IJoHS International Journal of Healthcare Simulation

ORIGINAL RESEARCH

# High-fidelity simulation and virtual reality: a mixed-methods crossover study evaluating medical students' experiences as observers

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https://ijohs.com/article/doi/10.54531/CWIL1515

## ABSTRACT

***Introduction:***
Active observers can benefit vicariously from the experience of hands-on learners in simulation. Kolb's experiential learning cycle and vicarious learning theory form the theoretical basis for directed observation during simulation teaching, although little is known about the impact of different simulation technologies on the observer experience.

***Methods:***
This mixed-methods crossover study compared student experiences as observers using a high-fidelity manikin and immersive virtual reality (VR) software. Forty-nine final-year medical students were divided into two groups, undertaking and observing scenarios using either the manikin or VR before switching to the other form of simulation.

***Results:***
Forty-eight questionnaires comprising Likert items were completed and analysed, with 11 students participating in focus groups. As observers, the students reported similar experiences with regards to engagement and reflection, with no statistically significant difference between the two technologies. However, the manikin scored higher in domains such as realism, enjoyment, clinical reasoning, usefulness and improved confidence. Students found that 'participating' is a more useful experience than 'observing' in both technologies. Thematic analysis revealed themes such as skills development, learning experience and technology.

***Discussion:***
Students valued observing their colleagues completing scenarios within both technologies, highlighting the benefits of observation in focus groups. The high-fidelity manikin scored higher for several domains; however, there was no difference between VR and high-fidelity simulation on perceived observation experience regarding engagement and self-reflection. This suggests VR may have a useful role in observational learning, without the need for a simulation suite.

**What this study adds**

- Although existing research has explored the role of observational learning in the context of simulation, there has been little research considering how different simulation technologies impact the educational experience for observers in simulation.
- This study compares the experiences of final-year medical students acting as observers within simulation teaching across two different forms of simulation technology: a high-fidelity manikin and virtual reality.
- The results from this study bring together both quantitative and qualitative data on how technology impacts the observer experience in simulation.
- The results demonstrate the difference between the two simulation technologies and explore how this may affect how these are used in undergraduate medical education curricula.

## Introduction

Simulation has grown to be a widely used method of teaching clinical skills in medical education [1]. One of the significant benefits of simulation is that it allows the learner to practise clinical skills in a safe environment. However, high-fidelity simulation (aiming to resemble more accurately real-life scenarios) can be associated with significant costs and may be resource-intensive, meaning that small group, rather than individual teaching is commonplace [2]. This means that despite the focus often being the development of clinical skills, students spend a significant proportion of simulation teaching observing their peers [3].

Learning in simulation is commonly described in relation to Kolb's experiential learning cycle, in which knowledge is formed through the 'transformation of experience' [4,5]. This learning cycle comprises four stages: concrete experience, reflective observation, abstract conceptualization and active experimentation [5,6]. With the development of more novel technologies, such as virtual reality (VR), consideration has also been given to how learning theories can be applied to virtual environments. Although further research is required in this area, there have been suggestions that the experiential learning cycle may be applicable to this form of simulation, in addition to constructivist learning theory, in which students learn actively and construct knowledge based on their lived experience [7–9]. However, where the experiential learning cycle may form the basis of simulation pedagogy, some have raised concerns that students undertaking an observer role in the simulation may not be able to undergo this learning process, as without actively participating there may be a lack of 'concrete experience' [4]. These concerns could also extend to constructivist learning theory within VR simulation, in which students should have the role as active learners and will construct knowledge based on learning experiences [9–11].

When considering the learning experience of students undertaking an observer role in simulation, the idea of vicarious learning is one theoretical basis that has been considered [3,4]. The concept of vicarious learning was first described by Bandura, who suggested a model in which learning could occur through observation of others [12]. Bandura's social learning theory described four key processes of observational learning: attention, retention, motor reproduction and motivation [12]. These concepts have since been further refined, with suggestions that the process of vicarious learning is one based on the use of imagination and is characterized by active listening and reflection [2,13,14].

There is an emerging body of evidence to suggest that vicarious learning can be as effective as 'hands-on' learning in health professions education [15] and can provide a valuable learning experience in simulation [3,16,17]. It is therefore important to consider how the educational experience for student observers in simulation-based teaching may be maximized. Bethards considered how Bandura's four processes of observational learning can be applied to simulation, with suggestions that checklists, guidelines for observers, outlining the importance of the observer role, rotating roles and debriefing may all relate to these processes [3].

To address some of the concerns about the observer role and consider how the observer may learn differently in simulation in comparison to the active participant, Johnson proposed a combined observational experiential model, which may be used to consider how educators can use the theoretical underpinning to support these learners [18]. This observational experiential learning framework combines elements of social learning theory [12] and Kolb's experiential learning theory [6], and demonstrates how concepts from social learning theory relate to Kolb's experiential learning, for example how attention and motivation affect the observer's 'concrete experience' [4,16,18].

The benefit of the observer role appears to be supported by educational theory and previous health education research. However, it is unclear whether the form of simulation has an impact on the educational benefits gained by the observer. With the introduction of novel forms of simulation technology, such as VR, it is not yet known what the impact on the observational experiential learning experience for observers will be. There are clear advantages and limitations of using different types of simulators for the participant [19–21], yet the impact on the observer experience using different forms of technology has not yet been explored. This is of particular relevance given potential differences in pedagogic principles underlying different forms of simulation technology.

This study aims to compare two forms of simulation technology, a high-fidelity patient simulator and VR simulation technology, to investigate how two different forms of simulation technology affect students' experiences as observers. We hypothesized that there would be differences in student experience between observing peers undertake a 'hands-on' simulation scenario and a virtual scenario.

## Methods

### Study setting and recruitment

The setting for the research was Castle Hill Hospital, Hull University Teaching Hospitals NHS Trust. Ethical approval was granted by the Hull York Medical School Ethics Committee (Ethics application number 20 27, approved 9th July 2020).

The study population consisted of final-year medical students at the Hull York Medical School. All final-year students attending simulation sessions were considered eligible. Exclusion criteria were lack of consent to participate and any condition that could be considered a safety issue, as outlined in the Oculus Rift safety manual [22].

All eligible students received invitations to participate via the university virtual learning environment. Further verbal announcements were made by faculty during teaching sessions.

A power calculation was not done due to lack of information on the standard deviation of the outcome measure.

### Study design

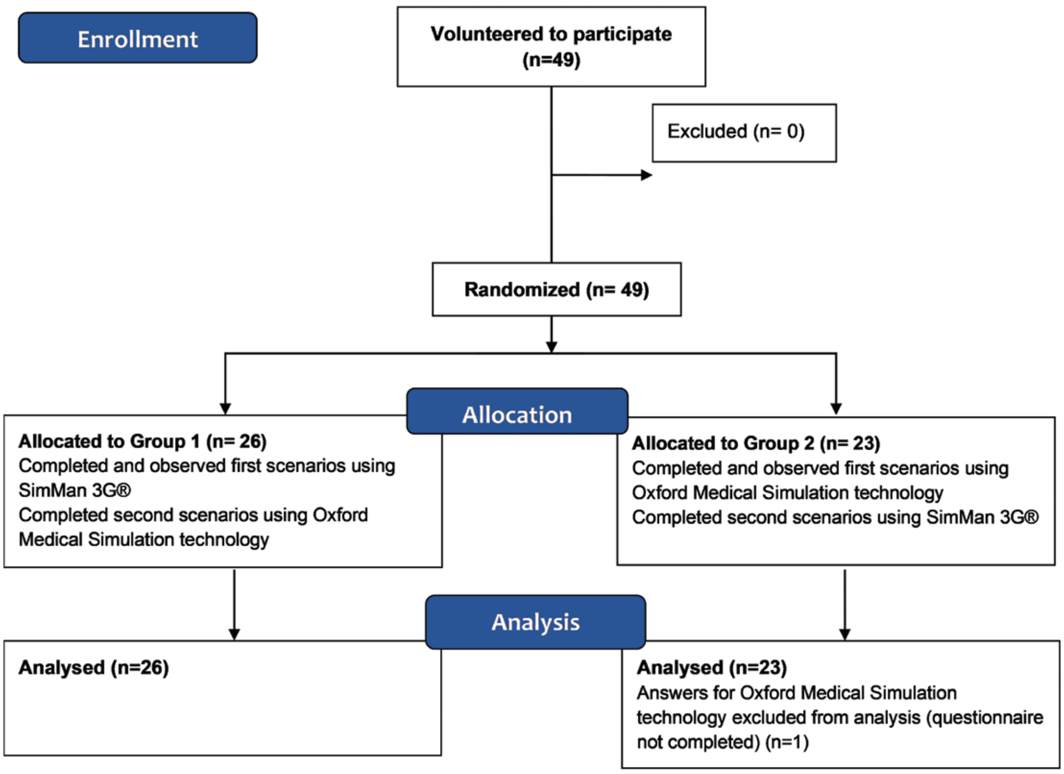
The research used a mixed-methods, crossover study design.

The two forms of technology being compared were a high-fidelity manikin (SimMan 3G®, Laerdal, Stavenger, Norway) and Oxford Medical Simulation (London, UK) VR software. The high-fidelity manikin is based in a dedicated simulation suite which aims to emulate the clinical environment. Oxford Medical Simulation technology was used with Oculus Rift (Oculus from FaceBook, San Jose, CA, USA), a head-mounted VR system. This system allows students to be immersed in a 360° virtual emergency room environment with the ability to work through clinical actions. In both scenarios, peers observe either in a dedicated viewing room for scenarios using the manikin or in the same room for the VR scenarios. To allow observing students to view the scenario, the VR experience of the participant was mirrored on a large screen, with the participant, tutor and observing students all in one room. In addition to being able to view the VR simulation, observers were also able to hear the same audio as the participant.

A total of 49 students volunteered to participate, all of whom provided written consent. The participants were divided into groups of between four and seven students for their timetabled simulation teaching.

All students in each small group session were then randomly allocated into two groups, Group 1 and Group 2. Each student in Group 1 participated in and observed scenarios on the high-fidelity manikin, following which they repeated the scenarios using the VR software. The Group 2 students first completed and observed scenarios using the VR software and then completed their second scenarios using the high-fidelity manikin (Figure 1). Each student completed a different 10- to 15-minute individual scenario whilst being observed by their peers. The students performed the same scenario on each technology. Prior to each scenario, students were provided with a pre-brief which consisted of a short introduction to the role of the

**Figure 1:** The flow diagram of recruitment, allocation and analysis in the study.



student, where appropriate (e.g. a Foundation Year One doctor based on the Acute Medical Unit), who the patient is (name and age) and the presenting complaint (e.g. shortness of breath). This was either provided verbally by the facilitator or by the virtual nurse within the VR scenario.

During scenarios undertaken on the high-fidelity manikin, an actor playing a nurse would be present during the scenario. The nurse would be able to perform tasks such as administering medications and undertaking clinical observations. In addition, the nurse was able to prompt the student when required (e.g. following a change in observations, or highlighting to the student options such as calling a senior). In these scenarios, students also had access to advice from a senior colleague over the phone. If remaining time was limited in the scenario, or the student appeared to be finding the scenario difficult, a senior colleague may also enter the scenario, prompting the student to give an 'iSBAR' style handover. Within scenarios using the high-fidelity manikin, students were expected to undertake certain tasks as would be required in a real clinical setting, for example 'inserting' intravenous access or prescribing fluids or medications. For prescribing purposes, students were provided access to the British National Formulary. In VR scenarios, options for history questions, examinations or medications are provided through drop-down menus. This meant that students had to choose from several pre-populated options for each aspect of their assessment. The VR scenarios also provided students with access to guidelines (e.g. sepsis guidelines) and clinical results, such as blood and radiology results, which was also a notable difference from the information available in the high-fidelity manikin scenarios.

During the simulation sessions, observing students were provided with specific roles. Using elements of the approach described by Bethards, the roles of the observing students focused on different concepts that would contribute to the debriefing process [3]. The aim of this was to promote engagement and attention processes as described in social learning theory [3]. The observer roles were rotated for each scenario. Following each scenario, verbal debriefing would take place, in the form of a discussion, facilitated by one or two tutors.

Bandura's work on observational learning informed the planning of the debriefing, including the allocation of specific roles, centring the debriefing around feedback from the observers and reinforcing the importance of the observer role. Through incorporating these aspects, this may aid in the attention, retention and motivation processes of Bandura's observational learning [3,12]. Rotating students between observer and participant roles also aligns with social learning theory through incorporating aspects of motor reproduction [3].

Four simulation scenarios were chosen for the research. These were acute asthma, upper gastrointestinal bleed, anaphylaxis and pneumothorax, as these could be undertaken using both technologies.

The simulation sessions were delivered by members of the research team (AFM, KAB and DH) as well as clinical teaching fellows. All those involved in the simulation sessions were from a clinical background, were experienced in delivering teaching using both forms of technology and had received relevant training on debriefing and feedback.

All participants had previously been orientated to both types of simulator and the simulation suite through verbal instructions and orientation videos. Prior to the research, all participants had also each completed at least one scenario using both simulation technologies and had observed at least three other scenarios being performed by their peers.

### Outcome measures

Immediately after completing a scenario, students were asked to complete the first part of the questionnaire for 'participants', which was designed to evaluate different aspects of the students' experience. The questionnaire comprised five-point Likert items, encompassing the following domains: confidence, satisfaction, usefulness, realism, development of clinical reasoning skills, engagement and reflection. In terms of questionnaire design, a pragmatic approach was taken to design the questionnaire based on elements that it was felt would help inform educational practices and shape future simulation within the medical school. The questionnaire was initially developed based on previous informal feedback during simulation teaching sessions from both students and faculty, as well as previously documented limitations of simulation technology in the literature [23]. Each domain represented potential strengths and limitations of the simulation technology that had previously been highlighted during this feedback.

Once the question domains had been decided, the questionnaire was constructed. As the domains were not similar enough to be grouped into a Likert scale, it was decided that the questionnaire would be comprised from individual Likert items, rather than including additional questions to form a Likert scale. These Likert items were presented to students as statements, with five possible options ranging from (1) strongly disagree to (5) strongly agree. This 'participant' part of the questionnaire was piloted in a previous research project [23], following which minor amendments were made to remove potential ambiguity in the questions.

After observing their colleagues performing scenarios, students were then asked to complete the first 'observer' questionnaire, which was similar in structure to the participant questionnaire. This part of the questionnaire was designed and presented in the same way as the questions for students who had just participated in a simulation scenario. The students completed this second section of the questionnaire, focusing on observer experience, after all the remaining scenarios on one technology were completed by their peers. The students then completed the second 'participant' and 'observer' questionnaires in the same way after moving to the other simulation technology.

Following participation in the study and completion of the questionnaires, students were invited to attend focus groups. The focus groups used semi-structured interviews to further explore the students' perceptions of their experiences. A focus group guide was developed in advance, containing an opening explanation to be read to those participating in the focus groups, as well as open questions and additional optional prompt questions to be used if required. Three focus groups were held, each including between two and six students. The interviews were conducted by two researchers (AFM and KAB) and were recorded using audio-visual recording software to allow for replay and transcription. The recorded videos allowed for transcription to be undertaken by a member of administrative staff.

### Statistical analysis

As the questionnaire comprised individual Likert items, which are distinct from a Likert scale, we decided to analyse the results using non-parametric statistical testing based on a review of the literature [24,25]. The scores for each Likert item were analysed using the Wilcoxon signed-rank test, based on a level of 5% statistical significance. SPSS software was used for the statistical analysis.

To allow for the non-parametric statistical analysis, the results were analysed according to the proportion who 'strongly agreed' or 'agreed' with each Likert item, with one exception being for the question about distractibility, in which the proportion 'disagreeing' and 'strongly disagreeing' was used.

For the qualitative data, a thematic content analysis was conducted, using the methodology described by Braun and Clarke [26]. This process was conducted independently by two researchers (AFM and KAB). Both reviewers independently reviewed and familiarized themselves with the videos and transcriptions of the focus group. They then independently highlighted codes that emerged from the discussions. Following this stage, further analysis of the data and codes allowed for identification of themes and subthemes. These were visually represented using mind maps. Following the independent analysis, both researchers compared findings, with any differences in identified codes or themes being discussed between the two reviewers until a consensus was reached. This discussion allowed the researchers to refine and define the themes identified and summarize these in a final mind map.

## Results

### Participants

A total of 49 final-year medical students participated in the study, with 48 students fully completing both parts ('participant' and 'observer sections') of the questionnaire. Likert item scores for VR were missing for one respondent, meaning that proportions for the high-fidelity manikin were based on a total of 49 respondents, whereas proportions for VR were calculated from 48 total responses. Eleven students participated in the focus groups.

Demographic data were available for 40 of the participating students, as demographic data for nine students had not been reported (Table 1).

### Quantitative results

#### *Observers*

A summary of the results for students observing their colleagues is presented in Table 2.

When asked whether they felt that observing their colleagues improved their confidence in performing an ABCDE assessment, there was a statistically significant difference in favour of the high-fidelity manikin, with a greater proportion of students stating that they 'agreed' or 'strongly agreed' that the high-fidelity manikin achieved this compared with VR (93.9% vs. 79.2%, $p < 0.001$).

In relation to usefulness of the technologies, all students (100%) either 'agreed' or 'strongly agreed' that observing scenarios on the high-fidelity manikin was useful to their learning, with 75% of respondents reporting the same for observing VR. This difference was statistically significant in favour of the high-fidelity manikin ($p < 0.001$).

Similar results were seen with the question of whether observing the technology provided an enjoyable experience, with a large majority (93.9%) of students 'agreeing' or 'strongly agreeing' that the high-fidelity manikin provided this and a large proportion of students reporting the same for VR (79.2%). Although most students felt that both technologies were enjoyable to observe, the difference between the proportion of students agreeing was still found to be statistically significant ($p = 0.006$).

In terms of allowing observing students to 'develop clinical reasoning skills', almost all (95.9%) felt that observing the high-fidelity manikin allowed them to do

**Table 1:** Demographic data of participating students and scenario types

| Demographic | Subgroup | Group 1 | Group 2 |
|---|---|---|---|
| | | Number (%) | Number (%) |
| Sex | Male | 10 (48) | 9 (47) |
| | Female | 11 (52) | 10 (53) |
| Rotation | Medicine | 13 (62) | 12 (63) |
| | Surgery | 8 (38) | 7 (37) |
| Scenario | Anaphylaxis | 5 (24) | 4 (21) |
| | Asthma | 7 (33) | 6 (32) |
| | Pneumothorax | 3 (14) | 4 (21) |
| | Upper Gastrointestinal bleed | 6 (29) | 5 (26) |

**Table 2:** Likert item responses for students observing the simulation technology

| | % who 'agreed' or 'strongly agreed' (rounded to nearest whole number) | | *p*-value (two-tailed) |
|---|---|---|---|
| | SimMan 3G (*n* = 49) | Oxford Medical Simulation virtual reality technology (*n* = 48) | |
| I feel more **confident** in performing an ABCDE assessment on an unwell patient having observed my colleagues using this simulation technology. | 93.9 | 79.2 | <0.001 |
| I **enjoyed** the learning experience provided by observing this simulation technology. | 93.9 | 79.2 | 0.006 |
| Observing this simulation technology provided a **useful** learning experience for me. | 100.0 | 75.0 | <0.001 |
| From my observations, the simulation technology provided a **realistic** experience of an acute clinical scenario. | 91.8 | 47.9 | <0.001 |
| I felt observing my colleague using this technology allowed me to develop my **clinical reasoning** skills (e.g. diagnostic reasoning). | 95.9 | 68.8 | <0.001 |
| I found myself getting **distracted*** (e.g. other thoughts, doodling) when observing my colleagues in this technology.<br>*Results for disagreed or strongly disagreed | 61.2 | 45.8 | 0.143 |
| Observing my colleagues undertake scenarios in this technology encouraged me to **reflect** on my own performance and learning. | 89.8 | 81.3 | 0.43 |

this, with over two-thirds (68.8%) of participants 'agreeing' or 'strongly agreeing' that observing VR scenarios also helped to develop this skill. Again, the results demonstrated a statistically significant difference between the two technologies ($p < 0.001$).

The biggest difference between the responses was seen for perceived realism of the technology when observing, with almost double the number of participants 'agreeing' or 'strongly agreeing' that observing the high-fidelity manikin provided a realistic experience compared to VR (91.8% vs. 47.9%). These results strongly favoured the high-fidelity manikin and demonstrated a statistically significant difference between that and VR ($p < 0.001$).

In contrast, when participants were asked whether observing the technology allowed for reflection on their performance and learning, 89.8% of participants 'agreed' or 'strongly agreed' that the high-fidelity manikin encouraged this and 81.3% responded the same for VR. The results showed no significant difference between the two ($p = 0.43$).

One issue for educators is the potential for observing students to be distracted, rather than engaged in the teaching. When comparing the proportion of students who 'disagreed' or 'strongly disagreed' with the Likert statement that they found themselves getting distracted, more students 'disagreed' when observing the high-fidelity manikin (61.2%), compared with only 45.8% students reporting this for the VR. However, the difference between the two was not statistically significant ($p = 0.143$).

### *Comparison of observer and participant experiences*

The responses from participants and observers were also compared across similar domains, such as improved confidence in performing an ABCDE assessment and realism. A summary of the comparison between students scoring technologies as observes and active participants in scenarios is summarized in Table 3.

When comparing the results between those participating in and observing scenarios ('participants' and 'observers'), for most of the domains evaluated, students valued observing their colleagues equally to participating in scenarios. There were no statistically significant differences between participants and observers for improved confidence and realism for both technologies. In relation to enjoyment, participating was found to be more enjoyable than observing with VR ($p = 0.031$), whereas there was no statistically significant difference between participants' and observers' scores regarding enjoyment for the high-fidelity manikin ($p = 0.414$).

The results also suggest that students found participating superior for developing clinical reasoning skills and more useful for their learning when compared to observation, with statistically significant results in favour of participating rather than observing for both technologies ($p = 0.039$ for both technologies). Although all participating students 'agreed' or 'strongly agreed' that the high-fidelity manikin provided a useful learning experience as both a participant and observer, due to the larger proportion of respondents stating that they strongly agreed with the statement as a participant, the differences were statistically significant ($p < 0.001$). The results for usefulness with VR also favoured participating rather than observing ($p = 0.022$).

In terms of realism, there was no statistically significant difference between participant and observer scores on either technology.

## Qualitative results

Two focus groups took place immediately after the simulation session, with another taking place 10 days

**Table 3:** Comparison of Likert item responses between students observing and participating in simulation scenarios

| Domain | Simulation technology | % of participants who strongly agreed/agreed | % of observers who strongly agreed/agreed | *p*-value (two-tailed) |
|---|---|---|---|---|
| Improved confidence performing an ABCDE assessment | SimMan 3G® | 95.9 | 93.9 | 0.066 |
| | Oxford Medical Simulation virtual reality technology | 75.0 | 79.2 | 0.617 |
| Enjoyed the learning experience | SimMan 3G® | 93.9 | 93.9 | 0.414 |
| | Oxford Medical Simulation virtual reality technology | 87.5 | 79.2 | <0.001 |
| Provided a realistic experience | SimMan 3G® | 93.9 | 91.8 | 0.149 |
| | Oxford Medical Simulation virtual reality technology | 37.5 | 47.9 | 0.391 |
| Technology provided a useful experience | SimMan 3G® | 100.0 | 100.0 | <0.001 |
| | Oxford Medical Simulation virtual reality technology | 79.2 | 75.0 | 0.022 |
| Helped develop clinical reasoning skills | SimMan 3G® | 93.9 | 95.9 | 0.039 |
| | Oxford Medical Simulation virtual reality technology | 81.3 | 68.8 | 0.039 |

after the simulation session. The focus groups took place in teaching rooms. A thematic analysis of the focus group transcriptions revealed three key themes: the student's learning experience, developing skills and the simulation technology (Figure 2).

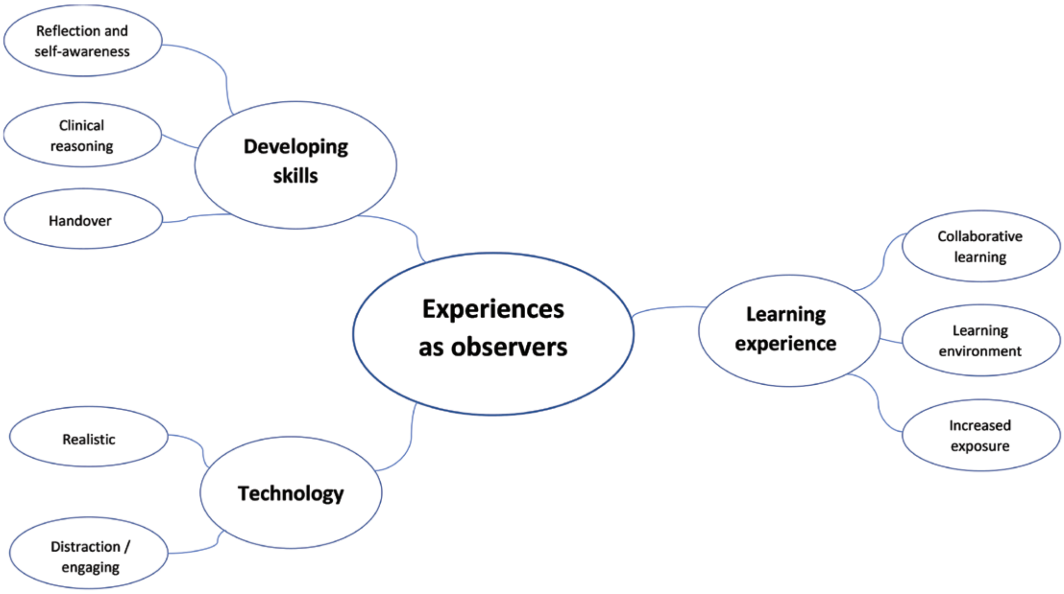
### *Learning experience*

A clear advantage for observers discussed in the focus groups was the increased exposure to a larger variety of scenarios. 'That just means you see more scenarios as well, it's a much broader learning thing than if you just did your one and disappeared' (FG2 Student3).

In contrast to this, one participant suggested that the learning experience from observation may be superficial. 'I think it, in a way it kind of hinders … how you would approach it if it was a new scenario because you [have] seen it before so … you might copy them rather than know it yourself' (FG3 Student2).

Another aspect that was highlighted in the focus group was the differences between the learning environments. Observers of scenarios using the high-fidelity manikin reported that they felt the learning environment was relaxed. This was also related to the possibility of collaborative learning whilst observing. '… it's definitely a lot more relaxed looking at everyone else doing it, and you do have a little discussion sort of while you're watching them do it with the tutors in the room' (FG1 Student2). In contrast, VR appeared to create a different learning environment due to the required set-up for the VR. During the interviews, students commented on the impact of being in the same room as the participant. 'In the VR you're kind of in the same room as the person doing the session, so you… don't want to

**Figure 2:** Thematic analysis of the observer experience.



distract them by discussing it with other people and break their flow' (FG1 Student2).

Despite this potential limitation, the possibilities of collaborative learning in this environment were also highlighted. '... you have the potential for people to work in a team to make those decisions better than in the actual SimMan scenario... with the VR everyone potentially could chip in at a certain point of the scenario so that could be helpful' (FG3 Student1).

### *Technology*

The impact of the technology on the observer experience was also considered by the participants. For example, being able to observe from different camera angles with the high-fidelity manikin was considered a benefit, whereas for the VR, watching on one screen and seeing what the participant is seeing was seen as both a potential advantage, due to being able to follow a peer's thinking, and disadvantage, as they were unable to see the entire picture.

The impact of the technology also influenced students' engagement. 'I felt more distracted on SimMan because I'm not in the room... whereas VR because you're all in the room together I concentrated more' (FG3 Student3).

Another factor that was technology-dependent was a sense of realism. In some cases, this was affected by the environment. 'I feel like it's [high-fidelity manikin] just kind of like watching a TV show' (FG3 Student3). However, the sense of clinical urgency was highlighted as an important factor. 'I think the SimMan is a lot more realistic, you don't have that kind of acute pressure in the VR that you would have in real life and that's what the SimMan gives you' (FG1 Student2); 'I feel like with the SimMan ... with all the beeping and ...the monitor and everything, I felt the sense of urgency...' (FG3 Student6).

### *Skills development*

The potential for developing skills through observation was also a key theme during the focus groups. Clinical reasoning was highlighted as a skill that was further developed through observation. 'You do find that the clinical reasoning does come to you in that [high-fidelity manikin] session, and you can kind of talk your way through what they're doing and what you think they're going to do next' (FG1 Student2); 'It's really beneficial to watch other people doing it as well because obviously you get to see more scenarios but also because you can be thinking about what you would be doing and what you think's going on...' (FG 3 Student5); '...for observing it's good to kind of see how others take that clinical decision-making as well ...' (FG3 Student2).

In addition, some participants suggested that observation helped with their communication skills, specifically the ability to perform a handover. Interestingly, another element that factored into the discussed was the ability of observing students to reflect on their own performance whilst preparing to feedback to their peers. As part of this, elements of being an active observer were highlighted, 'You can... go through the A to E assessment yourself as you're watching somebody else do it, but ... you might be able to write it down .... make a list...' (FG3 Student2).

## Discussion

Overall, the results show that students valued the learning experience gained through observation provided by both technologies, with no statistically significant differences between the two for experiences of engagement and reflection. However, the SimMan3G® simulator scored higher for increased confidence, usefulness, developing clinical reasoning skills, enjoyment and realism. The reasons for this are likely due to the different capabilities of the two technologies [21,23]. As highlighted in the qualitative research, the high-fidelity simulator, in a room designed to emulate the real clinical environment, can create some of the realistic elements of a medical emergency, creating a feeling of pressure and urgency. Although the observation aspect of the simulation was described as more relaxed than participating, it appears that students find observing the potentially more stressful high-fidelity manikin scenarios more realistic and useful for preparing for real clinical practice because of this aspect.

The ability to work collaboratively and have discussions in a separate observation room also appears to have contributed to students scoring the high-fidelity manikin higher for increased confidence and developing clinical reasoning skills. It is possible that by introducing a separate observation room for the VR scenarios, some of these barriers to collaborative learning could be overcome. With amended use of this technology, broader potential applications of VR could also be considered. For example, VR technology may provide additional opportunities for collaborative learning, including for distance learning, with students being able to join scenarios remotely or even participate in team-based VR scenarios [27]. However, regardless of the form of collaborative learning, previous research has highlighted potential barriers to collaboration for students assigned to observer roles, with suggestions that educators need to consciously structure the learning experience to allow for collaborative learning [28].

Interestingly, the results from the focus group suggested that some students naturally placed themselves in an 'active observer' role, by making lists whilst observing. This demonstrates the value of relevant educational theory in practice [3,4,12], as students highlighted this as a positive element of observation. This also aligns with existing research highlighting that use of observer tools, such as guided activity forms, are associated with increased role satisfaction and achievement of learning outcomes [17]. Furthermore, in relation to Kolb's learning cycle, students highlighted the ability to go through the clinical reasoning process themselves while observing their peers. While observing students were not able to undertake the physical assessment themselves, by being presented with clinical information whilst observing, they were able to practise this skill. It could, therefore, be argued that in relation to clinical reasoning, observing students are still able to go through the 'concrete experience' stage of the learning cycle [6]. In addition, in relation to the constructivist learning theory, this active, contextual learning may provide valuable learning experiences to help students build on previous experiences and construct their knowledge and understanding [9,10].

When directly comparing the observer experience to that of participants, students found participating a more useful experience than observing in both technologies. This was expected, given that the focus of the sessions was undertaking an ABCDE assessment, and feedback from participating students highlighted the perceived benefit of having the 'hands-on' practice, which has also been reflected in other research [29,30]. In addition, there was a concern from one student that learning from observation may be superficial, by simply mimicking their peers rather than having the required knowledge and the ability to apply it. Despite this feedback, research has demonstrated that observers in simulation learn and retain knowledge as well as their participating peers [16]. Furthermore, other research has also suggested that observation in simulation can also be equally effective as participating for developing clinical skills [31]. A systematic review conducted by Regan et al. further demonstrates the potential value of observational learning, describing several studies in which learning through observation was as good as, or superior to, hands-on learning in simulation using mannequins, actors, simulated patients or role-playing [17]. This suggests that, despite students' perceptions and experiences, vicarious learning may offer an equal learning experience in relation to clinical skills and knowledge. However, these studies compared the experience of participants using a mannequins or role-playing activities, meaning that the benefits of observing simulation have only been demonstrated on these forms of simulation; it is not clear whether the observation of other kinds of medical simulation, including more novel technologies, would convey the same benefits for knowledge or skills acquisition.

It is important to consider the outcomes used within this research; our study explored student perceptions of observing the technology which may not be indicative of what knowledge or skills may have actually been gained or developed from observation of simulation scenarios. This could be seen as one limitation of our research; however, student experience is an important aspect of education. Evidence suggests that factors such as enjoyment can have an impact on student motivation and participation [32], meaning that the results of this study may still help to guide educational practice and future research.

Further limitations of this study include the lack of blinding amongst facilitators. Whilst this would not have been possible due to the study design, it is important to recognize the potential impacts of this on the study results, such as facilitators approaching each simulation technology differently. Another potential limitation to note is the use of Likert items within the questionnaire. While there is support for use of Likert items in published literature, some argue that use, and analysis of, such items may be unreliable [33].

Understanding the role of vicarious learning and maximizing the learning experience for observers has become even more important given the context of the global COVID-19 pandemic [34]. As part of the response to the pandemic, universities had to move to alternative modes of teaching, with a significant increase in the amount of teaching delivered online [35,36]. One of the benefits of this is that educators are able to deliver teaching to larger audiences [35], meaning that while education has begun to transition to online and virtual learning, there may be a requirement for clinical teaching that has traditionally been more 'hands-on' to be delivered remotely [36]. While the future role of online teaching in medical education is not yet clear, many believe that the pandemic may lead to permanent changes in the way we teach future healthcare professionals [35–37]. A clearer understanding of how learning through observation can provide a useful learning experience may be vital in order to allow educators to navigate the changes in teaching delivery, and maximize the effectiveness of online learning for their students.

## Conclusions

Although simulation has become a vital part of medical education curricula, many students spend a significant proportion of their time in simulation teaching as observers. Our study compared the observer experience of final-year medical students using two different forms of simulation technology, a high-fidelity manikin and a VR simulator. Students generally valued the experience of observation using both technologies and highlighted benefits such as collaborative learning, increased exposure to more scenarios and their experiences as active observers. However, some differences between observing the two technologies were also noted, including the influence of the technology and learning environment on the student experience. Overall, the high-fidelity manikin simulator was considered to provide scored more highly in some domains, although the VR provided similar results in relation to engagement and reflection. There was also a general perception from students that participating in simulation sessions is more useful than observing.

Future studies exploring the benefits of observation of different simulation technologies, with a focus on more objective outcome measures, may further inform simulation practice and help understand educators how to optimize the student learning experience for observers.

## Declarations

## Authors' contributions

AM was involved in the research design, conducting of the study, data analysis and writing of the final article; KB was involved in the research design, conducting of the study, data analysis and review of the final article; AR was involved in the statistical analysis and review of the final article; TS and DH were involved in the research design and review of the final article.

## Funding

No funding was received for this research and there are no financial relationships to declare.

## Availability of data and materials

Available on request.

## Ethics approval and consent to participate

Ethical approval was granted by the Hull York Medical School Ethics Committee (Ethics application number 20 27, approved 9th July 2020). Informed consent was gained from all participants prior to them taking part in the research.

## Competing interests

The authors report no conflicts of interest.

## Reflexivity statement

AFM and KAB conducted the focus groups and led the simulation teaching sessions in which the research took place. Both researchers held positions as Clinical Teaching Fellows within the medical school, meaning that they had had previous contact with many of the participating students in an educational capacity. It was felt that both researchers had a good rapport with students due to previous teaching sessions and informal discussions with students. Some of this rapport was evidenced in the qualitative data, with the transcriptions reflecting a conversational flow to the focus groups. As both AFM and KAB were also graduates from the Hull York Medical School and junior doctors, they had some understanding of potential expectations and experiences from a student perspective. Their previous educational experience of teaching acute patient assessment using simulation, as well as undertaking previous research comparing both technologies, also provided additional understanding of the technology and its potential strengths and limitations.

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