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Research Paper

Problem-based Learning in the Metaverse Environment: Evaluation of Virtual Reality Applications in Medical Education

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ABSTRACT

The metaverse is defined as an inevitable evolution of the internet and holds great potential as a new medium for social interaction. Its integration into educational environments has been increasingly recommended. This study aimed to explore a technology-supported solution for the challenges experienced in the problem-based learning (PBL) process used in medical faculties, taking into account the characteristics of the current digitally native generation. Twelve medical students who had previously received face-to-face PBL training participated in the study. They were asked to evaluate both virtual and face-to-face PBL sessions in terms of the educational facilitator, physical infrastructure, educational process, and scenario. Descriptive statistics, the Wilcoxon signed-rank test, and the Mann–Whitney U test were used to compare the groups. All participants reported higher satisfaction with virtual PBL across all sub-dimensions. The overall score comparison revealed a statistically significant difference in favor of virtual PBL ($p < 0.05$). A significant difference was also found among female participants ($p < 0.05$), whereas no significant difference was observed among male participants ($p > 0.05$). Gender-based comparisons showed no statistically significant difference in satisfaction ($p > 0.05$). In conclusion, virtual PBL sessions can effectively enhance medical students' clinical reasoning, problem-solving, and communication skills while providing a flexible and engaging learning environment with high levels of satisfaction.

INTRODUCTION

Because life is a constant state of change, education practices should also be updated to reflect current trends. As it is known, the "Metaverse" is a recent media and a space where social communication takes place. Users have more freedom to produce and share in this environment. This environment allows learners to gain novel experiences that transcend temporal and spatial constraints (Alt & Raichel, 2022). Beyond gaming and entertainment, the metaverse is expected to alter our way of life and our economy. As a brand-new form of social communication, the metaverse has a lot of potential. It is advised that the metaverse be used as a learning environment in the future. By allowing students to actively participate in their education and expose them to a novel learning environment that defies time and space, the goal is to improve student interest and involvement (Kye et al., 2021). However, there are several issues with the problem-based learning (PBL) methodology employed in medical faculties. Current challenges in the implementation of PBL include limitations in physical space, organizational inefficiencies, reliance on printed scenarios, and facilitator workload. Therefore, technology-supported solutions were explored.

This study was designed as a result to give medical students technical and life skills, to offer new learning environments, to improve clinical reasoning, problem-solving, and communication skills, and to guarantee their professional and technical development in the virtual environment.

Problem-Based Learning in Medical Education

The idea behind problem-based learning is to use problems as a springboard for learning and assimilation of new information (Patel, 2023). The goal of problem-based learning (TEPBL) in medical education is to teach students basic and clinical skills based on a problem and to illustrate how these abilities will be applied in real-world situations that the students can see. One of the main components of education that inspires pupils is practice. In general, PBL involves a group of 6–8 students and an education facilitator examining a topic (Figure 1). Although there are at least two sessions, this number may rise depending on the problem's goal and associated subjects. In these sessions, students read a scenario and identify the issues of the educational facilitator through discussion. They also create hypotheses to explain the problems and indicate the subjects they need to study. Students use a variety of sources to obtain information on the subjects they will learn between sessions.

Figure 1. Analogy of problem-based learning

In Canada's McMaster University School of Medicine, problem-based learning was initially implemented in the late 1960s. From there, it quickly spread to other medical and health-related institutions around the globe. Numerous medical schools have problem-based learning as part of their curricula. Students have the opportunity to encourage the early development of cognitive skills and in-depth study through TEPD. The development of self-learning skills that last throughout a student's career and a rise in internal interest in the subject of study are two other ways that TEPD has been demonstrated to help boost motivation (Twenge et al., 2010; Norman & Schmidt, 1992; Albanese & Mitchell, 1993; McGregor et al., 1995; Morrison, 2004). Figure 2 illustrates the processes of a problem-based learning session in the medical curriculum at the AFSU Faculty of Medicine.

The first session of the script is read

- Problems are identified
- Hypotheses are put forward
- Learning topics are created
- Feedback and evaluation is done
- Free learning
  - Experts
  - Book
  - e-resources
  - Laboratory applications
  - Lecture presentations

The learned information is analyzed in the group

The second session of the script is read

- Problems are identified
- Hypotheses are put forward
- Learning topics are created
- Feedback and evaluation is done
- Free learning
  - Experts
  - Book
  - e-resources
  - Laboratory applications
  - Lecture presentations

The learned information is analyzed in the group

The third session of the script is read

The problem is solved and what has been learned is summarized

Scenario is completed with feedback

Figure 2. Problem-based learning session steps in medical education

Metaverse and Artificial Intelligence

People from all around the world can assemble in the metaverse, an interconnected virtual 3D environment, to exchange and improve their social interactions (Mystakidis, 2022). With immersive technologies like augmented reality (AR), virtual reality (VR), and artificial intelligence (AI), this environment provides people with rich living experiences. Together, these technologies enable the ongoing continuation of events like workplace meetings, discussions about music, e-sports, and more. By enhancing patient-centered care and medical education, metaverse and augmented reality technologies, including AR, VR, and AI, are believed to have a lot to offer the health sector. The idea of the metaverse is not new. The idea of immersive virtual 3D experiences was first explored in the early 2000s by the virtual 3D game Second LifeTM (Leong et al., 2008). Several important institutes then investigated how we may use 3D settings to facilitate changes in health after realizing the potential to interact with different generations and help public health campaigns. A new generation of medical experiences that were previously imagined may now be possible because of amazing advancements in computers and the development of augmented reality technology in recent years. Along with these developments, the metaverse not only improves accessibility but also fosters collaboration and offers the chance to expand, enhance, and broaden variety in the medical profession (Boulos et al., 2007).

The importance of artificial intelligence in medicine has grown increasingly evident during the past few years (Ahuja, 2019). For instance, it has been proposed that in the future, medical professionals would be able to do home screenings for diabetic retinopathy (DR) with the aid of artificial intelligence (Pieczynski et al., 2021). The rapid growth of research in this field, particularly around large language models and their integration into clinical and educational workflows, reflects a transformative trend in digital health ecosystems (Gencer & Gencer, 2025).

By telling patients in remote or places with limited access whether they exhibit DR symptoms and how urgently they require in-person ophthalmological evaluation, such a gadget would advance health equity.

However, this unexpected performance of AI could directly result in apprehension about using it in health care. Additionally, patients may perceive AI as being less impersonal and mechanical if digital avatars powered by AI are used in place of chatbots in a virtual reality setting. In turn, this may boost patient assurance, leading to broader acceptability. Accordingly, individuals with a variety of psychiatric diseases greatly benefit from the artificial intelligence-based technologies in the metadata warehouse. Patients with Borderline Personality Disorder (BPD), for instance, have a higher suicide rate. These individuals behave impulsively and hopelessly when committing suicide. A trustworthy "someone" they may always be with from an AI-based chatbot acting as a virtual helper or friend can help lessen these occasionally strong feelings. The responses given by these virtual assistants can be configured to come from dialectical behavioral therapy. Some BPD sufferers who have made suicide attempts in the past have stated that they were motivated by perplexing ideas but were too ashamed to ask for help, so they attempted suicide. Others claimed they had no one to trust and were feeling more and more empty. These patients can get an immediate, 24-hour outlet they can rely on thanks to a virtual assistant. A human's empathy, even in nonverbal signs like body language, may often reassure patients, yet AI struggles to mimic this kind of nonverbal communication. Theoretically, these restrictions may be removed if we move these applications to the metaverse, where virtual beings like avatars already exist (Montemayor et al., 2022; Wibhowo et al., 2021). When the "metaverse" search was done in April 2023, it was discovered that there were 238 articles, up from 51 in July 2022. It was discovered that in just nine months, the number of articles climbed by about five times. This article will discuss the implementation and assessment of augmented reality (AR, VR, and AI) and the metaverse phenomena in the problem-based learning settings of the medical education curriculum.

Metaverse and Medical Education

The future of medical education may be significantly impacted by augmented reality technologies. This technology can be used at every level of the medical education process, as evidenced by the expanding use cases for it. The development of our future medical education system will be accelerated by investigating and discussing these applications.

Applications of augmented reality technology may be useful during the first year of medical school when preclinical classes concentrate on fundamental subjects like anatomy, radiography, and other areas. Universities using AR and VR technologies as extra teaching aids for medical anatomy have produced promising results (Lopez & Hurley, 2021; Moro et al., 2017). Additionally, the utilization of these tools is being researched more and more for radiology teaching (Elsayed et al., 2020; Chachar et al., 2021). After assessing participants' academic performance, a review of the use of virtual reality for teaching radiology and anatomy revealed that the technology was successful in enhancing participants' understanding of anatomy (Chachar et al., 2021). All of this shows that, even though many programs are still in the early stages of development, augmented reality technology has tremendous potential for integration to support current preclinical medical curricula. Students have rare possibilities to practice physical skills, difficult clinical problems, and significant ethical concerns in virtual environments while remaining in a secure, low-risk setting (Bracq et al., 2019; Dyer et al., 2018). To gain a deeper knowledge of the long-term effects of the metaverse, it would be beneficial to further investigate the research's great potential. By strengthening the multiplicity of medical specialties, the Metaverse ecosystem and the collaborative atmosphere it creates can play a key role in supporting the growth of health equity initiatives. Although opposing efforts have gotten stronger in recent years, several medical specialties still lag because they have historically had low levels of diversity. Even in low-income areas, augmented reality and the metaverse collaborative ecosystem can serve to increase access to medical education and critical specialized exposure. Future medical professionals can network with peers early in a range of specializations and with new counselors from all over the world thanks to the educational opportunities made possible by this cutting-edge technology. Early exposure and education programs for this technology should be further investigated in light of these potential consequences (Mylavarapu et al., 2020; Ramirez and Franklin, 2019; Bing et al., 2021).

In recent years, the use of metaverse-based applications has extended significantly into the field of surgical education. High-fidelity simulators such as VR laparoscopic trainers, robotic-assisted surgery platforms, and immersive operating room simulations have been increasingly integrated into medical training programs. These platforms not only offer hands-on experience in a risk-free environment but also allow repeated practice of complex procedures, which is crucial for developing surgical competence. Additionally, the incorporation of haptic feedback technologies enables learners to develop tactile skills that closely mimic real-world surgical conditions. Such systems have been used to train students in procedures ranging from basic suturing techniques to advanced laparoscopic and robotic surgeries, contributing significantly to skill acquisition and confidence before actual patient encounters. The combination of these tools with real-time instructor feedback in metaverse environments offers a transformative potential in surgical education. Figure 3 shows a metaverse-based interactive medical education session where participants represented by avatars participate in a virtual seminar. The immersive environment includes a 3D auditorium with a central stage, a live presentation screen displaying ophthalmological images, and interactive avatars interacting with the session. Such platforms enable simulation-based learning, collaborative discussion, and real-time feedback in medical education without geographical constraints.

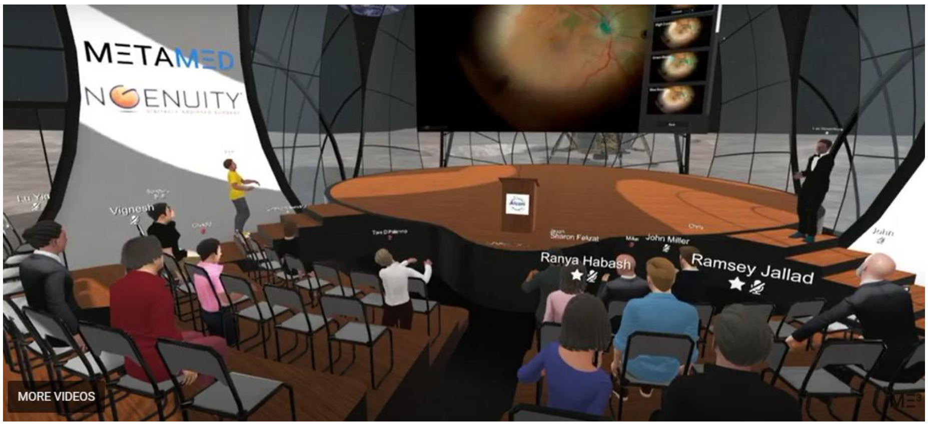

Figure 3. MetaMed Media provides 3D content for its Meta Quest 2 VR headset, including surgical videos, device demonstrations and panel discussions. A virtual reality-based medical seminar environment in the metaverse (Broytman et al., 2025).

MATERIALS AND METHODS

The design of this study was cross-sectional and inferential. The 3rd graders who are enrolled in the Faculty of Medicine during the 2022–2023 academic year and have previously participated in PBL training make up the study's universe. The sample size was calculated using the free trial version G.Power 3.1.9.4 program. Written consent was obtained from the participants in the study. Considering α=0.05, 1-β=0.80, and effect size 0.5 in the calculations, the sample size was determined as 28. However, due to technical inadequacy and budget constraints, the project was carried out with 12 people. A convenience sampling method was used. 12 students 6 boys and 6 girls participated in the study. All students were asked to evaluate the face-to-face PBL sessions in terms of the educational facilitator, physical infrastructure, educational process, and scenario before the start of the virtual PBL session. After the virtual PBL was over, the students scored the identical forms for the virtual PBL session. All analyses in this study were performed using the free trial version of the IBM SPSS 26.0 package application. After data collection, the Kolmogorov-Smirnov test was used to check for normality, and all data were confirmed to be normal. However, non-parametric tests were utilized rather than parametric tests because there were insufficient amounts of data. In the study, the Mann-Whitney U test was used for comparisons between independent groups, and the Wilcoxon ordinal sign test was employed for descriptive statistics, minimum and maximum values, mean, standard deviation, and two-group comparisons of independent groups. The function of gender in PBL education was looked at in this study because it is claimed in the literature that gender influences technology adaptation and dominance. Reliability analysis was conducted before the analysis, and it was continued after the "Cronbach's α" value of 0.921 was discovered.

Development of a Metaverse-Based Learning Environment

In this section, the process of developing a metaverse-based learning environment is discussed in detail. In the study, a metaverse-based learning environment was created using the Spatial.io platform within the scope of PBL course. Users logged in with their accounts at www.spatial.io.

After selecting the best environment from the options offered by the Spatial VR Metaverse Web application, taking into account the requirements of the PBL standards, objects related to the 3D and 2D Medical Faculty education boards were started to be added to the environment, considering these standards. This research involved the preparation of the problem-based learning simulation and the procurement of the necessary equipment. Some of these objects were added to the PBL environment to take advantage of the platform's opportunities, while others came from websites that offer free 3D models. fbx extension. Additionally, the Blender three-dimensional modeling application was used to place the environment and materials appropriate for PBL. 2D photos are sourced from the Pixebay website, which is copyleft-free. Using the free trial version of Adobe Photoshop CC software, changes were made to the images, and 3D texts were produced and added to the PBL environment.

Students can move their avatars using special gesture control apparatuses that they hold in their hands. With these apparatuses, the hands, arms and other body movements of the avatar are controlled.Avatars can perform various movements such as applause, approval, and rejection. These movements are done in a natural way with motion control apparatuses.A virtual classroom was created using the Spatial application and prepared to be used within the scope of Information Technologies course. The course materials and activities were structured for objectives such as recognizing computer hardware components, explaining their functions and identifying their problems.Students visited the virtual environment with the teacher and examined the related technologies in three dimensions and participated in the active learning process. Students were supported with practical activities such as locating the components on the motherboard.

The Spatial application can be downloaded to mobile devices and used in VR and AR modes. The teacher delivered AR supported lessons with Hololens 2 glasses and conducted lessons with VR devices.

Scenario

The Spatial VR application's virtual reality goggles were utilized. Within the framework of developing event scenarios; Using the Adobe Photoshop CC software, images were modified, and 3D texts were produced and added to the PBL environment. The Spatial VR application's virtual reality goggles were utilized. A scenario topic that supports the preclinical, clinical, and fundamental education of the students studying at the faculty of medicine as well as having fundamental learning goals and sub-goals has been determined and the scenario has been shaped in the metaverse environment in this direction. This is all part of the preparation of event scenarios. One scenario was examined within the parameters of the project, in keeping with the stated learning purpose. The following characteristics were taken into account when creating the scenarios.

- The topic under study in the scenario is designed to integrate basic sciences, preclinical sciences, and clinical sciences. The scenario is structured in a way that will pique the student's interest:
- The scenario's subject will be as clearly and unambiguously related to the committee's topics as possible.
- The information presented in the scenario will be supported by materials like laboratory findings and radiological examinations.
- The subject determined in the scenario will be concluded with a firm conclusion.
- It will be written in detail (from the general to the specific) what questions the education facilitators should ask students to achieve these learning goals.
- The scenario will follow the practice (taking patient information, questioning the system, CV/family history, allergy history, habits, physical examination, requesting necessary tests, referral, and asking for consultation). (Creating these questions will make it easy to generate standard referrals and ask standard questions in all training sessions,
- Which learning objective should be stressed less in the scenario note provided to training facilitators; it specifies which learning objective should be learned primarily.

RESULTS

Twelve participants helped to finish the study. The pupils are all 3rd graders who have finished the face-to-face PBL program. The layout of the virtual world is identical to that of the in-person setting. To grab the attention of the pupils, specifics like a round table, chairs (different from the tutorial), a virtual pen, and notepads on the table are arranged. Each student first signed up for the virtual environment using their e-mail addresses. The reporter (one of the students) was informed of the code while the students were using their glasses to join the virtual environment. After the reporter approved his admission on the computer, the remaining students were each taken to the environment in turn. In groups of three, the students entered the PBL session. They walked to the locations where the session would start after first visiting the metaverse environment, which was set up to facilitate preclinical, clinical, and basic education on the walls (Figure 4).

Figure 4. The metaverse environment is prepared to support preclinical, clinical, and basic education.

In a face-to-face setting, pupils come to class with name cards in hand. The education facilitator will be able to identify the students by name if they are given the option to access the virtual environment with their names and surnames.
The instructor assisted with it by reading and assessing the scenario, scoring the students in the VR environment after the training, and facilitating it during the training. During the scenario flow, the scenario reading continued in the virtual environment by writing the necessary notes in the Word file with the aid of the training guide. One of the students who participated in the session as a reporter shared a Word file from the computer and the scenario as a presentation (Figure 5).

Figure 5. Word document and presentation script shared

The instructor instructed the pupils to make notes of the subjects and materials that need to be studied for the upcoming sessions as needed during the scenario. As seen in the student identified as "Emirhan" in Figure 6 (Figure 6), the students used their notebooks and VR glasses to take notes on the subjects and resources they needed to learn.

Figure 6. A screenshot of pupils using a virtual environment to take notes

After the second training session for the scenario was over, the reporter stopped the session without any issues by notifying the router. Then, after the students evaluated the educational guide, the physical infrastructure, the educational process, and the scenario for the face-to-face and virtual environments, the descriptive statistics for the PBL evaluations are examined. For each item made for the virtual environment, "Small group work made it easier for me to learn" and "The structure of the scenario, to extract the learning objectives. it was appropriate." are found. All scores, except expressions, were found to be greater than face-to-face scores. From this, it may be inferred that PBL in the virtual world results in greater satisfaction for all students. (Table 1), (Table 2). In addition, during face-to-face PBL, expressions such as "The educational facilitator communicated nonverbally as an observer and avoided giving information to the students", "The education facilitator did not give direct information", "All friends actively participated in the discussions" were scored the lowest, while these expressions were scored in the virtual environment. expressions with increasing scores. From this, it can be concluded that the attention and participation of the students in the virtual environment is higher or that the education guide is more careful.

Table 1. Descriptive statistics regarding the evaluations of the educational environment and physical environment made in face-to-face and virtual environments

Factor	Expressions	Min.	Max.	**Face-to-face PBL**		**PBL in Virtual Environment**	
				Mean	Std. Deviation	Mean	Std. Deviati on
Training Router	The educational direction provided careful guidance to students through all steps of the PBL session process.	2.00	5.00	4.0833	0.7929	**4.6667**	0.4923
	Education direction. created a positive evaluation environment.	2.00	5.00	4.2500	0.8660	**4.6667**	0.4923
	Education direction. got everyone involved.	2.00	5.00	3.8333	1.0298	**4.5000**	0.5222
	The education facilitator helped the students, who had difficulties in finding the opportunity to participate in the subject, to take the floor.	2.00	5.00	3.9167	1.0836	**4.3333**	0.4923

	The instructional facilitator helped students focus on the topic and make connections between concepts.	2.00	5.00	4.0833	1.1645	**4.6667**	0.4923
	The instructional facilitator used nonverbal communication as an observer and avoided giving information to the students.	1.00	4.00	2.8333	1.0298	**3.1667**	1.4668
	Education direction. asked questions at appropriate times.	2.00	5.00	4.1667	0.9374	**4.4167**	0.5149
	The training router did not provide direct information.	1.00	5.00	3.2500	1.1381	**3.8333**	0.8348
	The training facilitator ensured that all discussions were in the group process and led the group to reach a consensus.	2.00	5.00	3.9167	0.7929	**4.5000**	0.5222
	The training guide informed us on how to access the resources.	1.00	5.00	3.5000	1.0871	**3.6667**	0.9847
	Education direction. I am satisfied with its performance.	2.00	5.00	4.2500	0.9653	**4.6667**	0.4923
Physical Avg.	The session environment was physically sufficient.	2.00	5.00	3.8333	0.8348	**4.0000**	1.1281
	The duration of the sessions was sufficient.	2.00	5.00	4.0000	0.9534	**4.5833**	0.6685

Table 2. Descriptive statistics on the training process and scenario evaluations in face-to-face and virtual environments

Factor	Expressions	Min.	Max.	**Face to face PBL**		**PBL in Virtual Environment**	
				Mean	Std. Deviation	Mean	Std. Deviation
Education Process	The start and end times of the sessions were complied with.	2	5	3.9167	1.3113	**4.3333**	0.7785
	The implementation of the sessions contributed to my learning of the content of the subject.	2	5	4.1667	0.8348	**4.4167**	0.5149
	The implementation of the sessions supported and improved my communication skills.	3	5	3.9167	0.5149	**4.4167**	0.5149
	Small group work made it easier for me to learn.	3	5	4.4167	0.7929	4.4167	0.6685
	I cooperated with my friends.	2	5	3.5000	1.2431	**4.5833**	0.6685
	All friends actively participated in the discussions.	1	5	3.1667	1,1934	**4.6667**	0.4923
	Education direction. gave more weight to guidance, not to information.	3	5	4.3333	0.7785	**4.5000**	0.5222
	Direction. intervened only when necessary.	2	5	4.0833	0.9003	**4.5000**	0.5222
	Direction. gave effective feedback.	3	5	4.500	0.6742	**4.7500**	0.4522
Scenario	Questions about the script led me to research.	2	5	4.0833	0.7929	**4.5833**	0.5149
	The structure of the script was suitable for extracting learning objectives.	4	5	4.3333	0.4923	4.3333	0.4923
	The script was interesting.	2	5	4.000	0.9534	**4.4167**	0.6685

It allowed me to associate our scenario information with the clinic.	3	5	4.4167	0.7929	**4.9167**	0.2886
Previous information with the script. i was able to use it.	2	5	3.9167	1.2401	**4.1667**	1.0298
I developed my previous knowledge of the script.	2	5	4.1667	0.9374	**4.7500**	0.4522
The scenario was realistic.	4	5	4.3333	0.4923	**4.9167**	0.2886
The scenario gave rise to different hypotheses.	1	5	3.7500	1.5447	**4.6667**	0.4923

Table 3. Comparison of overall scores for face-to-face PBL and virtual PBL environment

Group	Mean	Standard Deviation	Minimum	Maximum	p value
Face to face	120.4167	15.9741	92.00	143.00	0.016*
Virtual Environment	134.5000	8.5864	123.00	148.00	

*Wilcoxon sequential sign test, p<0.05 statistically significant

As a result of the overall score comparison for the face-to-face PBL and virtual PBL environment, a significant difference was observed for the two groups (p=0.016<0.05) (Table 3).

Table 4. Face-to-face PBL and virtual PBL environment-dependent group comparison of gender

Gender	Environment	p-value
Male	Face-to-face - Virtual	0.345
Female		0.028*

* Wilcoxon signed-rank test, p<0.05 statistically significant

A statistically significant difference between the face-to-face environment and the virtual environment was discovered when comparing whether the girls were more satisfied with the face-to-face or virtual environment (p<0.05). The comparison of whether the men were more satisfied with the face-to-face versus virtual environment revealed no statistically significant difference (p>0.05). This indicates that girls are more satisfied than boys with PBL in the virtual world (Table 4).

Table 5. Independent group comparison of gender in face-to-face PBL and virtual PBL environment

Environment	Gender	p value
Virtual	Female Male	0.818
Face to face	Female Male	0.065

*Mann-Whitney U test, p<0.05 statistically significant

The comparison of whether boys or girls were more satisfied with the PBL in the virtual world did not reveal any statistically significant differences (p>0.05). No statistically significant difference was discovered once more (p>0.05) when comparing whether girls or boys are more satisfied with PBL performed in a face-to-face context. They appear to be equally satisfied with the PBL in both online and in-person settings (Table 5).

DISCUSSION

The Covid-19 epidemic has made "distance education" a reality in the lives of both students and academic staff. Students and all educators have had a really difficult time during this process. On the other hand, even at the pre-clinical stage, medical education is at the forefront of teaching that cannot be done remotely. Even though this condition is well recognized, for a very long time, medical education was conducted remotely, except during the internship period. Limiting the distance learning time to the pandemic is not appropriate.

Every second of our existence is filled with this phenomenon, which is an exceptional situation in which unpredictable natural disasters like earthquakes, floods, avalanches, and air pollution happen. The drawbacks of distance learning can be reduced by creating an atmosphere that simulates a classroom in the home.

In light of this, the generation that is considered to be the future and was born between the years 2000 and 2020 resides in the digital age and has adapted to a wide range of digital technologies and applications (Binark & Karataş, 2015). Generation Z, also known as the "digital generation," is characterized by its dependence on technology, productive use of social media, era of high-tech communication, aptitude for problem-solving with technology, and level of connectivity (Kapil & Roy, 2014). This generation can obtain information rapidly, is tech-savvy, does not adhere to formality, picks things up quickly, and loves diversity because they grew up with the internet (4). They wish to safeguard their future and are self-assured (Özkan & Solmaz, 2015). They process information differently and think in distinct ways (Prensky, 2001). Because of this, it is anticipated that a learning environment built on the Metaverse will improve student learning, intrinsic motivation, and self-efficacy, increasing the perceived relevance of activities related to medical education.

Beyond gaming and entertainment, it is expected that the metaverse will alter our way of life and the way we do business. As a brand-new medium for social interaction, the metaverse has enormous promise. It is suggested that the metaverse be used as a learning environment in the future: By offering a fresh experience setting that transcends time and space, it is intended to improve student interest and participation through active participation in learning (Onu et al., 2024).

When combined with AI, AR, and VR, Metaverse has a wide range of potential health applications that can significantly advance medical education, medical literacy, and more. The metaverse can extend the reach of healthcare to better serve more people through the development of telemedicine. While there have already been some initiatives to use metaverse technology in healthcare, there is still a lot of space for development. Although there may be negative effects associated with using Metaverse in medicine that should be taken into account, patients with psychiatric problems may have more access to solutions like virtual therapy. Some colleges have begun to incorporate augmented and virtual reality technology as supplemental teaching aids in the curriculum for medical education. The conventional model of medical education could be completely altered by the use of augmented reality systems for surgical instruction. It's possible that using Metaverse in medicine will have downsides including high implementation costs, medical desensitization, miscommunications, broken equipment, and security flaws. Additionally, it has been shown that people can experience "Post-VR sadness" or "VR Hangover" in which they temporarily lose their mood after using virtual reality equipment (Peckmann et al.,2022).

Alt and Raichel (2022) emphasized that problem-based learning (PBL) in higher education is an important tool for developing long-term learning skills and should be supported by self- and peer assessments (Alt & Raichel, 2022). Our study similarly shows that PBL increases student satisfaction when applied in a virtual environment.

Kye et al. (2021) examined the potentials and limitations of using metaverse in education and suggested that this environment can enrich learning experiences. This study proves that the use of metaverse in PBL applications in medical education can increase students' satisfaction and motivation to learn.

Twenge et al. (2010), by examining the differences in work values between generations, stated that younger generations are more prone to technology and more open to learning with digital tools. In our study, it was found that especially Generation Z students showed higher satisfaction in the virtual PBL environment.

Norman and Schmidt (1992) examined the psychological foundations of PBL and emphasized that this method improves students' clinical thinking and problem-solving skills. Our findings support that the virtual PBL environment contributes to the development of these skills.

Morrison (2004) expressed concerns about the future of PBL and stated that this method may face various difficulties. Our study shows that PBL in a virtual environment can overcome these challenges.

Mystakidis (2022) suggested that the metaverse offers a new environment for social interaction and has a wide application potential in education. Our study reveals that metaverse can be successfully applied in medical education.

Boulos et al. (2007) examined the potential of using virtual worlds such as Second Life in health education and stated that these environments can provide students with new experiences. Our study also shows that metaverse enriches the educational experiences of medical students.

Ahuja (2019) examined the role of artificial intelligence in medicine and suggested that in the future, healthcare professionals may perform AI-assisted scans at home. Our study shows that the combination of AI and metaverse can provide significant advantages in medical education.

Moro et al. (2017) examined the effectiveness of virtual and augmented reality technologies in anatomy education and reported that these technologies improved learning outcomes. Our study similarly reveals that virtual reality technologies support PBL in medical education.

Dyer et al. (2018) examined the use of virtual reality for teaching empathy in medical education and showed that this technology increased student empathy. Our study supports that the virtual PBL environment improves students' communication and empathy skills.

Barrows and Tamblyn (1980) showed that PBL has a strong impact on learning and motivation in medical education. According to their study, PBL helps students develop clinical thinking and problem solving skills. In our study, it was observed that virtual PBL applications improved similar skills of students and provided satisfaction.

Schmidt and Moust (2000) stated that PBL is a student-centered approach and encourages active participation in the learning process. Our study shows that the virtual PBL environment increases student engagement and provides higher satisfaction than traditional face-to-face PBL.

Mantovani (2003) stated that virtual reality (VR) technologies offer an innovative and effective learning environment in medical education. In our study, it was found that the use of VR technology in PBL processes enriched students' learning experiences and increased satisfaction.

Dede (2005) suggested that metaverse technologies can increase student interaction and collaboration. In our study, it was observed that PBL sessions conducted in a metaverse environment increased student interaction and satisfaction. Recent studies have demonstrated that artificial intelligence-based dialogue systems can even approach or exceed human performance in domain-specific medical assessments, suggesting strong potential for integration in advanced educational settings (Gencer & Gencer, 2024).

Cook and Dupras (2004) stated that augmented reality (AR) technologies are an effective tool to improve students' clinical skills in medical education. In our study, it was observed that the use of AR and VR technologies in a virtual PBL environment improved students' clinical thinking and problem-solving skills and increased overall satisfaction.

Garrison and Anderson (2003) stated that online and virtual learning environments increase flexibility and accessibility, but technical problems and uninterrupted internet connection are critical. Similarly in our study, it was observed that virtual PBL environments provide flexibility to students, but the quality of internet connection and equipment is important.

Hrastinski (2008) stated that virtual learning environments can provide better engagement, especially for students who have difficulty in face-to-face communication. Our findings also show that the virtual PBL environment enabled students who were less active in face-to-face sessions to show higher engagement. Recently, the transformative role of extended reality (XR) and artificial intelligence in medical education has also been highlighted.

Curran et al. (2023) highlighted the effectiveness of XR tools such as virtual, augmented, and mixed reality in enhancing surgical and anatomical education through increased spatial context and engagement. Additionally, Rodgers et al. (2023) emphasized how AI-driven simulation environments can personalize learning, provide real-time feedback, and enhance learner performance tracking—offering a scalable approach to medical training.

Recent literature also highlights the growing implementation of low-cost, high-impact virtual surgery simulations in resource-limited settings. For example, (Bing et al., (2021)) demonstrated that immersive VR environments can deliver valuable surgical training experiences in African contexts where access to traditional operating room instruction is limited. Such findings align with the outcomes of our study and support the metaverse's potential to democratize surgical education globally by offering scalable and accessible alternatives. Moreover, Mylavarapu et al., (2020) emphasized the importance of increasing diversity and early exposure within competitive medical subspecialties. Metaverse-based platforms, with their ability to simulate varied clinical settings and enable interactions with peers and mentors across geographies, can play a pivotal role in addressing disparities in medical education and enhancing equitable access to specialty training.

CONCLUSION

In this study, problems with physical space, organizational structure, scenario presentation using paper and pencil, the simultaneous and extracurricular workload of PBL directors experienced in exceptional circumstances, or the PBL process in problem-based teaching courses in medical education were examined in light of current technological opportunities and the characteristics of the educated generations. There was a need for a technologically supported solution in the digital realm. The virtual environment has emerged as an environment with high satisfaction for students in every aspect compared to face-to-face education. Students who were introduced to PBL in the virtual environment and wore VR glasses for the first time expressed this situation with words expressing admiration such as wow, incredible, interesting, enjoyable, and very beautiful.

After this application, some results have been obtained showing some difficulties of living this experience in the virtual environment, and at the same time, PBL can be completed in medical education under difficult and extraordinary conditions. In terms of difficulties;

- The study's eyewear should be as light as possible to prevent the learner from losing focus due to fatigue.
- Some students find it difficult to communicate effectively in a virtual setting and are less able to use body language than they can in a face-to-face setting, which can make for a better learning environment.
- The biggest issue is the internet environment. To finish the session with all enrolled students, each student must have constant internet access at home.
- Conveniently, this environment has served as something of a hiding place for pupils who are shy and find it difficult to express themselves in front of others. But rather than hiding himself, this cover allowed the student to express himself more clearly.
- Students who like to blend into the background more in a face-to-face setting tend to express themselves more freely in a virtual setting. Additionally, the students who speak less in the face-to-face session are evaluated favorably in the virtual environment, as evidenced by their high scores.
- Some students claimed that they could concentrate more readily online than in person and that they did not bother their classmates.

There was no statistically significant difference between the face-to-face environment and the virtual environment for the boys, but there was a statistically significant difference when comparing whether the girls were more satisfied with the face-to-face environment or the virtual environment. This can be attributed to the fact that female students are more extroverted online than they are in person and that this difference is brought on by the ease with which they can express themselves. No statistically significant difference was discovered for either gender when comparing the satisfaction of boys and girls with the PBL in the virtual environment.

With the help of the digital environment and technological support, it is anticipated that the existing issues with PBL and the problem-based learning environment in the virtual world will be resolved. There are also not many studies on problem-based learning environments based on the metaverse. To help aspiring doctors find new mentors, the Metaverse might also increase access to educational opportunities for underprivileged communities. In conclusion, more patients will ultimately benefit from the application of the metaverse to the medical industry by expanding the range of alternatives available to patients, healthcare professionals, and educators. It has been found through this study, which involved students from the Faculty of Medicine, that developing professional and technical skills, offering new learning environments, enhancing clinical thinking/reasoning, problem-solving and communication skills, and more can all be done in a virtual environment.

REFERENCES

Ahuja, A. S. (2019). The impact of artificial intelligence in medicine on the future role of the physician. PeerJ, 7, e7702. https://doi.org/10.7717/peerj.7702

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. Academic Medicine, 68(1), 52–81.

Alt, D., & Raichel, N. J. (2022). Problem-based learning, self-and peer assessment in higher education: Towards advancing lifelong learning skills. Research Papers in Education, 37(3), 370–394. https://doi.org/10.1080/02671522.2020.1849371

Barrows, H. S., & Tamblyn, R. M. (1980). Problem-based learning: An approach to medical education. Springer Publishing Company.

Binark, M., & Karataş, Ş. (2015). Digital generations: How to study digital generations? In TBD 32. National Informatics Congress (Ankara). https://www.academia.edu/19706219/Dijital_Ku%C5%9Faklar_Dijital_Ku%C5%9Faklar%C4%B1_Nas%C4%B1l_%C3%87al%C4%B1%C5%9Fmal%C4%B1

Bing, E. G., Brown, M. L., Cuevas, A., Sullivan, R., & Parham, G. P. (2021). User experience with low-cost virtual reality cancer surgery simulation in an African setting. JCO Global Oncology, 7(1), 435–442. https://doi.org/10.1200/GO.20.00510

Boulos, M. N. K., Hetherington, L., & Wheeler, S. (2007). Second Life: An overview of the potential of 3-D virtual worlds in medical and health education. Health Information and Libraries Journal, 24(4), 233–245. https://doi.org/10.1111/j.1471-1842.2007.00733.x

Bracq, M. S., Michinov, E., & Jannin, P. (2019). Virtual reality simulation in nontechnical skills training for healthcare professionals: a systematic review. Simulation in Healthcare, 14(3), 188-194.https://doi.org/ 10.1097/SIH.0000000000000347

Broytman, D., Rosenberg, E., & Fewer, M. V. A. (2025). Expanding opportunities in ophthalmic surgical training. MetaMed Media. https://www.metamedmedia.com/

Chachar, T. S., Yousif, N., Sulaibikh, L., Abdulqader, F., Alqahtani, M., Yousuf, N., & Abdulqader Sr, F. (2021). First Report of Acute Myocarditis Post-Pfizer-BioNTech COVID-19 Vaccination in the Kingdom of Bahrain. Cureus, 13(12).https://doi.org/ 10.7759/cureus.20313

Cook, D. A., & Dupras, D. M. (2004). A practical guide to developing effective web-based learning. Journal of General Internal Medicine, 19(6), 698–707. https://doi.org/10.1111/j.1525-1497.2004.30029.x

Curran, V. R., Xu, X., & Meruvia-Pastor, O. (2023). Use of extended reality in medical education: An integrative review. Medical Science Educator, 33(1), 1–13. https://doi.org/10.1007/s40670-022-01698-4

Dede, C. (2005). Planning for neomillennial learning styles: Implications for investments in technology and faculty. In Educating the Net Generation (pp. 226–247). London: Lippincott Williams.

Dyer, E., Swartzlander, B. J., & Gugliucci, M. R. (2018). Using virtual reality in medical education to teach empathy. Journal of the Medical Library Association: JMLA, 106(4), 498.https://doi.org/ 10.5195/jmla.2018.518

Elsayed, M., Kadom, N., Ghobadi, C., Strauss, B., Al Dandan, O., Aggarwal, A., et al. (2020). Virtual and augmented reality: Potential applications in radiology. Acta Radiologica, 61(9), 1258–1265.https://doi.org/10.1177/0284185119897362

Garrison, D. R., & Anderson, T. (2003). E-learning in the 21st century: A framework for research and practice. Routledge.

Gencer, G., & Gencer, K. (2024). A comparative analysis of ChatGPT and medical faculty graduates in medical specialization exams: Uncovering the potential of artificial intelligence in medical education. Cureus, 16(8). https://doi.org/ 10.7759/cureus.66517

Gencer, G., & Gencer, K. (2025). Large language models in healthcare: A bibliometric analysis and examination of research trends. Journal of Multidisciplinary Healthcare, 223–238.https://doi.org/10.2147/JMDH.S502351

Hrastinski, S. (2008). Asynchronous and synchronous e-learning. Educause Quarterly, 31(4), 51–55. https://doi.org/10.1136/bmj.a683

Kapil, Y., & Roy, A. (2014). A critical evaluation of generation Z at workplaces. International Journal of Social Relevance & Concern, 2(1), 10–14.

Kye, B., Han, N., Kim, E., Park, Y., & Jo, S. (2021). Educational applications of metaverse: Possibilities and limitations. Journal of Educational Evaluation for Health Professions, 18. http://doi.org/10.3352/jeehp.2021.18.32

Leong, J. J., Kinross, J., Taylor, D., & Purkayastha, S. (2008). Surgeons have held conferences in Second Life. BMJ, 337.

López-Ojeda, W., & Hurley, R. A. (2021). Extended-reality technologies: An overview of emerging applications in medical education and clinical care. The Journal of Neuropsychiatry and Clinical Neurosciences, 33(3), 191–198. https://doi.org/10.1176/appi.neuropsych.21030067

Mantovani, F. (2003). VR learning: Potential and challenges for the use of 3D environments in education and training. In CyberPsychology: Mind, Cognitions and Society in the Internet Age (pp. 207–225). London: Lippincott Williams.

McGregor, D. B., Arcomano, T. R., Bjerke, H. S., & Little, A. G. (1995). Problem orientation is a new approach to surgical education. The American Journal of Surgery, 170(6), 656–659.https://doi.org/10.1016/S0002-9610(99)80036-1

Montemayor, C., Halpern, J., & Fairweather, A. (2022). In principle obstacles for empathic AI: Why we can't replace human empathy in healthcare. AI & Society, 37(4), 1353–1359.https://doi.org/10.1007/s00146-021-01230-z

Moro, C., Štromberga, Z., Raikos, A., & Stirling, A. (2017). The effectiveness of virtual and augmented reality in health sciences and medical anatomy. Anatomical Sciences Education, 10(6), 549–559. https://doi.org/10.1002/ase.1696

Morrison, J. (2004). Where now for problem based learning? The Lancet, 363(9403), 174. https://doi.org/10.1016/S0140-6736(03)15298-1

Mylavarapu, P., Gupta, N. E., Gudi, V., Mylavarapu, A., Daniels, L. B., & Patel, M. (2020). Diversity within the most competitive internal medicine fellowships: Examining trends from 2008 to 2018. Journal of General Internal Medicine, 35, 2537–2544. https://doi.org/10.1007/s11606-020-06008-5

Mystakidis, S. (2022). Metaverse. Encyclopedia, 2(1), 486–497. https://doi.org/10.3390/encyclopedia2010031

Norman, G. R., & Schmidt, H. G. (1992). The psychological basis of problem-based learning: A review of the evidence. Academic Medicine, 67(9), 557–565.

Onu, P., Pradhan, A., & Mbohwa, C. (2024). Potential to use metaverse for future teaching and learning. Education and Information Technologies, 29(7), 8893-8924. https://doi.org/10.1007/s10639-023-12167-9

Özkan, M., & Solmaz, B. (2015). The changing face of the employees—Generation Z and their perceptions of work (A study applied to university students). Procedia Economics and Finance, 26, 476–483. https://doi.org/10.1016/S2212-5671(15)00876-X

Patel, J., PBLP. (2023). Problem-based learning. http://rds.sem-ums.ac.ir/edc/downloads/problem-based-learning

Peckmann, C., Kannen, K., Pensel, M. C., Lux, S., Philipsen, A., & Braun, N. (2022). Virtual reality induces symptoms of depersonalization and derealization: A longitudinal randomized control trial. Computers in Human Behavior, 131, 107233. https://doi.org/10.1016/j.chb.2022.107233

Pieczynski, J., Kuklo, P., & Grzybowski, A. (2021). The role of telemedicine, in-home testing and artificial intelligence to alleviate an increasingly burdened healthcare system: Diabetic retinopathy. Ophthalmology and Therapy, 10(3), 445–464. https://doi.org/10.1007/s40123-021-00353-2

Prensky, M. (2001). Digital natives, digital immigrants. On the Horizon, 9(5), 1–6. NCB University Press.

Ramirez, R. N., & Franklin, C. C. (2019). Racial diversity in orthopedic surgery. Orthopedic Clinics, 50(3), 337–344. https://doi.org/10.1016/j.ocl.2019.03.010

Rodgers, D., Ahmed, R. A., & Misra, A. (2023). Artificial intelligence in healthcare simulation: Hype or hope. International Journal of Healthcare Simulation. https://doi.org/10.54531/CAPM8773

Schmidt, H. G., & Moust, J. H. C. (2000). Factors affecting small-group tutorial learning: A review of research. In G. R. Norman & H. G. Schmidt (Eds.), Academic medicine (pp. 708–722). Philadelphia: Lippincott Williams.

Twenge, J. M., Campbell, S. M., Hoffman, B. J., & Lance, C. E. (2010). Generational differences in work values: Leisure and extrinsic values increasing, social and intrinsic values decreasing. Journal of Management, 36(5), 1117–1142.https://doi.org/10.1177/0149206309352246

Wibhowo, C., & Sanjaya, R. (2021). Virtual assistant to suicide prevention in individuals with borderline personality disorder. In 2021 International Conference on Computer & Information Sciences (ICCOINS) (pp. 219–224). IEEE. https://doi.org/10.1109/ICCOINS49721.2021.9497160.