evaluation questionnaires and ad-hoc discussions in the VR studio also reflected an acquired sense of attention to those principles, particularly the need for seamless borders in a repeat design image file. A Level 2 student (P17) noticed that her design was, in her words, 'not a repeat', as seams could be seen in the application of her pattern onto a VR object (Fig. 3). In that sense, we observe that the VR tool would have worked as a safety net for students who failed to identify such issues when using image editors, before sending it for evaluation or production.

Fig. 3. Incorrect application of pattern caused by non-matching edges

Second, the VR tool has fostered the *identification of technical issues*. Unlike the previous case, those were not related to a lack of awareness to design principles, but glitches accidentally originated from a lack of precision when the creating the image, or artifacts generated when the image file is exported. Identifying those issues allowed students to correct them. '[In] design 1, the scale was off leaving an obvious line after each repeat, this has now hopefully been fixed', wrote P9, a Level 3 student, prompted by the questionnaire to describe improvements made to an image file previously visualized in VR. (Fig. 4). As in the previous case, learners would benefit from the VR tool as an environment where to detect those issues.

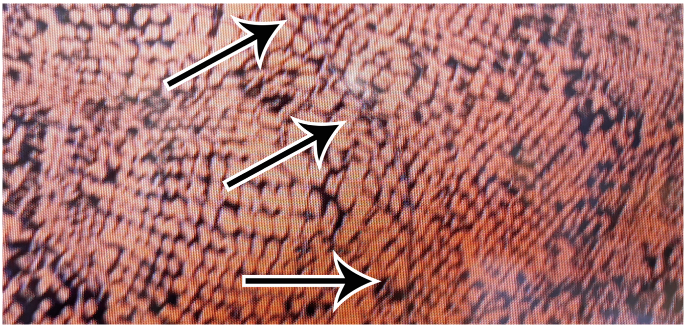

Fig. 4. Visible glitch in repeat pattern design, unnoticed during design in image editor, made evident through VR visualization.

Finally, the VR tool seemed to have a positive impact on students' *evaluation and reflection on their own design outcomes*. Indeed, previewing their design outcomes has allowed them to consider changes in both appearance and applications of the patterns they create. Take, for instance, this answer from a Level 3 student, on whether they considered changing their design after seeing it applied in VR:

> I think i will add more motifs to the design so that it has more movement, using VR helped me to see that the use of colour and composition isn't very balanced - which is something i will improve on. (P5)

Two weeks later, the participant had created a new pattern that attempted to address those points, resulting in a more balanced composition (Fig. 5).

In some cases, insights gained from interaction with VR resulted in better fabric print samples. Questioned about their thoughts on their design and possible further modifications, a Level 3 student wrote:

> Applying my design to VR has led me to think i want to increase the scale of my design, I also want to increase the contrast between hues for a more striking design. (P7)

Fig. 5. Original pattern (left) and a second version (right) - an attempt at increasing a sense of balance and movement.

In that particular case, the lack of contrast suggested by the VR visualization was later observed in a fabric print sample of that same pattern. The participant, then, made changes to the design, before visualizing it in a subsequent VR session (Fig. 6).

Fig. 6. Changes following VR preview: increase in image/background contrast. Initial lack of contrast was also noticeable in print output.

4.2 Considerations on Scale and Spatial Awareness

Given the initial motivation for this study —and the role physical dimensions plays in repeat pattern design —we proposed the following challenge to students using the application: *Apply the pattern you have designed in the scale you believe to be correct*. Participants would then use a slider in the user interface to scale the pattern to any dimension between 20 cm^2 to 200 cm^2, ideally aiming at the standard 64 cm^2. During the operation, students were able to see the pattern being re-sized in real time on VR objects and surfaces, but would not know the actual measurement until after confirming their choices. At the point, they would be able to revert its size to 64 cm^2. Data collected from 16 participants indicates that, out of 33 attempts, only 6 were scaled within a 25% margin of the standard size. On the other hand, 10 attempts were scaled at 200% or higher (Fig. 7). Although, at first sight, those results suggest a general lack of scale awareness from students, a closer look might reveal other possible explanations.

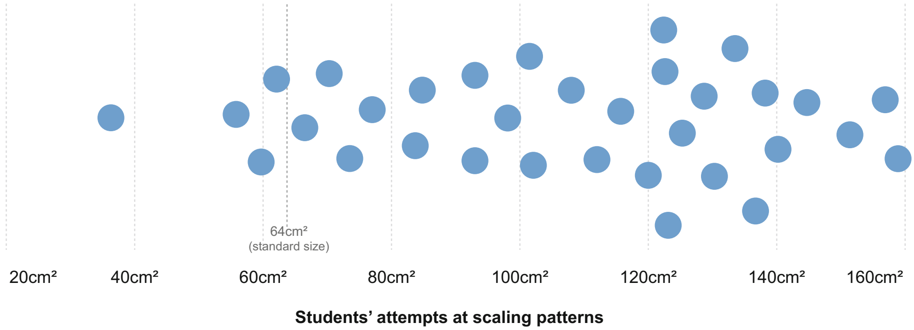

Fig. 7. Dimensions of pattern applied by participants, usually much larger than 64 × 64 cm industry standard.

First, the over-sized application of patters could reflect a desire to see details made imperceptible by *technical limitations* such as the headset's displays resolution (1832 × 1920 pixels), or recommended texture image resolution (2048 × 2048 pixels), and which could be possibly addressed by either the increase of texture image files' resolution or, if needed, the acquisition of higher-end headsets. However, only one participant expressed an opinion suggesting that 'the texture is unclear' (P17). Indeed, in that particular case, the texture looked blurry. However, that could be partially attributed to (a) image compression artifacts over fine line drawing, and (b) sub-optimal use of the image's area (Fig. 8), which suggests a second reason for the number of over-sized applications: the *unintended and/or unnecessary repetition of patterns within the image file*, when students include more than one instance of the repeat tile in their image files. In those cases, a single repeat would be more adequate for the design they have envisioned (Fig. 9).

Cases like the aforementioned ones suggest that students often need to see the repetition taking place within their image files, in order to visualize its application. In that case, other strategies for previewing the repetition (using image editor or otherwise) should be reinforced. It also suggests some students were expecting their patterns to look bigger when applied in the standard size. Indeed some students expressed that verbally, when asked of changes they would like to make to their designs, post-VR experience:

> Increasing the scale - my intention was to have larger motifs. (P4)

> As the VR mocked up my design in such a small scale, this made me want my final outcome to have a larger scale. (P8)

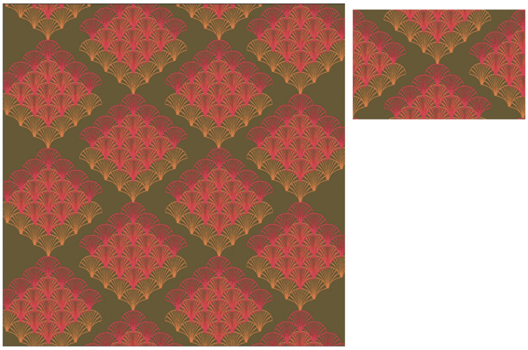

Fig. 8. Actual repeat pattern (right) would occupy approximately 16% of the area of the original image file

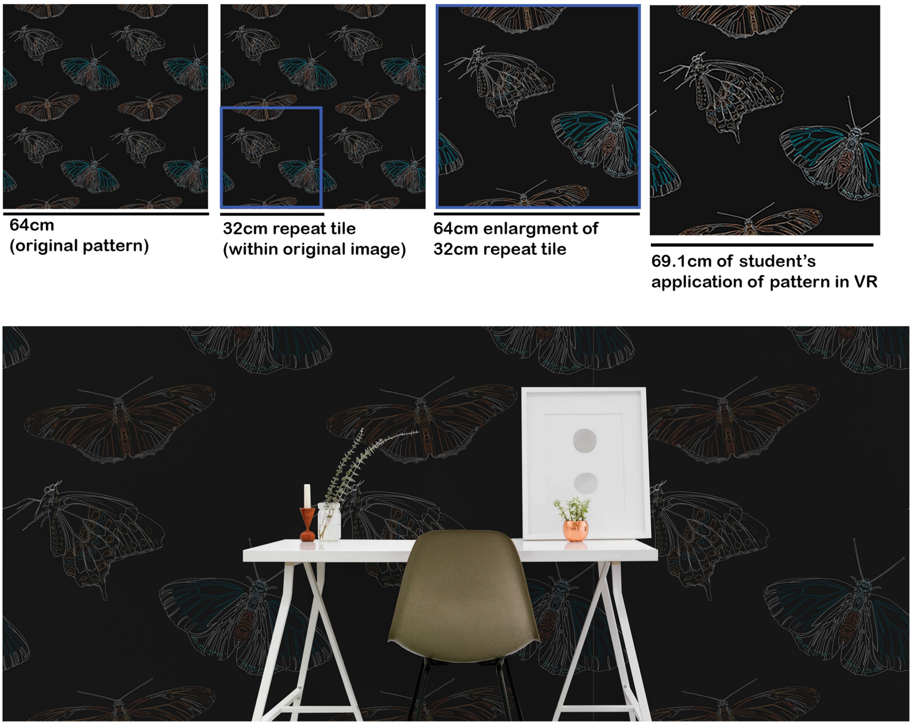

Fig. 9. Top: almost twice the standard size of 64 cm^2, student's size estimation would be closer to accurate if considering a single repeat tile only. Bottom: mock-up created by student before application in VR suggests a single repeat tile would have been the best approach to achieve the student's vision.

In fact, repeat tile for the patterns created by P4 and P8 occupied 70% and 50% of their respective image files. Moreover, as we observe a high concentration of attempts between 120 and 140 cm^2, i.e., roughly twice the standard size, we are drawn to the fact that 10 out of 11 of those attempts used image files where repeat tile appears twice horizontally and vertically (Fig. 10). In those cases, students' estimate would have been very close to accurate, as repeat tiles actually occupy an area close to 64 cm^2.

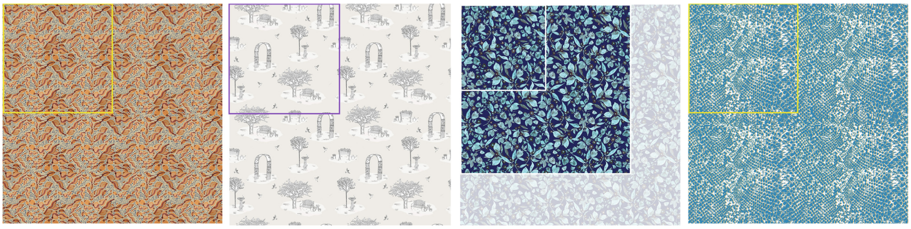

Fig. 10. Sample of image files that have been applied by participants at roughly twice the standard size. Inner squares highlight repeat tile within image.

Whereas enlarging patterns usually suggest an attempt to decrease the number of repeat tiles, making repetition less evident, in cases where there is a considerable amount of variation and detail, larger sizes would make those details more visible. Although more research on size estimation and awareness would be necessary to elucidate the points raised, this study suggests that students are often successful estimating the area their patterns would cover, but not so successful in understanding how their image files should be prepared to achieve that result.

4.3 Perceptions on the VR Tool

Students generally had an enthusiastic attitude towards the VR tool. Regarding its *usability*, the majority of surveyed participants (p = 12) perceived it as easy to use, easy to learn, and comfortable to use (Fig. 11). That assessment, however, contrasts with their frequent need to be remembered how to operate it, as well as with individual remarks. This suggests their previous lack of familiarity with VR tools has (a) prevented them to compare the tool to better realized VR applications, and (b) their enthusiasm has compensated for the tool's deficiencies. Moreover, it could suggest that students might have retrained themselves, holding back negative comments on the researchers and educators' work. In any case, an evaluative usability testing of the tool would be better suited for future iterations of the tool, rather than the initial prototype described in this study.

Students have also expressed their views on the *usefulness* of the VR tool, which mostly reflected the benefits previously discussed on their learning. In that sense, identifying technical problems and design shortcomings seemed useful.

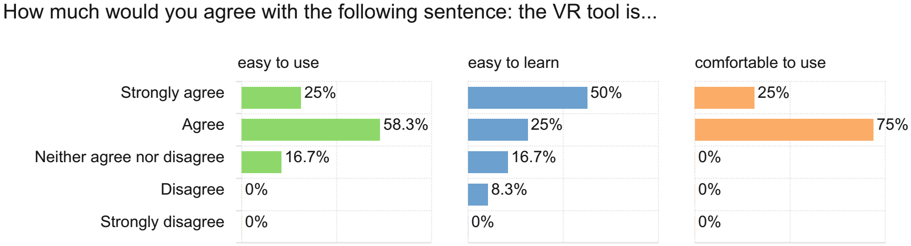

Fig. 11. Users' perceptions of tool's ease of use, learning, and comfort.

> I found that using the VR tool helped me to see the design in a bigger context which highlighted some of the faults with the repeat that i hadn't noticed before (P5).

The tool was also considered useful by students for providing a way of observing and reflecting on their creative work:

> (The VR experience) made me think about scale when i design on Photoshop and the impact of colors in a room. (P9)

In some cases, students also emphasized creative possibilities and a sense of experimentation and new insights.

> I designed (this pattern) originally for wallpaper, but i think it looks better on an object such as the lamp. (P17)

The use of the VR tool to preview the application of patterns was favorably compared by students to the production of mock-ups using image editor Adobe Photoshop (Fig. 12). In fact, some of the students used high-resolution screen captures taken from the VR tool to include in their portfolios for the module's assessment.

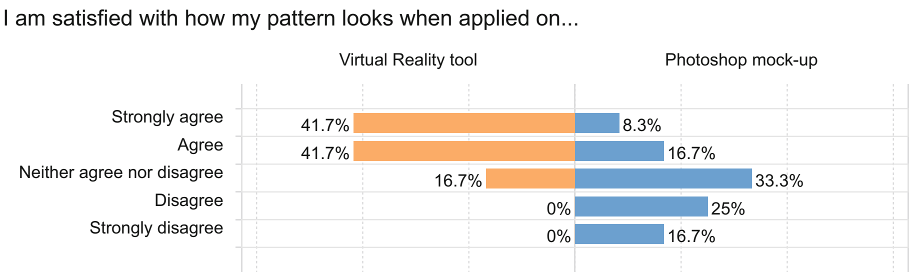

Fig. 12. Comparison of students' satisfaction with the application of their pattern using photoshop and VR environment.

Invited to express their opinions and give suggestions, students pointed out features and functionalities they would like to see implemented, many of which we plan to incorporate in subsequent versions of the tool. Those are: greater variety of objects and garments; greater variety of materials and textiles; testing multiple patterns at once; cloth simulation; better visualization for fashion items; additional environments and improved lighting and shading.

Finally, regarding the perspective of educators and researchers, it is fair to say the focus was shifted from improving students' spatial awareness —this study's initial motivation —to gaining clearer insight on how students understand, plan and execute, their repeat pattern designs. In that sense, the observation of students in their use of the VR tool was valuable, allowing educators to evaluate which aspects of repeat pattern design, from principles to techniques, might need to be reinforced in class.

4.4 Development Challenges and Opportunities

In recent years, the development of Virtual Reality application has been facilitated by real-time 3D game engines with VR capabilities that allow small teams, or even individuals, to engage in the production of this type of software. The in-house development of *VR Patterns*, prototyped by one of the authors, faced challenges that could be described as specific to work in higher-education institutions. Those were:

- **Limited time and flexibility for development and testing:** given the limited number of classes in a semester, and lack of flexibility in rescheduling them, significant modifications to a prototype could need to wait for a subsequent semester to be implemented.
- **Additional technical constraints:** in the case of *VR Patterns*, restrictions in wireless connectivity, possibly related to increased security settings, prevented the wireless connection between the VR headset and PC, in which case a USB cable had to be used.

On the other hand, we have identified opportunities within the academic environment that might help addressing those issues:

- **Close integration between teaching and tool development:** Continuous access to students and educators provide an excellent environment for a continuous development process informed by actual users, having in mind the improvement of current features, as well as the identification of desirable functionalities.
- **Expansion to other modules and programmes:** Outcomes from this study could help attracting new partners and collaborators across the department to help develop and test the application further, particularly those involved in fashion, graphics, product, graphic, and digital and interaction design.

5 Conclusion

This paper described the development and exploration of a Virtual Reality tool to support the teaching and learning of repeat pattern design in higher education. Overall, the use of the VR tool has influenced design outcomes in positive ways, accelerating student awareness on matters of repeat and scale. Initial results suggest students become more focused on the production of outcomes after interacting with the tool, occasionally diagnosing technical problems as well as identifying points for improvement in their design, such as balance, contrast, and use of color in their compositions. As an additional benefit, the tool made possible the identification of issues before print, allowing for corrections to take place before final execution. The VR tool was, overall, well-received by students. Although there was no conclusive evidence on benefits to increased spatial awareness, findings suggest that students can estimate the dimensions of design patterns more accurately and intuitively through the VR tool than through canvases of image editors, in which case the former could be used to support and inform the student's work on the latter.

The outcome and application of students' work in VR was helpful informing educators on design principles and technical information that needed to be reinforced, providing an overview of students' understanding of those. In that sense, having the VR application to inform and support those discussions had a positive, unexpected impact, beyond its use for real-size representation of student work and the training of their abilities in accurately estimating design output dimensions. Further development is recommended for implementation of features such as new virtual materials, objects and environments, ideally being informed by a co-design process involving students, developers, and educators.

Despite limitations in application and sampling, and challenges in development caused by time and infrastructure constraints, results of this study could be useful for educators involved with in-house production of VR tools for education and industry, particularly those related to textiles, fashion, and graphic design.

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