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Article

Evaluation of the Road to Birth Software to Support Obstetric Problem-Based Learning Education with a Cohort of Pre-Clinical Medical Students

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Abstract: Integration of technology within problem-based learning curricula is expanding; however, information regarding student experiences and attitudes about the integration of such technologies is limited. This study aimed to evaluate pre-clinical medical student perceptions and use patterns of the "Road to Birth" (RtB) software, a novel program designed to support human maternal anatomy and physiology education. Second-year medical students at a large midwestern American university participated in a prospective, mixed-methods study. The RtB software is available as a mobile smartphone/tablet application and in immersive virtual reality. The program was integrated into problem-based learning activities across a three-week obstetrics teaching period. Student visuospatial ability, weekly program usage, weekly user satisfaction, and end-of-course focus group interview data were obtained. Survey data were analyzed and summarized using descriptive statistics. Focus group interview data were analyzed using inductive thematic analysis. Of the eligible students, 66% (19/29) consented to participate in the study with 4 students contributing to the focus group interview. Students reported incremental knowledge increases on weekly surveys (69.2% week one, 71.4% week two, and 78.6% week three). Qualitative results indicated the RtB software was perceived as a useful educational resource; however, its interactive nature could have been further optimized. Students reported increased use of portable devices over time and preferred convenient options when using technology incorporated into the curriculum. This study identifies opportunities to better integrate technology into problem-based learning practices in medical education. Further empirical research is warranted with larger and more diverse student samples.

Keywords: reproductive anatomy; medical education; obstetrics; pregnancy; virtual reality

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1. Introduction

Accurate knowledge of anatomy and physiology is essential to safe and efficient clinical practice [1]. The provision of anatomy and physiology education in undergraduate medicine has evolved significantly over recent decades in response to a range of pedagogical developments including the integration of problem-based learning (PBL) curricula, a broadening of intended learning outcomes, and a growing focus on the integration of technology-enabled approaches and resources [2]. The gradual shift from traditional approaches, where anatomy and physiology are generally taught in isolation to other subjects, using dissection or prosected human remains, is increasingly challenged by integrated curricula approaches such as PBL [3].

A PBL curriculum differs from traditional approaches by integrating the learning of anatomical sciences through an aligned theme or body system [3]. This approach uses active learning organized around problems (e.g., patient cases, professional problems, and/or scenarios) among small groups of students rather than among large lecture groups [3]. Additionally, the coronavirus disease of 2019 (COVID-19) pandemic significantly impacted traditional "on-campus" anatomical sciences teaching, accelerating the adoption of digital technologies out of an adaptive necessity [4]. Moreover, emerging evidence suggests that the use of technology for teaching anatomy has become popular, allowing students more interactivity [4]. Some students are motivated by the integration of immersive virtual reality (IVR) in which the user is immersed in a virtual world using a head-mounted display (HMD) and augmented reality (AR) which projects a digital image over the already visible reality, thus augmenting what the user can see [4]. Though students demonstrate superior memory retention when using these technologies compared to learning from a textbook [4,5] and non-immersive (e.g., computer-based desktop) virtual reality approaches [6,7], less is known about the integration of technology-enabled approaches within a PBL curriculum.

Technology-enhanced education has been successfully integrated into traditional PBL approaches for health sciences students [8–11]; however, to our knowledge, this approach has not been described for teaching maternal anatomic changes during human pregnancy. Traditional model-based and dissection-based approaches provide the correct scientific educational frameworks for teaching maternal anatomy [12] and may provide an opportunity for building professionalism [13]; however, these approaches are unable to demonstrate the synchronous effects of pregnancy on the function and structure of the maternal cardiovascular, digestive, mammary, respiratory, and urinary systems [14]. Furthermore, previous research suggests learner manipulation increases learner motivation, engagement, and knowledge retention [15,16]. Digital technology for human maternal anatomy and physiology education has successfully been integrated into midwifery curricula and shows promise in improved learner engagement [14,17]. The integration of digital technology into obstetric PBL medical education provides an opportunity for learners to visualize the synchronous changes in maternal and fetal development from conception through 42 weeks' gestation [17] and may provide an opportunity to teach clinical decision making in a PBL setting. Therefore, the aim of this exploratory pilot study was to evaluate pre-clinical medical student perspectives and their use patterns of the Road to Birth (RtB) software during its integration into problem-based learning activities.

2. Materials and Methods

2.1. Study Design

This prospective, descriptive, mixed-methods study was approved by the university's Institutional Review Board (IRB#19891).

2.2. Setting and Participants

A purposive sample of second-year medical students (n = 29) enrolled at one large midwestern American university were eligible to participate in this study. Of the eligible individuals, 66% (n = 19) decided to participate in this study. Written informed consent was obtained from all study participants. Demographic information indicated that participant gender was 58% male and 42% female; participant race and ethnicity was 53% Asian, 32% White, 5% American Indian or Alaskan Native, 5% Black or African American, and 5% unknown, and the average student age was 31 (range from 27 to 40).

Consenting students underwent visuospatial ability testing using the mental rotation test [18] and were surveyed regarding their technological familiarity at study commencement. The mental rotation test evaluates a person's ability to compare three-dimensional objects that are rotated in various axes [18]. Visuospatial ability and familiarity with technology correlate with the educational effectiveness of technology-enabled education approaches [19]; thus, participant familiarity in these two areas was important for subsequent data interpretation.

2.3. Road to Birth (RtB) Software

RtB was conceptualized by midwifery experts and developed in collaboration with the technology innovation team at a large Australian university. The initial development goal of the RtB software was to identify alternative technology-enabled education approaches to teach midwifery students the dynamic concepts of maternal anatomy and physiology, intrauterine fetal positioning, and placental locations [20]. The technology behind the RtB software has been previously described [17,21,22]. Detailed development and initial testing of RtB software have also been previously published [20]. Briefly, RtB was originally designed to encompass a self-directed, active learner-driven approach to education that focused on user interaction, participation, contextualization, and knowledge retention [23]. The focus of the anatomical changes that occur during pregnancy focused on the effects of a growing gravid uterus and subsequent maternal complaints, including cephalad displacement of the diaphragm resulting in shortness of breath and decreased space for the maternal bladder, resulting in urinary frequency [20]. This enabled opportunities for student use outside of the classroom, to revisit and reinforce learning such as before clinical rotations, and for exam preparation. RtB was designed for use on the following:

- Apple (Cupertino, CA, USA) smartphone/tablet (SpT) applications;
- Android (Mountain View, CA, USA) SpT applications;
- and in IVR using a HMD.

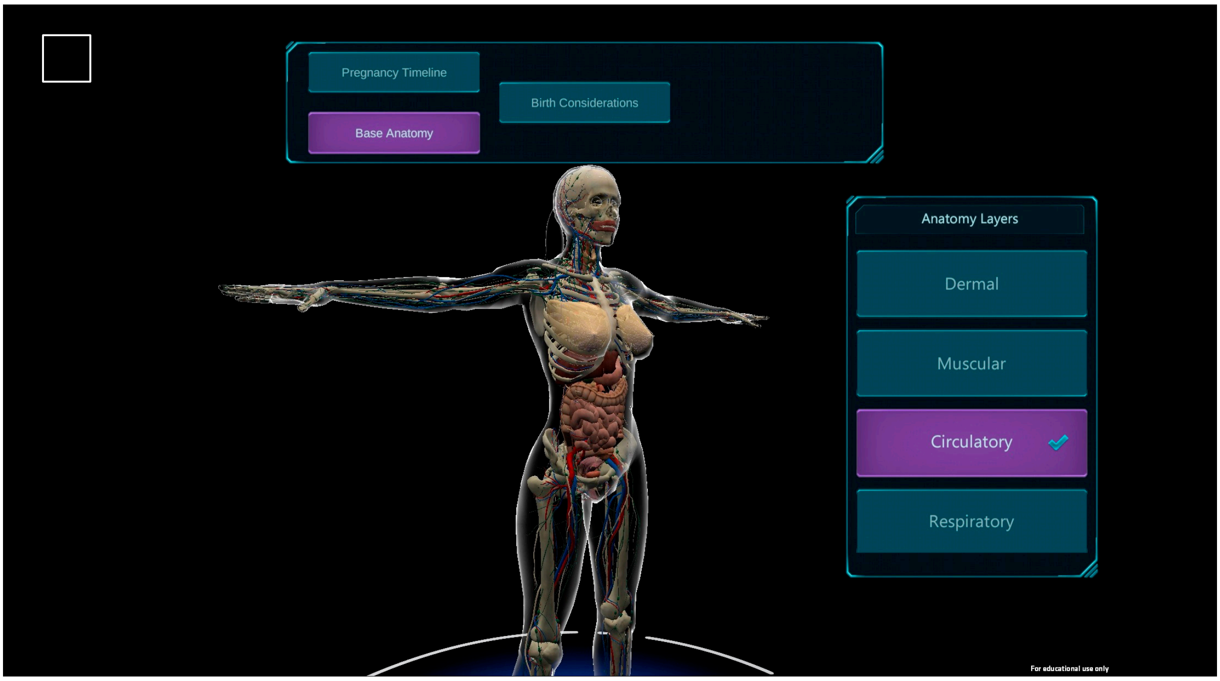
The software, which is displayed in Figure 1, consists of four main digital anatomy interfaces [20].

Interactive and modifiable organ systems included cardiovascular, dermal, digestive, mammary, respiratory, and urinary systems. Additionally, the uterus, placenta, and developing fetus were also designed for user interaction and modification [20]. The anatomy function enabled the user to remove various anatomic layers to better understand structural relationships during various gestational ages. A floating information panel provided additional context regarding the underlying rationale for these changes [20]. Maternal anatomic organ system modeling was developed using commercially available anatomical models, including Anatomy Learning—3D Anatomy, Complete Anatomy (Amsterdam, Netherlands), Anatomy 3D Atlas (Milano, Italy), and 3D Organon VR Anatomy (San Francisco, CA, USA), that were manipulated and animated in Unity 3D™ (Austin, TX, USA) using C# visual programming language [20].

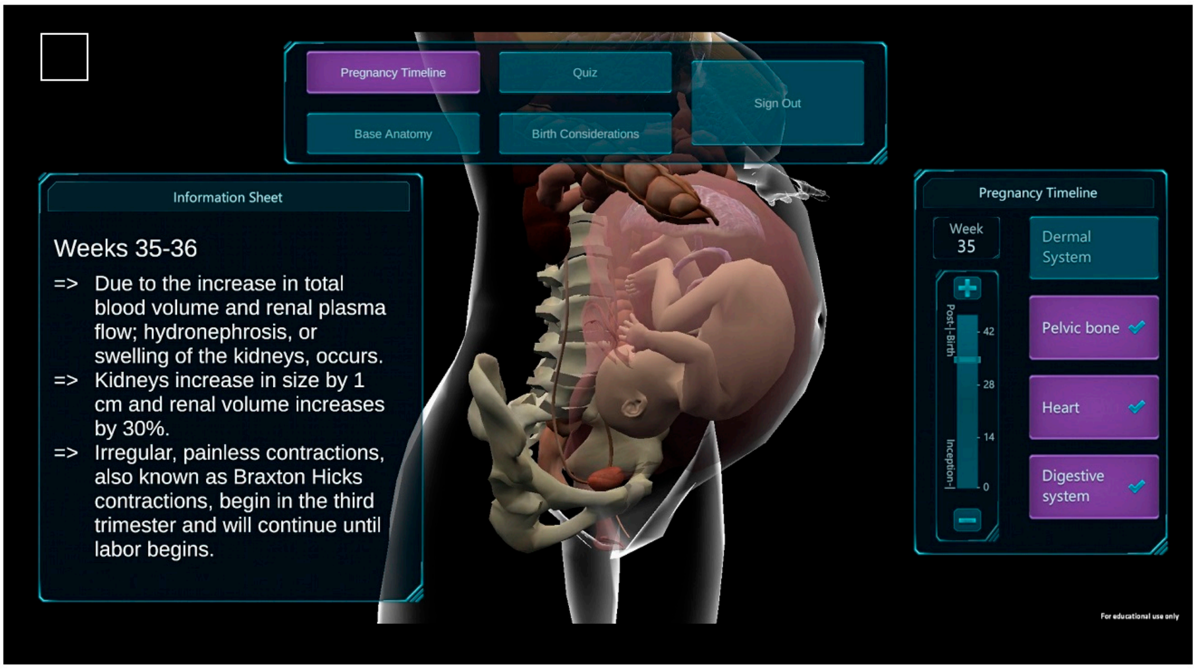
A collaborative research agreement between the American and Australian universities permitted system modifications to fit the allopathic curricular demands of the obstetrics course for American medical students. The software was modified prior to course commencement and included medical language modifications to target an American (versus Australian) audience and increased text detail to become more relevant for medical students (versus midwifery students).

2.4. Curriculum Integration

The second-year obstetrics course was conducted over an intensive three weeks that occurs approximately 15 months into the 20-month pre-clinical education. During the course, students were divided into four PBL groups of six to eight students [3]. These groups met for two-hour teaching sessions three days a week as part of their normal course schedule during the Fall 2019 semester. During these sessions, medical students and one faculty medical education facilitator worked through an obstetric clinical scenario to identify learning topics for the week. Learning topics were selected by the students and related to obstetrical anatomy, physiology, pathophysiology, pharmacology, and histopathology. While working through the clinical scenario, the facilitator utilized specific probes, related to anatomical and physiological changes that occur during pregnancy, to encourage student exploration of the educational content in RtB on either SpT or IVR platforms.

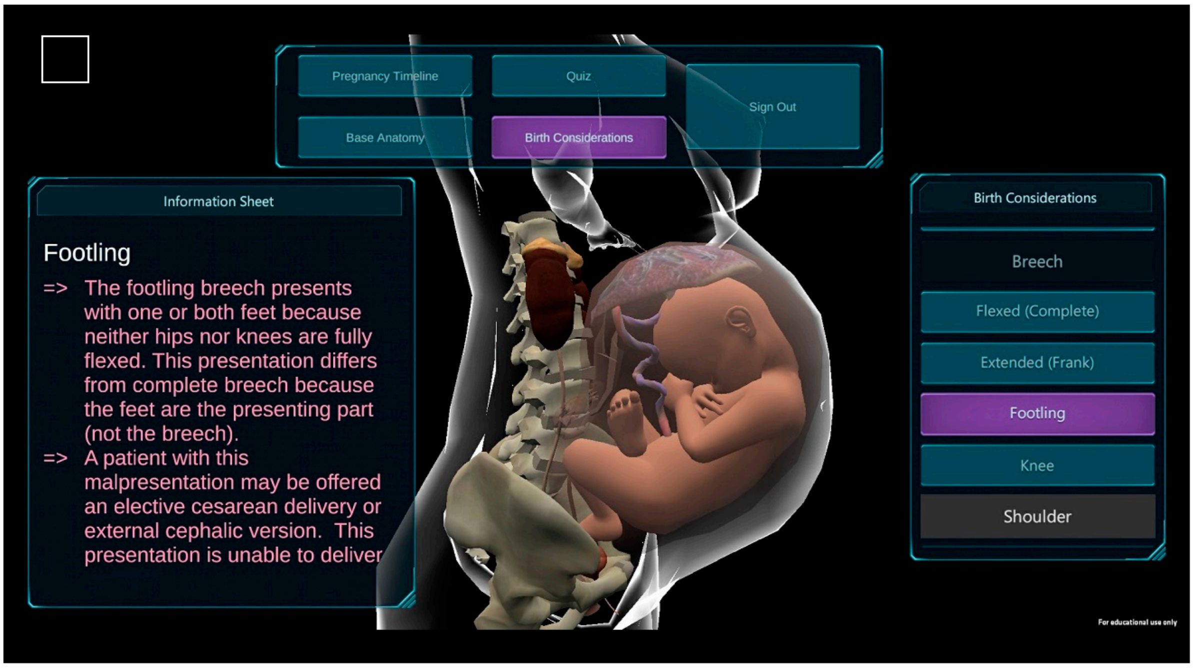


(**a**)



(**b**)

Figure 1. *Cont.*



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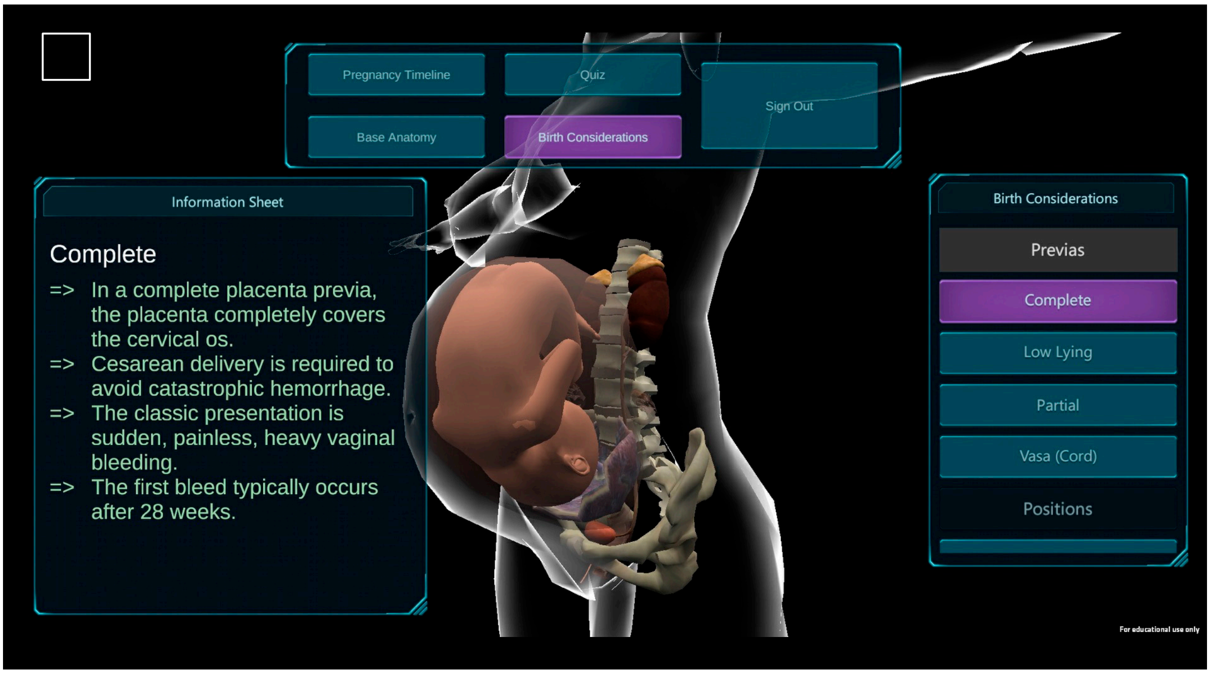

(**d**)

Figure 1. Road to Birth digital anatomy interfaces: (**a**) base anatomy, (**b**) pregnancy timeline, (**c**,**d**) birth considerations, and quiz mode (not shown).

Integration of RtB during PBL sessions is illustrated in Figure 2. In week one, two of the four PBL groups were assigned to use the RtB IVR platform during the PBL session while the other two PBL groups used the RtB SpT platform during the PBL session. Platform assignments were switched in the second week. The software was not required to be used during the final week; however, students could access the RtB SpT on their personal devices during any of the PBL sessions. The students accessed the software during the PBL sessions to answer question probes regarding maternal anatomical and physiological changes that occur during specific timepoints during pregnancy. In addition, throughout the duration of the course, the RtB SpT was available for use on each student's personal device and both the SpT and IVR were available at the university simulation center, library, and student lounge.

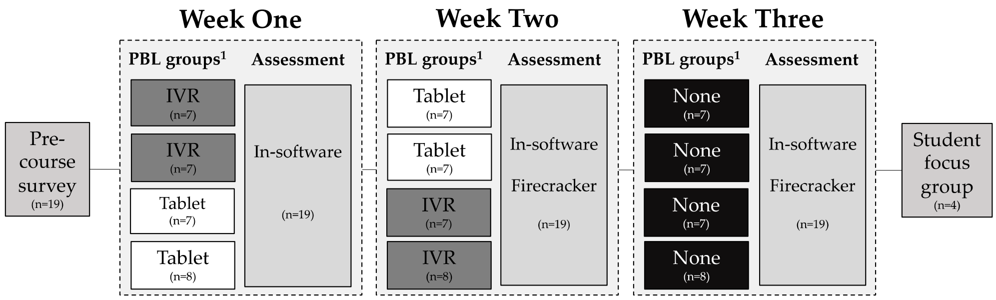

Figure 2. Schema of Road to Birth software integration into second year medical student problem-based learning groups during the obstetrics course. [1] Number of students within PBL groups includes the entire class (n = 29), rather than the number of students participating in the study. Abbreviations: PBL: problem-based learning; IVR: immersive virtual reality.

Each week, students completed a ten question RtB in-software quiz to assess their knowledge of the educational content and an optional program evaluation survey. Passing for these quizzes was set at or above 70% averaged over the three weeks. After the second and third weeks, students completed an 18–20 question external assessment quiz, which was administered via Firecracker (Wolters Kluwer, Alphen aam dem Rijn, The Netherlands), an online United States Medical Licensing Examination (USMLE) Step 1 preparatory tool. Passing for these quizzes was set at or above 70% averaged over the final two weeks. All students were invited to participate in a focus group interview following course completion. There was no financial or other incentive for focus group participation.

2.5. Data Collection and Analysis

A mixed-methods design incorporated both qualitative data from a focus group interview and quantitative data (e.g., surveys, device-captured data) as the research questions focused on student perceptions of the software. Quantitative measures included numerical survey responses, quiz performance, and time to complete the quiz. These data sets were assigned unique identifiers and personally identifiable information was removed. For survey items, descriptive statistics were calculated using Microsoft Excel (Redmond, Washington, DC, USA).

A qualitative descriptive methodology using inductive thematic analysis techniques was used to analyze focus group responses. The qualitative descriptive methodology was chosen for its ability to provide factual responses to questions about a phenomenon of interest within real-world contexts [24]. Qualitative descriptive methods follow traditional qualitative methods employing purposive sampling techniques, gathering focus group data, with analyses performed by an inductive thematic and/or content analysis of the data [24,25]. In the current analysis, transcribed focus group data were de-identified and checked for quality against the session recordings. An inductive thematic analysis was applied where data were coded and developed into representative themes [26]. Thematic analysis allows researchers to identify and explore patterns within qualitative data and is a widely used technique applied within mixed-methods research to provide a more comprehensive understanding of a phenomenon of interest [26].

Four students responded to the invitation to participate in a semi-structured focus group interview, which was conducted by one of the authors (RW). Questions were designed to prompt open-ended responses from participants, and the interviewer asked participants to compare their opinions to one another. The full text of the focus group interview protocol is available in Appendix A. Students provided written informed consent for focus group interview participation. The focus group interview was audio recorded and transcribed verbatim using a transcription tool (Temi.com, San Francisco, CA, USA) to ensure an accurate account of the resulting discussion. The transcript was reviewed and cleaned of identifying information. To increase validity and reduce researcher bias, the focus group transcript was first independently coded and then collectively coded by the study authors (MH, DJ) who were not involved in conducting the focus group session. Using an iterative approach, once codes were finalized by authors MH and DJ, the wider team of RG, SF, and RW met to discuss and develop a consensus of overarching themes arising from the codes. These themes are used to describe the data with representative quotations derived from the transcripts used to illustrate the qualitative findings.

3. Results

3.1. Quantitative Findings

Student median performance on the mental rotation test was 95% (range 45–100%) with 15.8% (3/19) of the students having had prior experience with a mental rotation test. Pre-course technologic experience survey results are detailed in Table 1. Most (12/19, 63.2%) of the students had used a smartphone and its associated applications at least weekly and none reported recreational IVR use.

Table 1. Second-year medical student pre-course technologic familiarity survey results (n = 19).

	Frequency of Use n (%)			
How often Do You Use Each of the Following?	**Never**	**Monthly**	**Weekly**	**Daily**
Non-portable game consoles	16 (84%)	3 (16%)	0	0
Portable game consoles	14 (74%)	3 (16%)	1 (5%)	1 (5%)
Use of virtual/augmented reality	19 (100%)	0	0	0
Course content on Compass	3 (16%)	1 (5%)	11 (58%)	3 (16%)
Online discussion forums	11 (58%)	31.6%	1 (5%)	1 (5%)
Firecracker	0	3 (16%)	14 (74%)	2 (11%)
Video conferencing	11 (58%)	3 (16%)	5 (26%)	0
Question banks	0	1 (5%)	10 (53%)	8 (42%)
Smartphone/tablet apps	10.5%	5 (26%)	21.1%	8 (42%)
Podcasts	47.4%	5 (26%)	3 (16%)	2 (11%)
Internet websites	1 (5%)	0	2 (11%)	16 (84%)
Google/Google Scholar	0	0	6 (32%)	13 (68%)
Wikipedia	1 (5%)	2 (11%)	10 (53%)	6 (32%)
Text messaging	5 (26%)	2 (11%)	1 (5%)	11 (58%)
Social media	8 (42%)	2 (11%)	2 (11%)	7 (37%)
YouTube	2 (11%)	2 (11%)	10 (53%)	5 (26%)

Reported platform use by week as measured by in-software surveys is illustrated in Figure 3. Over the three weeks of the course, students reported increased use of RtB on an SpT device and decreased IVR use for both studying purposes and taking the in-software quiz.

Students varied by week regarding if they felt RtB was an efficient use of their study time: 46.2% week one (6/13); 35.7% week two (5/14); 57.1% week three (8/14). Most students reported that RtB increased their medical knowledge each week: 69.2% week one (9/13); 71.4% week two (10/14); 78.6% week three (11/14).

The median student performance on RtB in-software weekly quizzes and Firecracker weekly quizzes were all above the passing threshold (70% correct on average) and are shown in Table 2. The median quiz time, as measured by the device, was compared by platform modality, IVR vs. tablet: week one 14.7 vs. 14.5 min; week two 7.5 vs. 13.1 min; week three 10.5 vs. 14.3 min (Figure 4).

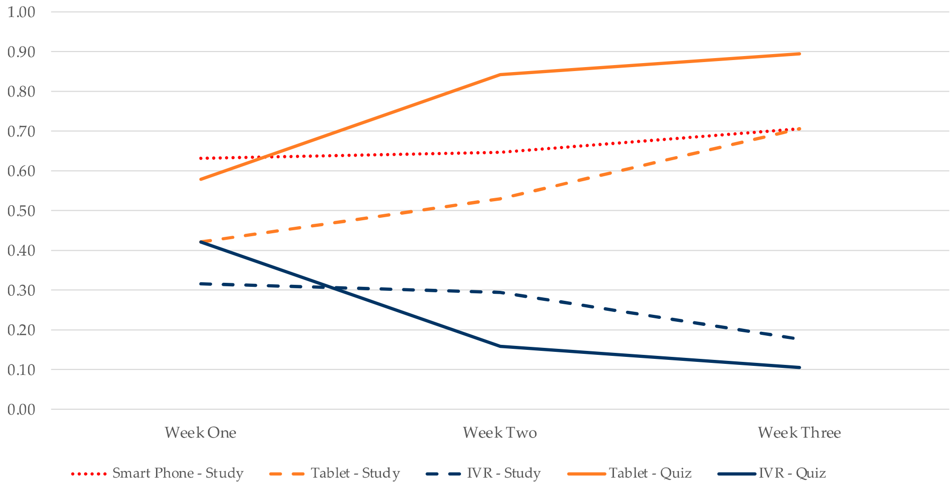

Figure 3. Reported platform use by week as reported on weekly surveys. Abbreviations: IVR: immersive virtual reality.

Table 2. Second-year medical student assessment results (n = 19).

	Median (% Correct)	Interquartile Range
Road to Birth in-software week one quiz	87	17
Road to Birth in-software week two quiz	79	21
Road to Birth in-software week three quiz	86	14
Firecracker week two quiz	75	15
Firecracker week three quiz	89	11

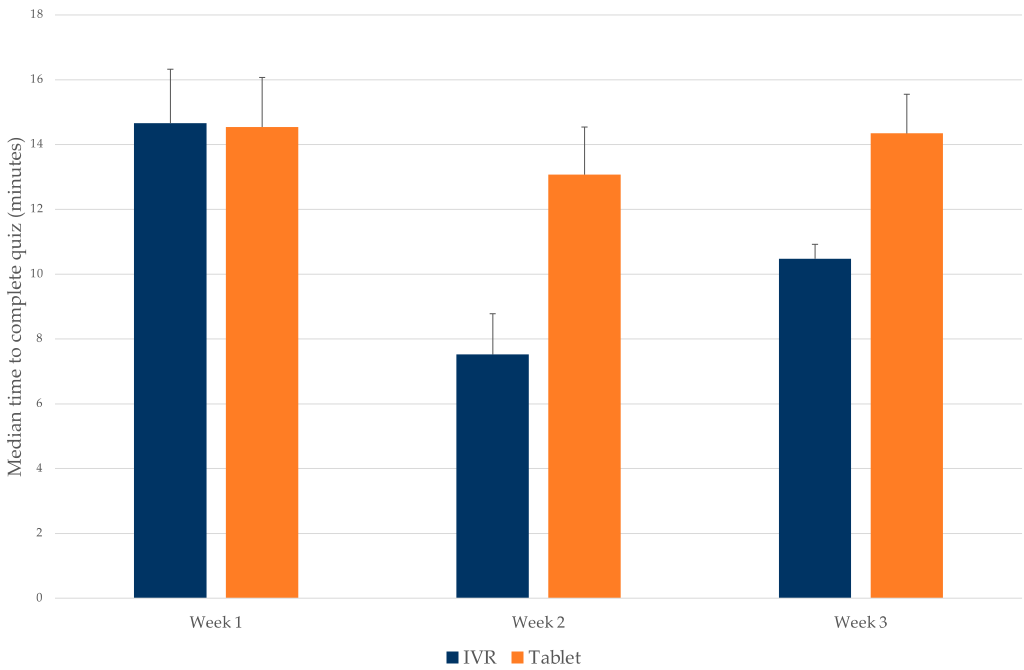

Figure 4. Median in-software quiz time by week. Black bars represent standard error. Abbreviations: IVR: immersive virtual reality.

3.2. Qualitative Findings

Three main themes were generated from the qualitative analysis and are detailed in Table 3:

1. Students want a usable, professional-grade product.
2. The use of technology should be optimized for its purpose.
3. Students prefer content suitable for multiple uses.

Table 3. Themes, sub-themes, and representative quotes from four second-year medical students.

Main Themes	Sub-Themes	Representative Quotes
1. Students want a usable, professional-grade product	Design of product (artwork, text)	"I was kind of disappointed in the quality of the software." "I think. . .there could be. . . more detail in some. . . of the changes."
	Utility of product (usability, convenience)	"Being able to zoom in and spin. . . the model around [on the smartphone] was almost pointless just because the screen was so small. I can't see any detail." "I found my primary use. . . for it was actually it was a convenient pocket resource to have since I did have it on my phone."
2. The use of technology should be optimized for its purpose	IVR for educational use should build on its interactive nature	"Where you get an advantage in VR over just looking at pictures in a textbook." "My experiences with VR for educational purposes, I'm not convinced that it's. . . really that great. It can be useful for some people, but I think for some people. . . it doesn't really add very much." "If you're going to use this platform to quiz us, at least use a 3D model and be like, here is this placenta previa or not previa? Where is this? What is it?" "I don't think that most people in this school have even given or even tried the 3D anatomy for normal anatomy. Yet they complained about anatomy, and. . . no one came over there to do it. I invited people to come out. But everyone's automatically like 'VR? No thanks.'"
	IVR provides an enjoyable learning experience	"[I was] the one who actually used it in the PBL session. I had a blast. I thought it was. . . lots of fun. I was crawling on the floor trying to get better viewpoints for them." "I think VR is cool and I'd love to see it. . . used in education more."
3. Students prefer content suitable for multiple purposes	Desire for a product that teaches pathology and physiology	"I. . . liked [the previas] . . . I would say those. . . plus the breech, were probably the best parts of the [software]."
	Road to Birth as a tool to teach others	"I think it'll be very beneficial when it comes to showing someone who doesn't understand. . . a lot of information." "I was talking about pregnancy changes with someone who was not in. . . the field of medicine. . . What I was able to do is I was actually [able] to pull it out and scroll to 32 weeks cause the individual was approximately 32 weeks, and actually physically showed them what that looked like internally and explained how somebody's symptoms that they're experiencing were a result of those changes in the organs."

Abbreviations: IVR: immersive virtual reality; VR: virtual reality; 3D: three-dimensional; PBL: problem-based learning.

From each main theme, two sub-themes emerged. Sub-themes for main theme one included "the design" and "the utility" of the RtB program. Sub-themes for main theme two included "IVR provides an enjoyable learning experience" and "IVR use should build on its interactive nature." Sub-themes for main theme three included "students want a product that teaches pathology/pathophysiology in addition to anatomy/physiology" and "students want a product that can be used to teach others".

Themes and Sub-Themes

Theme one. A usable, professional-grade product: Design of product (artwork, text):

Students reported that the design of the RtB software was not the same quality they are used to in commercially available products, such as Visible Body (Boston, Massachusetts, USA) or Anatomy 3D Atlas (Milano, Italy). One student reported, "*I was kind of disappointed in the quality of the software.*" Students reported some difficulty with the organization of the text and wished some features that were available in commercially available software could be made available in RtB, including a scroll button and the ability to minimize certain features while using others. Though the software text was edited to become more detailed for medical student education, the artwork was not modified from that which was originally developed for midwifery students. As a result, some medical students felt "*there could be*. . . *more detail in some*. . . *of the [visual] changes.*" Medical students felt that the depth of detail in the artwork and text should be concurrent.

Theme one. A usable, professional-grade product: Utility of product (usability, convenience):

As the smartphone was the most popular platform for student RtB use (35/53 weekly reported uses, 66.0%), students in the focus group interview primarily discussed the use of RtB on their smartphones. Several students echoed the report, "*My primary use*. . .*for it was actually it was a convenient pocket resource to have since I did have it on my phone.*" Although a tablet would afford a larger screen and more than half of the students (30/53 reported uses, 56.6%) reported using the tablet platform, students in the focus group interview did not discuss the use of the software on a tablet. Rather, students reported difficulty with the size of the smartphone screen; for example, "*being able to zoom in and spin*. . . *the model around was almost pointless just because the screen was so small; I can't see any detail.*" Furthermore, some students reported that traveling to the campus library to use the IVR platform was an inconvenience and did not bother with trialing it for this reason; however, another student retorted, "*It's a real far stretch to say that it's [an] accessibility [issue] to make a student come to a library on a college campus when you're enrolled in school. I think that's a very reasonable thing.*" The convenience of RtB SpT usage was one of the driving factors for preferred platform use.

Theme two. Optimize technology for its purpose: IVR provides an enjoyable learning experience:

Although several students in the focus group interview agreed with the statement "*I think VR is cool and [would] love to see it*. . . *used in education more,*" they also reported the hesitancy of their classmates to use IVR even prior to trial of the RtB product. One student said, "*I don't think that most people in this school have*. . . *even tried the 3D anatomy for normal anatomy. Yet they complained about anatomy, and*. . . *no one came over there to do it. I invited people to come out. But everyone's automatically like 'VR? No thanks.'*" Although few students reported using the software on the IVR platform (13/53 reported uses, 24.5%), those "*who actually used it*. . . *had a blast. I thought it was lots of fun. I was crawling on the floor trying to get better viewpoints for them and stuff.*" Furthermore, the students reported excitement about the future of IVR in education. One student said, "*I would be totally excited to watch VR lectures, especially if they had an active component of some kind.*"

Theme two. Optimize technology for its purpose: IVR for educational use should build on its interactive nature:

Although students hesitated to use the IVR-based platform and others felt "*for some people*. . . *it doesn't really add very much,*" most students felt that the use of IVR was justified when used in a method that builds on its interactive nature. Students who used this modality described a positive educational experience, "*where you get an advantage in VR over just looking at pictures in a textbook.*" Students reported "*the general sentiment is that the VR aspect [of the software] was underutilized,*" but they shared ideas for improvement. For example, students expressed a desire for using "*this platform to quiz us... use a 3D model and be like, here is this placenta previa or not previa? Where is this? What is it?*" "*Or rotate the baby... now he's in transverse, now he's in breech, now he's in footling as you... move the baby.*"

Theme three. Content preferences: Product that teaches pathology/pathophysiology in addition to anatomy/physiology:

RtB focused on the application of general anatomy and physiology to the pregnant state because the first two years of medical school focus on learning the basic sciences and preparing for USMLE Step 1. The researchers expected students to prefer content that was geared toward this exam, as this exam follows the completion of the second year of medical school and is important for applications to medical residency programs. Content on various obstetric pathologies, including fetal malpresentations and placental anomalies, was included to engage the students. In addition to wanting "*more details in there about the underlying physiology,*" they also wanted to see "*more of the pathologies in pregnancy.*" Students reported eagerness to learn clinical information beyond the anatomy and physiology of pregnancy and "*liked [the previas] ... I, in fact, I would say those, those plus the breech, were probably the best parts of the [software].*"

Theme three. Content preferences: Product that can be used to teach others:

Though RtB was designed for their education, the medical students identified ways to use the software to educate others, including patients, family, and friends. One student described "*talking about pregnancy changes with someone who was not in... the field of medicine... What I was able to do is I was actually [able] to pull it out and scroll to... 32 weeks cause the individual was approximately 32 weeks, and actually physically showed them what that looked like internally and explained how somebody's symptoms that they're experiencing were a result of those changes in the organs.*" Students described using RtB as a possible "*substitute*" for the "*3D models of things in doctors' offices... [to] show patients.*" Furthermore, at the completion of their course, students were excited to "*keep this [software] installed on my phone into my clinical years. I would actually anticipate using this [to teach patients].*" Students described the possibility of the development of two parallel software systems: "*One that is a little bit more detailed and that would be for... our education... I felt like while it was handy for a quick reference, it wasn't particularly comprehensive of what we needed to know. Um, and the second set of text, which is simplified and meant for educating a patient... And I think those two different extremes would... bring the maximum utility.*"

4. Discussion

This study details the piloting of the RtB software among one cohort of 19 medical students during their second-year obstetrics course from one midwestern American university. The study contributes to the growing body of literature exploring health professional student opinions and use patterns of the integration of digital technologies into PBL curricula for the teaching and learning of reproductive anatomy, which is otherwise not feasible with traditional anatomy teaching using static models and prosected human remains. Despite the abundance of human anatomy educational software applications available on SpT platforms, to our knowledge, none distinctly explores the dynamic changes in maternal anatomy that take place during the course of a term pregnancy. This research provides valuable student insight into optimal software content and platform features that may facilitate learning within the PBL context. Students participating in this study reported mixed feelings regarding the software; they enjoyed the obstetrical pathology content but disliked the level of detail in the artwork.

Initial survey results indicated most (63.2%) students used a smartphone and its associated applications at least weekly with no students reporting using IVR. These results may, in part, explain the increasing preference and use of the RtB on SpT platforms over time and reluctant engagement with IVR during their PBL course. Moreover, qualitative feedback collected via focus group suggests the medical students in this study valued convenience when integrating a new digital educational tool which was again demonstrated by the student technology use patterns with increasing SpT adoption rather than IVR across the course. Students were motivated and found it convenient to use a portable product, rather than traveling to campus for an IVR experience. Though students reported using the IVR product required more time, device-acquired data reporting time to complete in-software quiz time by week was similar during the first week, and time to complete the quiz was lower on IVR in subsequent weeks. This may be due to student perceptions of time being influenced by expectations of time needed to set up equipment, or this may be due to self-selection bias (i.e., students who were more efficient with using IVR continued to do so while students who were less efficient with IVR switched to SpT, thus lowering the average time to complete the quiz on IVR). Students performed well on assessments regardless of platform, suggesting a similar efficacy by platform.

Although integration of RtB into the institutional curriculum occurred prior to the COVID-19 pandemic and its required pedagogical changes, the use of digital technology appears to be a viable option for medical student anatomy education when remote learning environments are required [4]. Prior to the COVID-19 pandemic, many medical schools had already begun utilizing more online tools for their anatomy education [2,27–29]. Although the pandemic forced all medical schools to exclusively virtualize anatomy education [4], follow-up research on student performance and feedback demonstrated that virtual anatomy tools are an insufficient substitute for in-person dissections and a combined or adjunct approach may be optimal [30,31].

As future clinicians, medical students strive to identify ways to improve patient education regarding their medical conditions and may desire digital technology that can be used for this purpose and may explain the emergence of two unexpected sub-themes from the focus group RtB data:

1. The ability to use the software in remote learning environments;
2. The ability to use the software as a patient education resource.

Although RtB was not specifically designed for patient education, the students engineered methods to use this technology in creative ways to teach patients and others outside of the medical community. Our group is currently evaluating RtB as an educational tool for midwifery patients. Several groups have integrated these modalities into education for pregnant or post-partum patients [32–34] and people of childbearing age may be optimally suited for this type of education as other studies have suggested that young patients demonstrate an increasing interest in learning from technology [35,36]. These modalities have been integrated among several medical specialties and may improve patient engagement [37], healthcare literacy [37], and patient satisfaction [38]; however, the long-term health outcomes [39], and cost effectiveness [40] remain unknown. Although the use of RtB as a patient education tool sounds preliminarily promising, further research is needed to optimize this technology for that use.

We recognize the limitations of this study and have identified additional research opportunities. This was a single-institution pilot study with a small sample size, which limits its generalizability. Additionally, the design of the qualitative portion of the study does not allow for generalizability (nevertheless, the focus group procedures followed best practices for the analogous criterion of trustworthiness). There were no controls and one of the researchers conducted the focus group. To minimize the impact of potential bias, this researcher was not involved in the final round of coding in the qualitative portion of this study. Despite these limitations, this research highlights key next steps for software optimization and curriculum integration. Future research directions include evaluating the efficacy of each platform as a learning tool to examine best practices for implementing technology into the educational curriculum. As a result of this study's findings, improvements have been incorporated into the software, including a more responsive text scroll button and an expand/minimize feature. Other improvements under consideration include modifications to the artwork that enable more detailed views of maternal anatomical changes during pregnancy.

Although this research centers around the use of IVR and SpT for pre-clinical medical students learning maternal anatomy and physiology, the greater application to other health disciplines cannot be discounted. Early pilot data assessing the educational utility of RtB for student midwives [20] yielded positive feedback. Australian midwifery students using RtB SpT reported an improved understanding of intrauterine fetal positioning, felt it was an easy-to-use program, and identified RtB as a possible patient education resource [20]. Belgian midwifery students similarly felt RtB IVR was easy to use and provided an enjoyable learning environment [20]. While student midwives may seem motivated to use SpT and IVR technology, further empirical research must determine the efficacy of such technologies and their ability to be integrated into traditional medical educational curricula. The different experiences student midwives and student doctors reported using RtB highlight the need to design and test a tailored product for each type of learner to optimize its educational potential. Existing research regarding the use of digital technology is limited to studies with small sample sizes and pilot studies, highlighting the challenges and need to design and evaluate these products for different learner populations [14,17].

This study highlights important considerations for the development of digital technology resources for undergraduate medical obstetric anatomy and physiology education. Ongoing and future research directions include the incorporation and evaluation of RtB into osteopathic medical school curricula to improve the generalizability of the software. Because it is well established that the PBL pedagogy is very effective for medical education [41], RtB was incorporated into the existing PBL curriculum. The use of technology and its potential benefits or hindrance within the PBL session has not been extensively explored and this study was not designed to address this question. Future research is warranted to explore the efficacy of transformative technological tools during PBL sessions.

5. Conclusions

Though RtB was originally developed to provide midwifery students with new and innovative methods of teaching and learning [17], this research highlights additional, broader applications in an allopathic medical education program. The purpose of this study was to evaluate pre-clinical medical student perspectives and use patterns of RtB implemented in the curriculum, and based on the findings of this study, we conclude that undergraduate medical students may use RtB as an adjunctive anatomy learning tool concurrent to traditional cadaveric approaches or may use it exclusively during times when remote learning is necessary. Furthermore, RtB may be used for patient education and may improve patient–physician communication and health literacy. Readily available tools may be used to educate and empower patients regarding expected changes that occur during pregnancy. When optimally integrated into medical education, these resources may ultimately lead to more effective and safer pregnancy care.

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Appendix A. College of Medicine Road to Birth Student Focus Group Interview Protocol

1. Did you have any experience with similar mobile technologies prior to undertaking this course?
2. Have you and/or are you using any program similar to the Road to Birth (RtB)?
3. What were your expectations prior to using the content?
4. What did you view as advantages of using the virtual reality (VR) version of RtB? Disadvantages?
5. What did you view as advantages of using the tablet version of RtB? Disadvantages?
6. Do you feel that they added to or hindered education during the session?
7. What factors influenced you to take your assessment in the format you selected (VR or tablet)?
8. How can the software be improved?
9. If only one version of the software could be used in a course, which version do you think should be selected? Why?
10. Do you see yourself using RtB in the clinic and if so, how?

If offered, would you be interested in being involved in modifying, building upon, and improving the software?

References

1. Bergman, E.M.; van der Vleuten, C.P.; Scherpbier, A.J. Why don't they know enough about anatomy? A narrative review. *Med. Teach.* **2011**, *33*, 403–409. [CrossRef] [PubMed]
2. McMenamin, P.; McLachlan, J.; Wilson, A.; McBride, J.; Pickering, J.; Evans, D.; Winkelmann, A. Do we really need cadavers anymore to learn anatomy in undergraduate medicine? *Med. Teach.* **2018**, *40*, 1020–1029. [CrossRef] [PubMed]
3. Bergman, E.M. Teaching and learning anatomy in a PBL curriculum. In *Teaching Anatomy: A Practical Guide*; Chan, L.K., Pawlina, W., Eds.; Springer International Publishing: Cham, Switzerland, 2020; pp. 143–152.
4. Iwanaga, J.; Loukas, M.; Dumont, A.S.; Tubbs, R.S. A review of anatomy education during and after the COVID-19 pandemic: Revisiting traditional and modern methods to achieve future innovation. *Clin. Anat.* **2021**, *34*, 108–114. [CrossRef]
5. Gloy, K.; Weyhe, P.; Nerenz, E.; Kaluschke, M.; Uslar, V.; Zachmann, G.; Weyhe, D. Immersive Anatomy Atlas: Learning factual medical knowledge in a virtual reality environment. *Anat. Sci. Educ.* **2021**, *15*, 360–368. [CrossRef] [PubMed]
6. Chytas, D.; Salmas, M.; Skandalakis, G.P.; Troupis, T.G. Can immersive virtual reality function as a suitable alternative to conventional anatomy education methods? *Anat. Sci. Educ.* **2021**, *14*, 693–694. [CrossRef] [PubMed]
7. Kurul, R.; Ögün, M.N.; Neriman Narin, A.; Avci, Ş.; Yazgan, B. An alternative method for anatomy training: Immersive virtual reality. *Anat. Sci. Educ.* **2020**, *13*, 648–656. [CrossRef]
8. Nelson, L.; Sadler, L.; Surtees, G. Bringing problem based learning to life using virtual reality. *Nurse Educ. Pract.* **2005**, *5*, 103–108. [CrossRef]
9. Tudor Car, L.; Kyaw, B.M.; Dunleavy, G.; Smart, N.A.; Semwal, M.; Rotgans, J.I.; Low-Beer, N.; Campbell, J. Digital Problem-Based Learning in Health Professions: Systematic Review and Meta-Analysis by the Digital Health Education Collaboration. *J. Med. Internet Res.* **2019**, *21*, e12945. [CrossRef]
10. Cavicchia, M.L.; Cusumano, A.M.; Bottino, D.V. Problem-based learning implementation in a health sciences blended-learning program in Argentina. *Int. J. Med. Educ.* **2018**, *9*, 45–47. [CrossRef]
11. Alverson, D.C.; Saiki, S.M., Jr.; Kalishman, S.; Lindberg, M.; Mennin, S.; Mines, J.; Serna, L.; Summers, K.; Jacobs, J.; Lozanoff, S.; et al. Medical students learn over distance using virtual reality simulation. *Simul. Healthc.* **2008**, *3*, 10–15. [CrossRef]

12. Sugand, K.; Abrahams, P.; Khurana, A. The anatomy of anatomy: A review for its modernization. *Anat. Sci. Educ.* **2010**, *3*, 83–93. [CrossRef] [PubMed]
13. Kumar Ghosh, S.; Kumar, A. Building professionalism in human dissection room as a component of hidden curriculum delivery: A systematic review of good practices. *Anat. Sci. Educ.* **2019**, *12*, 210–221. [CrossRef] [PubMed]
14. Fealy, S.; Jones, D.; Hutton, A.; Graham, K.; McNeill, L.; Sweet, L.; Hazelton, M. The integration of immersive virtual reality in tertiary nursing and midwifery education: A scoping review. *Nurse Educ. Today* **2019**, *79*, 14–19. [CrossRef]
15. Barmaki, R.; Yu, K.; Pearlman, R.; Shingles, R.; Bork, F.; Osgood, G.M.; Navab, N. Enhancement of Anatomical Education Using Augmented Reality: An Empirical Study of Body Painting. *Anat. Sci. Educ.* **2019**, *12*, 599–609. [CrossRef]
16. Stepan, K.; Zeiger, J.; Hanchuk, S.; Del Signore, A.; Shrivastava, R.; Govindaraj, S.; Iloreta, A. Immersive virtual reality as a teaching tool for neuroanatomy. *Int. Forum Allergy Rhinol.* **2017**, *7*, 1006–1013. [CrossRef]
17. Jones, D.; Siang See, Z.; Billinghurst, M.; Goodman, L.; Fealy, S. Extended reality for midwifery learning: Mixed reality and virtual reality demonstration. In Proceedings of the VRCAI '19: The 17th International Conference on Virtual Reality Continuum and its Applications in Industry, New York, NY, USA, 14 November 2019.
18. Peters, M.; Laeng, B.; Latham, K.; Jackson, M.; Zaiyouna, R.; Richardson, C. A redrawn Vandenberg and Kuse mental rotations test: Different versions and factors that affect performance. *Brain Cogn.* **1995**, *28*, 39–58. [CrossRef] [PubMed]
19. Lin, Y.S.; Suh, A. The role of spatial ability in learning with virtual reality: A literature review. In Proceedings of the 54th Hawaii International Conference on System Sciences, Honolulu, HI, USA, 5 January 2021.
20. Jones, D.; Hazelton, M.; Evans, D.J.R.; Pento, V.; Siang See, Z.; Van Leugenhaege, L.; Fealy, S. The Road to Birth: Using digital technology to visualise pregnancy anatomy. In *Digital Anatomy: Applications of Virtual, Mixed and Augmented Reality*; Uhl, J.F., Jorge, J., Lopes, D.S., Campos, P.F., Eds.; Springer: Cham, Switzerland, 2021; pp. 325–342. [CrossRef]
21. Fealy, S.; Irwin, P.; Zeynep, T.; See, Z.; Jones, D. Enhancing nursing simulation education: A case for XR innovation. *Virtual Worlds* **2023**, *2*, 218–230. [CrossRef]
22. See, Z.S.; Ledger, S.; Goodman, L.L.; Matthews, B.; Jones, D.; Fealy, S.; Ooi, W.H.; Amin, M. Playable experiences through technologies: Opportunities and challenges for teaching simulation learning and extended reality solution creation. *J. Inf. Technol. Educ. Innov. Pract.* **2023**, *22*, 67–90.
23. Radianti, J.; Majchrzak, T.; Fromm, J.; Wohlgenannt, I. A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Comput. Educ. J.* **2020**, *147*, 103778. [CrossRef]
24. Neergaard, M.A.; Olesen, F.; Andersen, R.S.; Sondergaard, J. Qualitative description—The poor cousin of health research? *BMC Med. Res. Methodol.* **2009**, *9*, 52. [CrossRef]
25. Sandelowski, M. Whatever happened to qualitative description? *Res. Nurs. Health* **2000**, *23*, 334–340. [CrossRef]
26. Roberts, K.; Dowell, A.; Nie, J.-B. Attempting rigour and replicability in thematic analysis of qualitative research data; a case study of codebook development. *BMC Med. Res. Methodol.* **2019**, *19*, 66. [CrossRef] [PubMed]
27. Bartikian, M.; Ferreira, A.; Gonçalves-Ferreira, A.; Neto, L.L. 3D printing anatomical models of head bones. *Surg. Radiol. Anat.* **2019**, *41*, 1205–1209. [CrossRef]
28. Jaffar, A.A. YouTube: An emerging tool in anatomy education. *Anat. Sci. Educ.* **2012**, *5*, 158–164. [CrossRef] [PubMed]
29. Weyhe, D.; Uslar, V.; Weyhe, F.; Kaluschke, M.; Zachmann, G. Immersive anatomy atlas-empirical study investigating the usability of a virtual reality environment as a learning tool for anatomy. *Front. Surg.* **2018**, *5*, 73. [CrossRef]
30. Kim, J.W.; Myung, S.J.; Yoon, H.B.; Moon, S.H.; Ryu, H.; Yim, J.J. How medical education survives and evolves during COVID-19: Our experience and future direction. *PLoS ONE* **2020**, *15*, e0243958. [CrossRef]
31. Shahrvini, B.; Baxter, S.L.; Coffey, C.S.; MacDonald, B.V.; Lander, L. Pre-clinical remote undergraduate medical education during the COVID-19 pandemic: A survey study. *BMC Med. Educ.* **2021**, *21*, 13. [CrossRef]
32. Acquavita, S.P.; Krummel, D.A.; Talks, A.; Cobb, A.; McClure, E. Assessing the digital divide among low-income perinatal women: Opportunities for provision of health information and counseling. *Telemed. J. E Health* **2019**, *25*, 48–54. [CrossRef] [PubMed]
33. Fealy, S.; Chan, S.; Wynne, O.; Eileen, D.; Ebert, L.; Ho, R.; Zhang, M.; Jones, D. The Support for New Mums Project: A protocol for a pilot randomised controlled trial designed to test a postnatal psychoeducation smartphone application. *J. Adv. Nurs.* **2019**, *75*, 1–13. [CrossRef]
34. Tang, K.; Gerling, K.; Chen, W.; Geurts, L. Information and communication systems to tackle barriers to breastfeeding: Systematic search and review. *J. Med. Internet Res.* **2019**, *21*, e13947. [CrossRef]
35. Connaghan, R.; Poyade, M.; Rea, P.M. Evaluation of child-friendly augmented reality tool for patient-centered education in radiology and bone reconstruction. *Adv. Exp. Med. Biol.* **2019**, *1171*, 105–126. [CrossRef] [PubMed]
36. Gordon, N.P.; Crouch, E. Digital information technology use and patient preferences for Internet-based health education modalities: Cross-sectional survey study of middle-aged and older adults with chronic health conditions. *JMIR Aging* **2019**, *2*, e12243. [CrossRef]
37. Conard, S. Best practices in digital health literacy. *Int. J. Cardiol.* **2019**, *292*, 277–279. [CrossRef] [PubMed]
38. Pandrangi, V.C.; Gaston, B.; Appelbaum, N.P.; Albuquerque, F.C., Jr.; Levy, M.M.; Larson, R.A. The application of virtual reality in patient education. *Ann. Vasc. Surg.* **2019**, *59*, 184–189. [CrossRef] [PubMed]
39. McCabe, C.; McCann, M.; Brady, A.M. Computer and mobile technology interventions for self-management in chronic obstructive pulmonary disease. *Cochrane Database Syst. Rev.* **2017**, *5*, Cd011425. [CrossRef]

40. Cahn, A.; Akirov, A.; Raz, I. Digital health technology and diabetes management. *J. Diabetes* **2018**, *10*, 10–17. [CrossRef]
41. Nandi, P.L.; Chan, J.N.; Chan, C.P.; Chan, P.; Chan, L.P. Undergraduate medical education: Comparison of problem-based learning and conventional teaching. *Hong Kong Med. J.* **2000**, *6*, 301–306. [PubMed]