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Research article

# The impact of three-dimensional visualisation on midwifery student learning, compared with traditional education for teaching the third stage of labour: A pilot randomised controlled trial

Michelle Gray [a,c,*], Terri Downer [b], Donna Hartz [a], Patrea Andersen [b,d], Julie Hanson [b], Yu Gao [a]

[a] College of Nursing and Midwifery, Charles Darwin University, Darwin, Northern Territory, Australia
[b] School of Nursing, Midwifery and Paramedicine, University of the Sunshine Coast, Queensland, Australia
[c] School of Nursing and Midwifery, Edith Cowan University, Western Australia, Australia
[d] Centre for Health and Social Practice, Waikato Institute of Technology, Hamilton, New Zealand

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ABSTRACT

*Background:* Complex physiological processes are often difficult for midwifery students to comprehend when using traditional teaching and learning approaches. Face to face instructional workshops using simulation have had some impact on improving understanding. However, in the 21st century new technologies offer the opportunity to provide alternative learning approaches.
*Aim:* To investigate the impact of using three-dimensional (3D) visualisation in midwifery education on student's experience of learning, and retention of knowledge at three points in time.
*Design:* A pilot study involving a two-armed parallel Randomised Controlled Trial (RCT) comparing the retention of knowledge scores between the control and intervention groups.
*Setting:* An Australian University in the Northern Territory.
*Participants:* The sample included second year Bachelor of Midwifery students ($n = 38$). All received traditional midwifery education before being randomly allocated to either the intervention ($n = 20$) or control ($n = 18$) group.
*Methods:* A new immersive virtual environment was introduced to complement existing traditional midwifery education on the third stage of labour. This intervention was evaluated using a demographic survey and multiple-choice questionnaire to collect baseline information via Qualtrics. To measure change in knowledge and comprehension, participants completed the same multiple-choice knowledge questionnaire at three time points; pre, immediately post and at 1 month post intervention. In addition, the intervention group completed a 3D student satisfaction survey.
*Results:* Baseline knowledge scores were similar between the groups. A statistically significant increase in knowledge score was evident immediately post intervention for the intervention group, however there was no significant difference in knowledge score at one month.
*Conclusions:* The results support the creation of further three-dimensional visualisation teaching resources for midwifery education. However, a larger randomised controlled study is needed to seek generalisation of these findings to confirm enhanced student learning and retention of knowledge post 3DMVR, beyond the immediate exposure time.

## 1. Introduction

The introduction of anatomy and physiology in the first year of midwifery education is crucial in providing foundational knowledge from which subsequent learning is scaffolded. This enables midwifery students to develop understanding of the anatomy and physiology of the reproductive system and physiology of childbirth. The third stage of labour is the period after the birth of the baby when the uterus contracts to expel the placenta and membranes. This is taught both theoretically and as a clinical skill to midwifery students (De-Vitry, 2019).

* Corresponding author at: College of Nursing and Midwifery, Charles Darwin University, Darwin, Northern Territory, Australia.
*E-mail address:* michelle.gray@ecu.edu.au (M. Gray).

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An essential part of midwifery education is to facilitate the linking of theoretical principles to practice however, conceptual understanding of normal physiological events is inhibited by the inability to visualise body functions. Misconceptions about physiological phenomena are often difficult to address from reading and observing two dimensional images in textbooks (Breitkreuz et al., 2021; Hanson et al., 2019). Events such as physiological involution of the uterus are impossible to recreate through analogies of the mechanics of the myometrial muscles contracting upon blood vessels to stem haemorrhage. Advances in Information and Communications Technologies (ICT) offer an opportunity to explore innovative pedagogical solutions to help students develop these skills in a safe environment (Volejnikova et al., 2021).

The use of virtual reality (VR) technology has the potential to enhance teaching and learning in midwifery education. According to Lee et al. (2010) it is the characteristics of VR that allows for complex and multifactorial subject matter to be more easily represented. Reification is one such characteristic and is particularly useful in learning abstract concepts. Learning abstract scientific concepts is a foundation of midwifery knowledge. Through reification one -dimensional representations can be transformed, or resized, into visualisations that allow students to enter inside the human body and see not only structure but also the functioning of a human cell for example (Mikropoulos and Natsis, 2011).

### 1.1. Background

Online innovative eLearning technologies can provide a complementary addition to the suite of blended learning resources used to teach undergraduate nursing and midwifery curriculum (Volejnikova et al., 2021). Ewens et al. (2016) acknowledge that virtual environments 'offer students an authentic learning experience, which complements and builds upon their clinical practice and classroom experiences' (p. 82). However, despite the current 21st century passion for using online technologies to teach healthcare students, midwifery educators have been slow to adopt eLearning resources in undergraduate midwifery education, thus there is limited research literature reporting their use (Downer et al., 2020). Where eLearning has been embraced within midwifery curriculum, this has often been in the form of virtual reality simulations to teach neonatal resuscitation (Williams et al., 2018) or, 'Second life' simulation for teaching the management of haemorrhage (Honey et al., 2009, p. 1222).

In a literature review spanning over 10 years, Ghanbarzadeh et al. (2014) found that virtual worlds serve an important pedagogical benefit in the application of knowledge and the development of new ways of thinking. Immersing healthcare students in environments where avatars are used as patients can have the benefit of facilitating problem solving without the risk of causing danger to patients (Ghanbarzadeh et al., 2014; Chan et al., 2021). Of the 62 papers reviewed by Ghanbarzadeh et al. (2014), only one addressed midwifery education. This focused on the management of post-partum haemorrhage, and used second life simulation (Honey et al., 2009). Since Ghanbarzadeh et al.'s review, Williams et al. (2018) have created a virtual reality (VR) learning resource which supports users to practice neonatal resuscitation in a virtual environment wearing a headset, while this can be used by midwives it is also targeted at other practitioners that need be competent in this skill. Virtual simulation resources created to teach midwifery-specific content are scarce.

Virtual environments have been reported suitable for online learning with the online format increasing student access to learning activities (Chan et al., 2021). Multiple students can simultaneously access online learning at locations around the world with no requirement for lecturer presence after the initial set up (King et al., 2018; Chan et al., 2021). Research is emerging that evaluates knowledge acquisition and satisfaction of nursing and midwifery student learning using new technologies (Breitkreuz et al., 2021; Chan et al., 2021; Hanson et al., 2019). Visualisation technology is reported to enhance teaching and learning approaches to science-based concepts by making use of pedagogical strategies that can stimulate more senses, especially sight and sound (Hanson et al., 2020). A disadvantage of innovative teaching technology is cost and access with issues of equity being raised where large universities with multisite campuses are unable to replicate resourcing (Hanson et al., 2019). Three-dimensional (3D) visualisation using a handheld device that provide viewing of structures with stereoscopic lenses has been reported to offer a complementary low-cost approach that mitigates inequitable access to technology-based learning by using personal devices such as mobile phones (Hanson et al., 2020).

To address the dearth of new technology in midwifery specific teaching resources a new 3D midwifery visualisation resource (3DMVR) was created to teach midwifery students the physiological process inherent in the third stage of labour. The 3D artefact was developed by the Visualisation Development Team at the University of the Sunshine Coast under the guidance of midwifery experts (Gray et al., 2018). The 3DMVR illustrates the internal environment of the uterus and the physiological process of separation of the placenta and membranes and haemostasis. This innovative education resource was initially developed as a 3D Cave Automatic Virtual Environment (CAVE™) artefact. CAVE2™ accommodates up to 20 people. Once inside students observe the 3D visualisation through 3D glasses while the tutor provides instruction on the complex concepts being taught. A preliminary evaluation by Downer et al. (2020) reported that the resource was suitable for midwifery students. However, further research was needed to ascertain the potential value of this cutting-edge technology for teaching and learning in midwifery.

For this project the original 3DMVR CAVE™ version was modified so that it was viewable on a personal handheld mobile device. A pre-recorded narration explaining the physiological sequence was added to direct the student's attention to the points of interest and immerse the learner in the subject matter. Providing instruction to direct the student's gaze increases engagement with the learning materials, and ability to absorb the intended information it also increases cognitive retention (Bailenson et al., 2008; Bowen and Watson, 2017).

Research is needed to evaluate and substantiate 3D immersive visualisation as an effective means to engage students in their studies and to improve measurable learning outcomes (Downer et al., 2020). To date there has been little examination of the impact of 3D immersive visualisation on knowledge retention in midwifery education.

### 1.2. The research aims

The aim of this pilot study was two-fold; first to establish if there were any differences in student's knowledge from multiple choice questionnaire (MCQ) scores between students exposed to an educational supplementary 3DMVR via a hand-held device, compared to the scores of students who receive traditional education methods only. Second, to assess the satisfaction and comfort ratings scores for students exposed to the 3DMVR.

### 1.3. Research questions

1. What are the differences in student MCQ test scores between students exposed to a) traditional teaching only, and b) traditional teaching followed by 3DMVR?
2. What are the differences in satisfaction ratings and self-assessed comfort scores of students exposed to the 3D midwifery visualisation resource (3DMVR)?

The null hypothesis was that there is no difference in the test scores between students exposed to a) traditional teaching only and b) traditional teaching followed by 3DMVR.

## 2. Methodology

This pilot study employed a parallel two-armed randomised controlled design to compare acquisition and retention of knowledge of the third stage of labour. Participants were randomly assigned to an intervention or a control group to examine any difference in knowledge at three times points; before their mandatory pre-semester clinical teaching block (CTB), immediately after the CTB intervention and one month later.

### 2.1. Ethical approval

Ethical approval was granted: H19086.

### 2.2. The sample

The sample consisted of midwifery students in their second year of a Bachelor of Midwifery at an Australian university. To be eligible to participate students must have been attending the second-year pre-semester CTB in preparation for their clinical practice placement.

### 2.3. Recruitment

In February 2020, all second-year students ($n = 80$) were invited to participate in the study. A sample size of approximately 35 students in each arm was speculated to have more than 80% power to detect at least 10% score difference between intervention and control group, assuming a two-sided, type 1 error of 0.05, traditional deviation of 4, and auto-correlation of 0.8.

A recruitment flyer was sent to student's university email account. Interested students emailed the lead investigator who replied with an information sheet and consent form prior to their pre semester CTB.

### 2.4. Randomisation

In March 2020 consenting students were randomly assigned to the control group or intervention group using a computer-generated block randomisation table (Research Randomizer, 2020). Names were entered in the order of consent was received. Participants did not know which group they were allocated to until after they had received their scheduled education. Fig. 1: 3DMVR pilot RCT flow diagram shows participation numbers at each point of data collection.

### 2.5. Data collection procedure

All participants completed a demographic survey and MCQ to establish baseline knowledge.

#### 2.5.1. The control group: traditional teaching

After their scheduled education the control group remained in the original teaching space to complete the post MCQ. Participants were invited to complete the MCQ one month later.

#### 2.5.2. The intervention group: the 3D midwifery visualisation resource (3DMVR)

After their scheduled education, the intervention group was shown to another room. A link to the pre-recorded narrated 3DMVR (https://www.youtube.com/watch?v=_pDW4rcRFsE) was sent to their

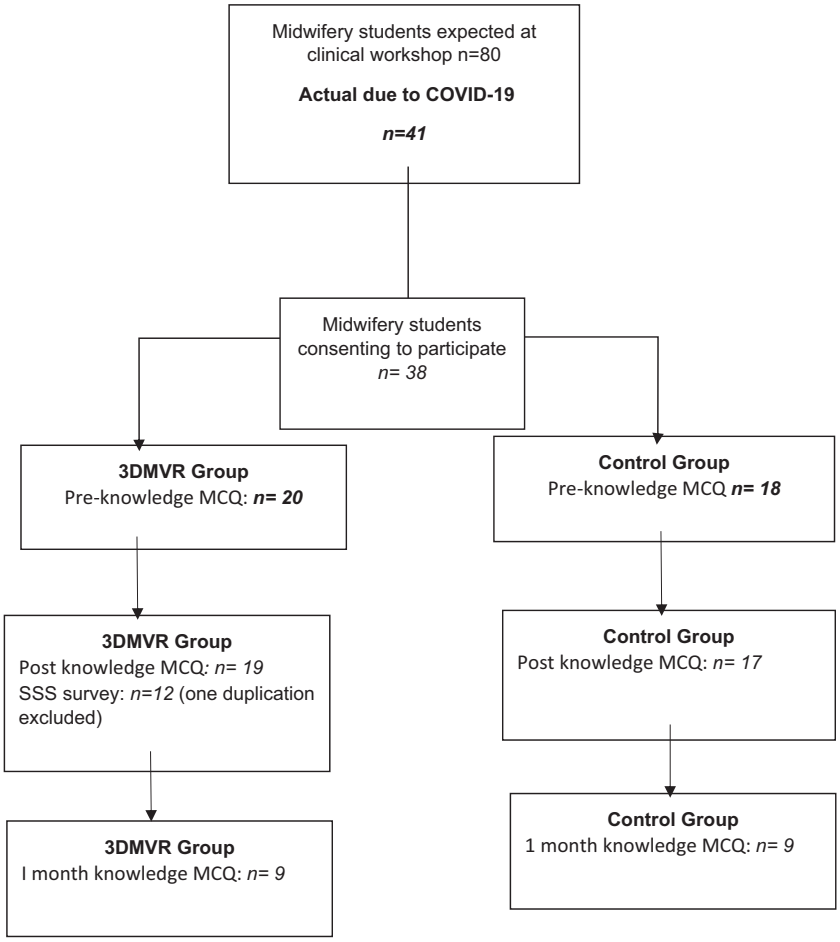


**Fig. 1.** A flow diagram illustrating the random allocation of the sample and data collection.

mobile phone via Qualtrics. The students wore 3D glasses (stereoscopic lenses) attached to their mobile phone (Fig. 2). Earpieces were used for audio. All students were advised to watch the 3DMVR seated, as the literature suggests a potential risk of cyber sickness with the use of virtual environments for users who are particularly affected by postural changes (Risi and Palmisano, 2019).

The visualisation resource displayed close-up images of the internal anatomy and physiology of the uterus (Fig. 3), and the process of achieving haemostasis to prevent haemorrhage, after the birth of the placenta and membranes.

After watching the 3DMVR participants completed the post MCQ. Participants were invited to complete the MCQ one month later.

### 2.6. Data collection tools

#### 2.6.1. Demographic survey

All consenting students completed a demographics survey in Qualtrics at the start of the pre-semester CTB.

#### 2.6.2. Multiple choice questionnaire (MCQ)

The purpose-built questionnaire contained 30 questions created by a team of midwifery academics and its suitability was verified through internal and external consultation. Final validation was confirmed with a group ($n = 5$) of third year students at a university not involved in the study.

The MCQ was completed by all participants before commencement of the subject content on the third stage of labour, immediately post education, and at one-month later. The initial scores were used as a baseline marker from which to measure any change in scores, thus results were not shared with students.

#### 2.6.3. Student satisfaction with 3D Midwifery Visualisation Resource Scale

This survey contained 17 statements which asked the students to rank their perceptions about their 3D learning experience, ease of use, and comfort using a 5-point Likert scale. This survey was sent to the intervention group immediately after they had watched the 3DMVR. Four open ended questions ascertained perceptions of influence on learning, and any advantages or disadvantages.

### 2.7. Analysis

The baseline demographics are presented descriptively, and Chi squared tests of association explored differences between the groups. Categorical variables were used to compare the baseline demographics and knowledge score differences at each time point between the intervention and control groups. A generalised linear mixed-model repeated measures analysis was used to investigate the differences in mean knowledge score prior to, immediate post, and one month post the intervention.

Student satisfaction categorical variables were presented as a number and percentage. All analysis was performed in Stata 16 (STATA, 2020).

## 3. Results

Of the expected 80 students enrolled in the unit, only 41 students attended the workshop due to travel restrictions enforced during the COVID 19 pandemic, 38 students consented to participate and were randomly allocated into either the intervention ($n = 20$) or control ($n = 18$) group. The randomised groups for the pilot RCT were well balanced as a result of the computerised randomisation allocation with no statistically significant differences for any of the baseline characteristics (Table 1).

### 3.1. Multiple choice questionnaire knowledge scores

There was no significant difference in the pre knowledge MCQ scores between the groups. Despite the small number of students participating in this pilot study during the Covid 19 pandemic, a statistical difference in the immediate post MCQ (Table 2) within the intervention group who had a significantly higher score of 4.9 points compared to the control group. A sustained higher knowledge score at one-month was not significantly different (see Table 2 and Fig. 4).

Table 2 illustrates the MCQ knowledge scores at three time points between the intervention (3DMVR) and control groups.

Fig. 4 illustrates the multi-level model controlling for clustering effect for the repeated knowledge score measures over the three time points between the groups. Multi-level model controlling for clustering effects for the repeated knowledge score measures over three time points between the groups also demonstrated that there was a significant difference only at the immediate post CTB time point. While the mean and median knowledge scores remained higher for the control group at one month post CTB this was not significantly different (see Fig. 4).

### 3.2. Student satisfaction with 3D Midwifery Visualisation Scale Survey

Twelve students completed the Student Satisfaction with 3DMVR Survey immediately post intervention. One participant was removed from the data set as they had completed the survey twice.

While 92% of participants found the instructions for using the 3DMVR simple and easy to use, technical issues accessing the 3DMVR was initially problematic with 67% requiring assistance. Half found that

**Fig. 2.** Stereoscopic lenses and mobile phone set up for viewing the 3DMVR visualisation.

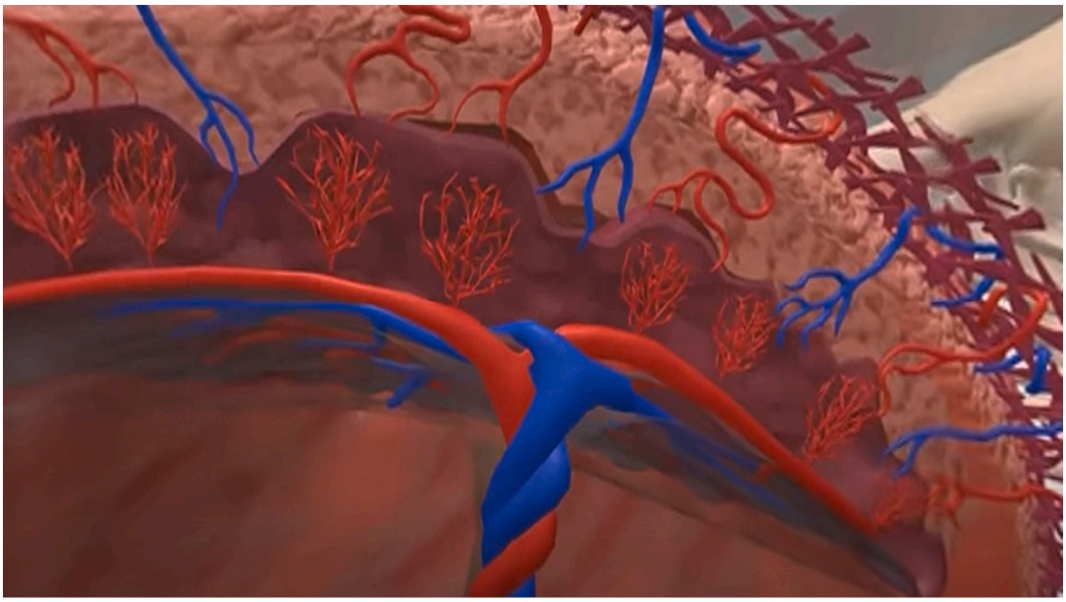

**Fig. 3.** Close up view of the maternal placenta intervillous space.
Images taken from: https://www.youtube.com/watch?v=LvG7i5HbdSE&feature=youtu.be.

**Table 1**
Baseline characteristics of the students who participated in the first survey.

| Factor | Control | Intervention | *p*-Value |
|---|---|---|---|
| *n* | *n* = 18 | *n* = 20 | |
| Gender | | | |
| Female | 18 (100%) | 20 (100%) | |
| Please identify your age range | | | 0.99 |
| 20–29 | 7 (39%) | 7 (35%) | |
| 30–39 | 9 (50%) | 11 (55%) | |
| 40–49 | 1 (6%) | 1 (5%) | |
| 50–59 | 1 (6%) | 1 (5%) | |
| What is your previous highest level of education? | | | 0.91 |
| Master Degree | 2 (11%) | 1 (5%) | |
| Post Graduate Diploma | 1 (6%) | 1 (5%) | |
| Bachelor Degree | 5 (28%) | 9 (45%) | |
| Certificate | 3 (17%) | 3 (15%) | |
| Completion of Year 12 high school | 5 (28%) | 4 (20%) | |
| Completion of the tertiary preparation pathway | 2 (11%) | 2 (10%) | |
| Are you studying full time or part time? | | | 0.91 |
| Full time | 12 (67%) | 13 (65%) | |
| Part time | 6 (33%) | 7 (35%) | |
| Have you attended a birth and witnessed the third stage of labour? | | | 0.84 |
| Yes | 14 (78%) | 15 (75%) | |
| No | 4 (22%) | 5 (25%) | |
| Did you complete the recommended pre-reading? | | | 0.34 |
| Yes, all of the readings recommended | 4 (22%) | 4 (20%) | |
| Some of the readings recommended | 5 (28%) | 10 (50%) | |
| No, not yet | 9 (50%) | 6 (30%) | |
| Do you associate yourself with any of the following groups of students? | | | 0.40 |
| Aboriginal | 0 (0%) | 1 (5%) | |
| International student | 0 (0%) | 1 (5%) | |
| First in the family to attend university | 1 (6%) | 4 (20%) | |
| Living in a rural or remote area | 5 (28%) | 3 (15%) | |
| Studying while caring for dependents | 6 (33%) | 8 (40%) | |
| Experience challenges with learning new materials | 1 (6%) | 0 (0%) | |
| None of the above | 5 (28%) | 3 (15%) | |

**Table 2**
MCQ knowledge scores at three time points for the intervention (3DMVR) and control groups.

| MCQ time point | 3DMVR group | Control group | *p* value |
|---|---|---|---|
| Pre- commencement knowledge | *n* = 20 | *n* = 18 | |
| Mean score (sd) | 17.8 (2.7) | 18.7 (2.9) | 0.29 |
| Median Score (IQR) | 17.5 (16.0, 19.5) | 19.0 (17.0, 20.0) | 0.28 |
| Post CTB knowledge | *n* = 19 | *n* = 17 | |
| Mean score (sd) | 23.0 (20.0, 25.0) | 18.4 (2.6) | <0.001* |
| Median score (IQR) | 22.3 (3.0) | 18.0 (16.0, 20.0) | <0.001* |
| One month post CTB knowledge | *n* = 9 | *n* = 9 | |
| Mean score (sd) | 21.2 (3.5) | 19.4 (4.2) | 0.34 |
| Median score (IQR) | 22.0 (18.0, 24.0) | 18.0 (16.0, 22.0) | 0.37 |

CTB: clinical teaching block.
* $p < 0.05$ is significant.

the 3D stereoscopic lenses fitted their mobile device and worked well.

All (100%) participants claimed that the audio function using earpiece worked well, and that the narration helped them to understand the physiological process and where complications could occur. Ninety two percent (92%) agreed that the 3DMVR helped them conceptualise 2D illustrations in textbooks and 65% believed the artefact helped them apply pre-readings to physiological events. Further, 75% percent of participants agreed that using the 3DMVR improved their understanding of the anatomy and location of the uterus, placenta, and membranes, 83% indicated that use of the 3DMVR increased their understanding of physiology and circulation of blood between the placenta and maternal circulation including the intervillous space.

Fifty percent (50%) of participants disagreed that 'the use of technology made me feel nauseated or unwell'. Of the remaining half, 17% were unsure and 33% confirmed physical effects. These were later reported in opened end questions as feeling dizzy or eyes having to adjust to the 3D environment. Table 3 summarises the findings of the Likert section of the Student Satisfaction with 3D Midwifery Visualisation Scale Survey.

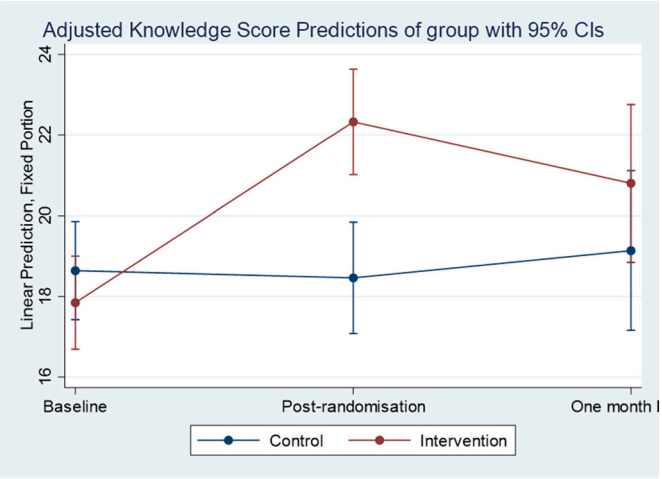


**Fig. 4.** Multi-level model cluster effect for the repeated knowledge score measures over the three time points between the groups.

The free text provided students with an opportunity to clarify any issues. Table 4 provides examples of participant's responses to open-ended questions which gathered data on students' experiences of the 3DMVR. Three students identified that the visualisation affected their vision and commented that they had to wait for their eyesight to adjust before they could watch the 3DMVR clearly. This could potentially be caused by the closeness of the glasses to the mobile phone device. One problem highlighted was that 50% of the respondents found the glasses did not fit their phone well, and in the free text responses one student identified that; '*The glasses were very hard to see through and very close to the screen. I also couldn't wear my glasses with them*' (p. 5). Table 4 provides further examples of participant responses to open ended questions.

## 4. Discussion

In this pilot-study the incorporation of the anatomy and physiology and the physiological process of the separation and birth of the placenta and membranes are brought together in the virtual environment of the uterus. This artificially created immersive learning environment enabled midwifery academics to illustrate the placenta, membranes, capillaries and intervillous space to simulate an inaccessible learning environment when visualisation of the real thing is not possible (Polcar and Horejsi, 2015). For students struggling to understand the complex concepts of the third stage of labour, visualisation of the internal structures simplified the anatomy and physiology and physiological processes. Visualisation mitigates the need for students to create mental representations of incoming data such as when reading from a book (Andersen et al., 2012). Schweppe et al. (2015) suggests that visualisation can remove barriers to learning by simplifying the complex cognitive processes required for filtering, selecting, organizing, and integrating information normally received from books and lectures. However, in a recent study, Servotte et al. (2020) suggested that viewing VR can cause minor discomfort for users, which has been questioned by Hanson et al. (2020) therefore future research needs to investigate the impact on participant's vision when viewing on different devices. In this study student satisfaction ratings and self-assessed comfort scores

**Table 3**
Student Satisfaction with 3D Midwifery Visualisation Scale Survey.

| Q# | Question | Likert scale: Strongly disagree–strongly agree | | | | | Comment |
|---|---|---|---|---|---|---|---|
| | | Strongly disagree | Disagree | Unsure | Agree | Strongly agree | Summary *n*-12 |
| 1 | I found the instructions for using the 3DMVR simple and easy to follow. | | | 8% (1) | 75% (9) | 17% (2) | 92% (11) agree or strongly agree |
| 2 | I had no issues with accessing the 3DMVR site on my mobile device. | 8% (1) | 58% (7) | | 17% (2) | 17% (2) | 66% (8) disagree or strongly disagree |
| 3 | I needed assistance to activate/start/manoeuvre the 3DMVR. | 8% (1) | 25% (3) | | 42% (5) | 25% (3) | 67% (8) agree or strongly agree |
| 4 | The 3D glasses fitted my phone and worked well. | 8% (1) | 42% (5) | | 33% (4) | 17% (2) | 50% (6) Disagree V;s 50% agree |
| 5 | The audio worked well. | | | | 50% (6) | 50% (6) | 100% (12) agree or strongly agree |
| 6 | I found the use of 3D technology made me feel nauseated or unwell. | 17% (2) | 33% (4) | 17% (2) | 25% (3) | 8% (1) | 50% (6) disagree or strongly disagree |
| 7 | I remained seated while I watched the 3DMVR. | 17% (2) | 8% (1) | | 25% (3) | 50% (6) | 75% (9) agree or strongly agree |
| 8 | The 3DMVR enabled me to view the process of a physiological third stage of labour. | | | | 67% (8) | 33% (4) | 100% (12) agree or strongly agree |
| 9 | The 3DMVR helped me apply what I read in the pre-readings to the physiological events. | | | 25% (3) | 42% (5) | 33 (4) | 75% (9) agree or strongly agree |
| 10 | The 3DMVR helped me conceptualise the 2D diagrams from the textbooks. | | | 8% (1) | 67% (8) | 25% (3) | 92% (11) agree or strongly agree |
| 11 | The 3DMVR has improved my understanding of the anatomy and location of the uterus, placenta, and membranes. | | 17% (2) | 8% (1) | 25% (3) | 50% (6) | 75% (9) agree or strongly agree |
| 12 | The 3DMVR increased my knowledge and understanding of the anatomy and physiology, and the circulation of blood between the placenta and maternal circulation. | | 8% (1) | 8% (1) | 33% (4) | 50% (6) | 83% (10) agree or strongly agree |
| 13 | My understanding of the anatomy and physiology of the intervillous space was improved. | | 8% (1) | 17% (2) | 25% (3) | 50% (6) | 75% (9) agree or strongly agree |
| 14 | The 3DMVR increased my knowledge and understanding of the physiological process regarding separation of the placenta and membranes from the decidua. | | | 8% (1) | 33% (4) | 59% (7) | 92% (11) agree or strongly agree |
| 15 | My understanding of haemostasis and the contraction of the myometrial muscles of the uterine blood vessels is improved after watching the 3DMVR. | | | 17% (2) | 50% (6) | 33% (4) | 83% (10) agree or strongly agree |
| 16 | The 3DMVR narration helped me understand where complications could occur in the physiological process. | | | | 42% (5) | 58% (7) | 100% (12) agree or strongly agree |
| 17 | The 3DMVR was a valuable learning experience. | | 8% (1) | | 42% (5) | 50% (6) | 92 (11) agree or strongly agree |

One student removed as they undertook the evaluation twice. Final $n = 12$ participants.

**Table 4**
Participant responses to open ended questions in the Student Satisfaction with 3D Midwifery Visualisation Scale Survey.

| Q# | Question | Participant response |
|---|---|---|
| 18 | How did the use of 3DMVR influence your learning? | • Much easier to understand being a visual learner compared to textbooks (P13)<br>• Visually it was helpful to see the separation of the placenta from the uterine wall (P14)<br>• I am a visual learner and found this to be very helpful (P10) |
| 19 | Identify the main advantage that stands out in your recollection of the 3DMVR | • Moving through the uterus and having each part explained with an accurate visual aid (P7)<br>• Understanding and retaining information (P8)<br>• It makes the organ pictures easier to compare to the book (P4) |
| 20 | Identify any disadvantage that stands out in your recollection of viewing the 3DMVR | • Difficulty accessing the 3DMVR from my phone (P13)<br>• The difficulties connecting with headphone jacks and access to the 3D display. Plus your eyes adjusting to the 3D (P15)<br>• I could not concentrate on the audio for the first few minutes because I was so distracted by the visual (P14)<br>• Eyes dizzy (P5) |
| 21 | Comment on your experience of the 3D visualisation, for example do your feel it helped improve your learning? | • Definitely improved learning (P13)<br>• The 3D was helpful…I liked the video with the voice over (P15)<br>• Important for students to understand that they can walk around to see the graphic from different angles (P4) |

reported that exposure to the 3DMVR caused minor visual disturbance.

The 3DMVR used audio and animation. Animation has been identified as superior to drawings, diagrams, or images and text (Schweppe et al., 2015; Mayer, 2014). Furthermore, evidence suggests that when learners hear narration in addition to animation, they perform better on tests and have improved retention of knowledge, than those who received animation and on-screen text without narration (Mayer, 2014; Schweppe et al., 2015). These claims were corroborated by the findings of this study in which students in the intervention group who viewed the 3DMVR in addition to their traditional studies were able to achieve a significantly higher score of 4.9 points in their MCQ than the students in the control group, not exposed to the 3DMVR.

Educational psychologist Richard Mayer, in 2014 confirmed that deeper learning and improved retention of knowledge can be achieved when pictures are accompanied with text or narration. The students in the control group who did not see and hear the 3DMVR had the same or poorer scores on the MCQ, immediately after.

The optimum timing of when to assess retention of knowledge intervals vary considerably in the literature, with studies spanning one to ten weeks (Fernández Alemán et al., 2011; Schweppe et al., 2015; Chan et al., 2021). Fernández Alemán et al. (2011) assessed knowledge retention at four time points and reported the use of eLearning resulted in superior scores in immediate follow-up tests; however, when followed up 10 weeks later the results were no different to those of students who received traditional education. In comparison, Chan et al. (2021) performed their post-test one week after their intervention and Schweppe et al. (2015) two weeks after their intervention. Schweppe et al. (2015) have shown that adding a picture to text facilitates immediate recall and recall up to two weeks later. Schweppe et al.'s (2015) participants were presented with information of a pulley system in different formats, either text alone, or text and pictures. Educational content that contained both text and pictures substantially improved retention of knowledge recall at two weeks (Schweppe et al., 2015). More research evidence is needed to confirm consistency in optimum retention of knowledge periods, and also consider the educational format (images, animation, text or narrated) of the knowledge being assessed.

The findings of this study demonstrate that using 3DMVR to layer information in addition to traditional education improved student's comprehension of the third stage of labour in the initial period after the intervention. Pedagogical research supports implementation of innovative ways to engage students in learning through the design of new formats which engage students in ways that improve their learning outcomes (Bowen and Watson, 2017).

Previously, simulation has been used to teach the third stage of labour and layer learning which has been found to improve critical thinking (Frost et al., 2020). Traditional face-to-face education has many benefits and simulation activities are recognised as the gold standard for teaching clinical skills in a safe environment (Bogossian et al., 2018). Nevertheless, on campus teaching can disadvantage students that need to study at a distance (King et al., 2018). Online virtual reality such as the 3DMVR has the unique potential to make health care education more readily available to students off campus. Ferguson (2015) has recommended the creation of further resources to assist student learning, such as the 3DMVR used in this study to improve theoretical knowledge.

Students in this study were only exposed to the 3DMVR once, with positive improvement seen in test scores. However, Chang and Weiner (2016) espouse that one benefit of virtual reality simulations is the opportunity to provide learners with open access to learning resources; this enables repeated student-led asynchronous access that permits repeated viewing and has the potential to increase retention of knowledge over time. Therefore, when introducing online virtual resources allowing open access to students could overcome the issue of deteriorating knowledge overtime.

Chang and Weiner (2016) also make a point about online virtual environments being a time efficiency for faculty staff as student can access online virtual resources at their convenience. However initial set up of virtual online resources is time intensive to create (Akpan and Shanker, 2017) and requires motivated and innovative teams to create original resources that are suitable for the specific learning needs. Commercially created resources could be the solution to this time intensive activity.

### 4.1. Limitations

The Covid 19 pandemic was a major barrier to recruitment and implementation of this study, consequently, the anticipated sample size ($n = 80$) was significantly reduced ($n = 38$), and the follow up one month later suffered a drop in responses ($n = 9$). While these results cannot be generalised, as a pilot study the number of participants was not a factor in the testing of the study protocol.

Unfortunately, due to Covid-19 travel restrictions the lead researcher was unable to be present during the intervention and alternative processes were implemented to guide the students in the use of the 3DMVR. Some students reported issues with using the 3D glasses and needed assistance to activate the visualisation on their phones. The technological issues experienced by these participants affected their viewing experience resulting in lower scores on the student feedback survey. These issues would have been avoided if staff familiar with the technology had been present as they could have provided additional student orientation.

## 5. Conclusion

This pilot study demonstrates that an online 3DMVR learning resource can provide an additional layer to traditional education, that increases knowledge in the short term for midwifery students learning about the third stage of labour. However, longer term benefits for knowledge retention remain questionable. MCQ scores were higher in

the intervention group, there was no evidence to suggest an increase in retention of knowledge one month later. As this study only collected data at the point of the intervention and one month afterwards, longer term effects of the intervention are unknown.

Technological issues in using 3DMVR technology needs to be considered to enable a better student experience. However, there is a perceived value and merit for students in increasing their knowledge and understanding of the scientific foundations of midwifery knowledge using this technology. Research literature suggests that providing open access to online resources allows student-led asynchronous learning opportunities that theoretically infer an increase in knowledge retention would occur through repetition, based on frequent access to consolidate understanding and overcome the issue of deteriorating knowledge overtime.

Online 3DMVR shows promise in enhancing current traditional methods of midwifery education. Despite technological issues this mode is valued and perceived as a useful resource by students.

### 5.1. Recommendations

As a pilot study the findings cannot be generalised. Replication of this study in a larger cohort across several universities is warranted to ascertain the long-term impact of online 3DMVR on student midwifery knowledge retention. Future research is needed to substantiate the 3DMVR as an effective means to immerse students in their studies. Research should measure knowledge based on frequency of exposure, the optimum time-period for testing retention of knowledge, and the impact on participant's vision when viewing on different devices.

Finally, based on student feedback additional new three-dimensional learning resources are needed but funding is necessary to enable the development of such resources.

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## CRediT authorship contribution statement

Michelle Gray: Project leader of research project, writing, reviewing and editing the manuscript
Terri Downer: Writing, reviewing and editing the manuscript
Julie Hanson: Reviewing and contributing to the manuscript.
Donna Hartz: Funding acquisition, planning of data collection resources, data curation and analysis, reviewing and editing the manuscript
Patrea Andersen: Data curation, verification and validation of the results, reviewing and editing the manuscript, preparing figures for the manuscript
Yu Gao: Verification of the quantitative data results, preparing the table and figures for the manuscript.

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