

Effectiveness of a Spatial.io-Based Metaverse for Enhancing Cooperative Learning among Radiology Students in a Quasi-Experimental Study

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Abstract - Metaverse refers to a 3D virtual world in which immersive, interactive, and collaborative learning experiences can be achieved in higher education. In this study, a metaverse for educational purposes using Spatial.io was designed for training in interventional radiology and tested for its effectiveness on enhancing cooperative learning of university students in Peru. The research was done using a quasi-experimental pretest-posttest design, where there was a control group (CG, n=18) and experimental group (EG, n=18). EG underwent 15 sessions of metaverse-based learning while the CG underwent conventional learning. Seven dimensions of cooperative learning were measured using a validated scale. The normality of data was evaluated by utilizing the Shapiro-Wilk test, and the differences between the groups were tested using the Mann-Whitney U test with a $p < 0.05$ level of significance. The findings showed a significant improvement in the outcomes of cooperative learning in the experimental group when comparing to the control group ($p < 0.001$ post-test). There was significant improvement in positive interdependence ($p = 0.022$), interaction ($p = 0.006$), social skills ($p = 0.000$), group reflection ($p = 0.002$), evaluation ($p = 0.020$), and tutoring ($p = 0.000$). However, there was no significant difference in the heterogeneity dimension ($p = 0.279$). The results have shown that Spatial.io metaverse can effectively boost cooperative learning and socialization skills of radiology students and therefore should be used as one of the innovative educational methods in health sciences.

Keywords: Cooperative Learning, Metaverse, Interventional Radiology, Virtual Reality, Education, Spatial.io

I. INTRODUCTION

Education within the health sciences field is evolving rapidly, as modern learners are very competent in using technology and expect more interaction and collaboration within the education process (Krishnamurthy et al., 2022). It has long been suggested that learning is best conducted in a team, but

actually, learning works best in pairs or in small groups, because this kind of activity solves the issue of misunderstanding and provides better possibilities for teaching each other. Knowledge acquisition thus takes place much more efficiently (Pan et al., 2023). Such approach in higher education has proved to result in improved attitudes, academic performance, clinical skills, and overall satisfaction from the course (Lee et al., 2025).

Utilization of virtual reality in higher education has created new vistas of cooperative learning and innovative support systems, particularly in the case of higher professions like interventional radiology (Wang et al., 2023). Cooperating learning techniques have been found more fruitful in comparison with competing peer-to-peer learning techniques. Class interaction used to occur only in face-to-face interactions, but due to the COVID-19 virus in 2020, it became evident that online interaction should also remain adaptive in nature (Peter et al., 2024). This has resulted in the utilization of various kinds of learning aids like self-paced modules, online courses, virtual conferencing, webinars, podcasts, blogs, and social media-based education (Lewis et al., 2024).

Teaching professionals had to face problems of adjusting to new changes and platforms, as well as how to deliver optimal education to their learners through communication problems, assessing the performance of learners, the online learning environment, pandemic-induced anxiety and stress, technophobia, and time management (Rajab et al., 2020). Although there are various applications like Zoom, Google Meet, and Microsoft Teams that are used for remote education, these applications are basically oriented toward 2-dimensional interaction instead of collaborative and engaging ones (Peter et al., 2024). The platforms in the sense

of using platforms for remote education can be used to create breakout rooms, where learners can engage in group sessions of 3 to 4 individuals by watching the isolated and stationary learner (Wang et al., 2023). These innovative and motivating learning tools could not be developed without the use of augmented, mixed, and virtual reality in this digital age (De Gagne et al., 2023; Cano et al., 2024).

The use of technology within the process makes what we call “digital” or “technology-oriented” medical students more familiar and engaged with digital technology. Some different medical specialties (e.g., otolaryngology, surgery, radiology, etc.) have incorporated technology into their curriculum (Aguado-Linares & Sendra-Portero, 2023). Emerging technologies offer much promise not only for further development of technology but also for new approaches to classical educational methods in medicine (Tsao et al., 2023) e.g., simulations or virtual technology, or even online platforms (Lewis et al., 2024).

Collaboration of specialists in various fields is a key element of success in health science practice. Interventions are carried out by multidisciplinary teams which must collaborate in order to ensure patient safety and provide optimal treatment (Fowler et al., 2018). Professional communication is an important aspect of developing interpersonal skills necessary for communication with patients, radiologists, and other healthcare professionals, and efficient communication within an effective working environment (Peter et al., 2024).

Games, mobile applications, and simulations can be used in education to enhance the learning process, engagement, and cooperation of peers. What is most important is that it allows students to remain involved and to grasp complex assignments (Krishnamurthy et al., 2022) in contrast to traditional classes that are less interesting than these ones. Motivation, engagement, performance, and memorization of information become better thanks to it (Banerjee et al., 2023). Since the Millennials (1982–1996) and Generation Z (1997 onwards) make up the bulk of college students, the use of games becomes an educational approach that corresponds to their needs (Mobley et al., 2023).

Cooperative Learning

The CL method is student-oriented, and therefore the correct implementation of the method is crucial for the professional and social development of students (Atxurra de Blas et al., 2015). It involves performing educational activities in small groups of 3 to 5 people, where students develop not only their own knowledge but also the knowledge of other students. Based on the research, the use of a mediator is crucial for working with students and solving given assignments (Cascante et al., 2016).

There are a number of dimensions in cooperative learning. The first dimension is positive interdependence, meaning that for the group members to accomplish the goal of the task, each member must succeed. Each individual is not only

concerned about his or her task but is also concerned about the task of others. Interaction entails communication between peers, and it involves helping one another to be successful in the task at hand.

Social skills become one more significant aspect, including building trust, assertiveness, and good organizing. Skills development helps to create a favorable learning atmosphere and enhance academic performance.

Group reflection: At the end of the session, all group members have to reflect upon their strengths and weaknesses to improve themselves personally. It is a perfect opportunity to assess behavior, attitudes, skills, and learning of all group members through self-assessment and peer assessment.

The heterogeneity of the group emphasizes the necessity to create a group of different abilities, interests, and other features and shows positive academic performance compared to the homogeneous one (Cascante et al., 2016).

It is crucial because the evaluation takes into account not only the individual but also the group work by using techniques like rubrics, checklists, and combined evaluations. Lastly, tutoring means the assistance that is given by the teacher in helping the students understand the academic activity in which they are engaged and giving timely assistance. The teacher is the facilitator, the guide, and supervisor of the teaching-learning process; likewise, an active role is expected from him/her (Atxurra de Blas et al., 2015).

Metaverse

The metaverse is an innovative idea used in education that was conceived way back in 1992 in a book by Neal Stephenson titled **Snow Crash**, wherein he describes a world in which digital agents called avatars interact with each other. It has been noted recently that the metaverse is a space where the real world intersects with the virtual world, creating new avenues for education (Chen et al., 2025). Facebook made headlines when in 2021 it changed its name to Meta (Zhang et al., 2022).

It has three basic characteristics: the first being that it is a shared space; the second being that it is a persistent space; and thirdly, it is a decentralized space using technology like blockchain (Chen et al., 2025).

The Metaverse in Education

During the last third of the twentieth century, there have been conversations regarding the definition of virtual reality (VR), which entailed all sorts of technology, hardware, and software modeling a user's engagement in a virtual environment (Rodríguez-Flórido et al., 2024). At present, this technology is becoming easier to use for both teachers and students, but it should certainly not pose any obstacle to the teaching of academic content. In addition, the study of the metaverse recorded few citations between 2019 and 2021,

from 0 to 16 citations; however, in 2022, it changed drastically with 1,146 citations. In the period of 2023 to 2024, the number of citations increased from 7,752 to 17,438 through the combination of works on pedagogical models modified for use in interactive environments, especially in East Asia and North America, but not in Africa and Latin America; this is because of the high cost of devices, the fact that articles are mostly written in English, and lack of cooperation with the developed countries, while in the field of application, education and healthcare are prominent with such key terms as education, e-learning, and healthcare. Therefore, the development of virtual learning environments which mimic traditional classroom learning at universities has resulted in numerous opportunities for improvement in learning and fostering collaboration (Prakash et al., 2023).

In summary, metaverse makes learning more efficient, minimizes the physical presence at the university classroom, and promotes environmentally-friendly educational initiatives. Thus, it is advantageous for the students of universities because it enables them to build their social skills, creativity, critical thinking, cooperation, and communication (Park & Kim, 2022).

Avatars

An avatar refers to an online image of oneself inside a digital space. They are created by users who use them to interact and collaborate with other users irrespective of geographical locations (Matwala et al., 2024). An avatar can engage in different actions in the virtual space, including liking, giving hearts, dancing, jumping, flying, sitting, and moving objects; some of these may remain inactive, depending on user behavior. It is critical in helping people develop a feeling of ownership of their bodies and communicating with other users (Kyrlitsias & Michael-Grigoriou, 2022).

Within an educational environment, avatars can simulate a classroom scenario where teachers use them to improve their learning strategies through interactive and collaborative activities. It has been found that game elements used in such environments have improved students' engagement and academic performance (Wang et al., 2023).

Spatial.io

Spatial.io is a metaverse platform that allows users to create a virtual environment with geographical, climatic, educational, and architectural features, generating a space with their own rules that could resemble real locations or simply be a product of the imagination (Susilana et al., 2024). Developed in 2016, with a focus on group work and therefore features a wide range of tools. In other words, it is a rapidly growing metaverse platform that leverages virtual reality technology.

The platform provides collaborative spaces wherein one can collaborate with others irrespective of distance, just by the presence of the avatar. It is meant to upload files, images, videos, and 3D models, which should be in GLB/GLTF,

FBX, or OBJ format. It can be used to take one's selfie to create an avatar out of it. It is also compatible with VR headsets, although it is not mandatory, as one can access the platform on a computer or phone (Susilana et al., 2024).

In addition, it comes with predefined templates that one can modify and tailor to fit their unique requirements (educational, narrative, architectural, etc.). The software also gives you the opportunity to build your own design from scratch, which then after completion can be shared with other users. Regarding its usage, the free version lets you upload files up to 100 MB and accommodates up to 10 users whereas the PRO version can upload files up to 500 MB and accommodate up to 50 users; the latter is a paid subscription. Overall, Spatial emerges as the most easily-accessible and versatile virtual environment for world building (Susilana et al., 2024).

The conventional method of radiology education that utilizes the video conferencing application like Zoom or Google Meet is dependent on a two-dimensional setting that hampers interaction and collaboration between the students (Peter et al., 2024; Wang et al., 2023). Moreover, the shift towards the online mode of education has shown problems of communication, engagement, technology adaptation, and higher stress levels (Rajab et al., 2020). However, despite the use of digital means for expanding access to education, the immersive and interactive experience remains lacking (Lewis et al., 2024).

In contrast to this, immersive technology including virtual reality, augmented reality, and metaverse has proved its superiority in engagement, understanding space and collaborative learning (De Gagne et al., 2023; Wang et al., 2023). The use of immersive technology enables students to interact within a three-dimensional space, making the process of learning experiential and cooperative. In addition to that, metaverse combines all these immersive aspects along with real-time interaction making it a potential means of medical education (Rodriguez-Florido et al., 2024; Tsao et al., 2023).

The research questions include: Does the implementation of an educational metaverse based on interventional radiology improve cooperative learning among university students? And as specific questions: Does the intervention based on the metaverse enhance the facets of cooperative learning (positive interdependence, interaction, social skills, group reflection, evaluation, and tutoring)? Are there notable statistical disparities between the control and experimental cohorts for pre-test and post-test results? Which dimension of cooperative learning shows the greatest improvement after the intervention?

Objective: The general goal of this study is: To evaluate the effectiveness of the use of an educational metaverse (Spatial.io) to enhance cooperative learning and its dimensions among radiology students from a university in Lima, Peru. Moreover, the specific objectives are: To evaluate whether the intervention using metaverse enhances

the dimensions of cooperative learning. To evaluate the statistically meaningful disparities between the control and experimental cohorts prior to and subsequent to the intervention. To identify the cooperative learning dimension that has experienced the most improvement through the intervention.

This research will be of significance in the area of medical education because it will provide empirical evidence through a quasi-experimental design of the effect of metaverse learning on cooperative learning. In contrast to previous researches which have been on the perception and descriptive analysis of cooperative learning, this research will quantify the effect of cooperative learning in a three-dimensional environment in a Latin American setting.

The structure of the document is delineated as follows: Section II examines the current literature regarding learning within metaverse settings, Section III provides details about the methodology and experiment design, Section IV covers the results, Section V analyzes the results, and Section VI wraps up the paper by addressing limitations and prospective research.

II. LITERATURE REVIEW

Recently, innovations in educational technologies have pointed out the weaknesses of the conventional approaches used in education, especially in health sciences education. These weaknesses include the promotion of passive learning as well as restricted interactions between students and among themselves due to the nature of the tools being used, which include lectures and two-dimensional virtual environments (Peter et al., 2024). This became more obvious during the recent coronavirus pandemic (Rajab et al., 2020).

In addressing this dilemma, there is a burgeoning interest in immersive technologies like virtual reality, augmented reality, and Metaverse experiences. Learning contexts that are immersive can improve student engagement, motivation, and the ability to retain information. A recent comprehensive analysis uncovered that studying using virtual reality greatly elevates conceptual knowledge and educational

achievements, particularly in scientific and health disciplines (Radianti et al., 2020).

In healthcare education, the metaverse has become one of the new tools that combine immersive environments with interactive approaches. In medical education, research indicates that learning using metaverse technology can enhance practical skills and collaborative learning. For instance, research on medical training indicates that metaverse environments can improve emergency skills performance of students as compared to the conventional approach (Huang et al., 2024). Likewise, current research in radiology education shows that outcomes obtained from metaverse environments are similar to or even better than those obtained using the conventional approach (Rudolphi-Solero et al., 2025; Rimada & KL Mrinh, 2026).

Moreover, it is possible to interact in 3-D through avatars, thus making it easier to communicate, work as a team, and learn practically (Asqarov et al., 2026). All of these aspects are especially important in health sciences education where collaboration and practical experience is crucial. Yet, despite all the benefits, there are certain difficulties that arise (Hamash et al., 2025).

However, at this point, the available literature indicates that immersive technology, including the metaverse, presents considerable benefits when compared to traditional and non-immersive technological means. At this point, however, one can say that very little empirical research conducted within an experimental design exists in the Latin American region or the field of radiology. Hence, further investigation of this issue becomes necessary.

III. METHODOLOGY

Quantitative, applied, and explanatory research methods were utilized in this research. The quasi-experimental approach of pre- and post-test frameworks, including control and experimental cohorts, was utilized to evaluate the influence of an educational metaverse on collaborative learning among university students.

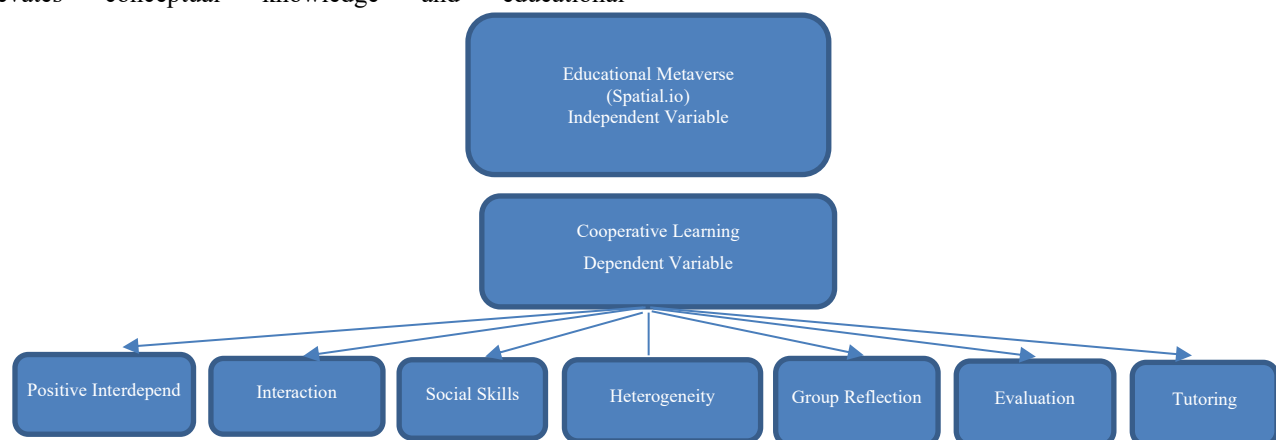


Fig. 1 Conceptual Diagram of the Study Variables

As presented in fig. 1, the independent variable is the educational metaverse which was built using Spatial.io, while the dependent variable is cooperative learning. Cooperative learning is expressed by means of its seven dimensions such as positive interdependence, interaction, social skills, heterogeneity, group reflection, assessment, and tutoring. The educational metaverse is thought to positively influence collaborative learning.

Participants

The dataset included 36 undergraduate students participating in the Interventional Radiology course at a public institution in Lima, Peru, over the 2025 academic year. Subjects were allocated to a control group ($n = 18$) and an experimental group ($n = 18$). The average age was 22.08 years ($SD = 3.597$), with a range from 18 to 34 years, and a balanced gender ratio (50% male and 50% female). Data were gathered using a validated tool that assesses cooperative learning, comprising 44 items categorized into seven dimensions: positive interdependence, interaction, social skills, heterogeneity, group reflection, assessment, and tutoring. Responses were documented on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), yielding ordinal data. The dataset comprises pre-test and post-test evaluations, facilitating comparative and inferential statistical examination of the intervention's impact.

The eligibility requirements stipulated that students must be registered in the interventional radiology course and engage in both the pre-test and post-test surveys. The exclusion criteria were students who were not enrolled in the course, who did not take both tests, or who did not wish to participate in the study.

Instruments

The independent variable was the proposal of the educational metaverse based on interventional radiology, while the dependent variable was cooperative learning with its seven dimensions. The technique used was a survey, which is a procedure for obtaining data or information. The utilized tool was the one suggested, designed to assess the extent of Cooperative Learning Application in Higher Education (CLAS) and is founded on seven dimensions: positive interdependence, interaction, social skills, heterogeneity, group reflection, evaluation, and tutoring (Atxurra de Blas et al., 2015). It consists of 44 items and is designed on a 1-to-5 Likert scale.

Procedure

A visit was made to the facilities of the public university in Lima, Peru, to present the research. Following this, a random selection was conducted since all students had an equal chance of being chosen. The classroom had 42 students according to the roster, but as the weeks progressed, only 36 students remained enrolled; therefore, 18 students were selected for the experimental group and 18 for the control group. After selecting the group that would serve as the

experimental group, the pre-test questionnaire was administered to all students. Subsequently, a virtual meeting was held with the experimental group for the signing of the informed consent form and orientation to the Spatial.io virtual environment. The students in the control group attended classes as usual with the instructor assigned by the university. Both groups followed the units and topics provided in the institutional syllabus for the Interventional Radiology course.

Data Collection

The metaverse intervention was implemented using the Spatial.io platform, configured to support synchronous cooperative activities in a virtual 3D environment. The intervention was conducted over a period of 15 weeks, during which 13 structured educational sessions were delivered, with each session lasting approximately 90 minutes. Students accessed the platform Spatial.io for personal devices (laptops or smartphones) with a stable internet connection. Virtual spaces were designed to simulate interventional radiology scenarios, incorporating interactive elements such as multimedia content, group discussion areas, and task-based activities. A significance criterion of $p < 0.05$ was used for data analysis. The Shapiro-Wilk test was utilized to evaluate data normality, and owing to the non-normal distribution, the non-parametric Mann-Whitney U test was employed to analyze group differences. All statistical evaluations were conducted utilizing IBM SPSS Statistics program (version 26).

Ethical Considerations

The research procedure received scrutiny and endorsement from the institutional ethics committee of the involved university, designated as R.D. N°0202-2024-FTM-UNFV. All participants were apprised of the study's objectives and methodologies and granted informed consent before their involvement. Involvement was optional, and both secrecy and anonymity were assured. No personal identifiers were gathered, and the data were utilized solely for research objectives in alignment with ethical guidelines for human subject's research.

IV. RESULTS

The cohort comprised 36 students, with an average age of 22.08 [$SD: 3.597$], with ages spanning from 18 to 34 years. In terms of gender distribution, 50% ($n=18$) were male and 50% ($n=18$) were female. To access the Spatial.io metaverse, students enrolled through email, complied with data security measures, and were required to have a mobile device (laptop or smartphone) along with a reliable internet connection.

In terms of descriptive statistics, the students who participated in the interventional radiology educational metaverse exhibited comparable scores to the control group on the pre-assessment. Following the conclusion of the 13 teaching sessions, the scores of the experimental group were elevated.

The metrics for the cooperative learning variable: positive interdependence in the pre-test assessment revealed that the control and experimental groups achieved scores of 88.9% and 94.4% at the high level; 11.1% and 5.6% at the medium level; and none at the low level. In the post-assessment analysis, the control and experimental cohorts achieved scores of 77.8% and 83.3% at the high level; 22.2% and 16.7% at the medium level, with no participants at the low level.

In the interaction dimension, the control and experimental groups achieved scores of 77.8% and 72.2% at the high level, 22% and 27.8% at the medium level, and none at the low level during the pre-test. In the post-assessment, it was noted that the control and experimental cohorts attained 55.6% and 83.3% at the high tier; 44.4% and 16.7% at the medium tier, with no participants at the low tier.

In the realm of social skills, the pretest indicated that the control and experimental groups achieved 94.4% and 83.3% at the low level, whereas they attained 5.6% and 16.7% at the medium level. Following the post-test assessment, the control and experimental cohorts achieved 61.1% and 100% at the high proficiency level, while the control group alone attained 38.9% at the medium proficiency level.

In terms of the heterogeneity aspect during the pretest, the control and experimental groups exhibited 88.9% and 94.4% at the high level, 11.1% and 5.6% at the medium level, and none at the low level. Conversely, the post-test results

indicated that the control and experimental groups achieved 83.3% and 88.9% at the high level, 16.7% and 10% at the medium level, and 5.6% at the low level, the latter being exclusive to the experimental group.

In the group reflection aspect, the pre-test results indicated that the control and experimental groups achieved 61.1% and 66.7% at the high level, 38.9% for both at the medium level, and none at the low level. Subsequent to the post-test, the control and experimental groups achieved scores of 44.4% and 88.9% at the high level, 50% and 11.1% at the medium level, and 5.6% only at the low level in the control group.

Concerning the assessment criteria, the pretest revealed that the control and experimental groups achieved scores of 77.8% and 88.9% at the high level, and 22.2% and 11.1% at the medium level. In the post-assessment, it was noted that the control and experimental groups had 50% and 83.3% at the high level, 50% and 16.7% at the medium level, with no participants in the low level.

Ultimately, concerning the tutoring aspects in the pre-test, the control and experimental groups achieved scores of 88.9% and 77.8% at the high level, 11.1% and 22.2% at the medium level, and 5% at the low level (exclusively in the experimental group). Following the experimental program, the control and experimental groups achieved scores of 44.4% and 88.9% at the high level, 27.8% and 11.1% at the medium level, and 27.8% at the low level exclusively in the control group.

TABLE I COMPARATIVE ANALYSIS OF THE PROPOSED METAVERSE-BASED APPROACH AND PREVIOUS STUDIES

Author(s)	Methodology	Technology / Approach	Key Findings	Limitations
Rudolphi-Solero et al., (2025)	Experimental / quasi-experimental	Virtual world (Second Life, metaverse)	Demonstrated positive effects of competitive game-based learning on radiology knowledge and student engagement.	Focuses on radiology context; voluntary vs compulsory participation effects vary.
De Gagne et al., (2023)	Review study	Metaverse in nursing education	Identified enhanced engagement and interactive learning in virtual environments.	Limited empirical evidence and implementation challenges.
Huang et al., (2024)	Quantitative review (collaborative learning focus)	Collaborative learning in the metaverse	Achievement of learning outcomes and motivation through collaborative learning interventions in formal academic settings.	Limited generalizability beyond specific skills and platforms.
Chen et al., (2025)	Experimental study	Immersive virtual reality (VR)	Showed improved learning outcomes in anatomy education.	Focused on VR rather than fully collaborative metaverse environments.
Wang et al., (2023)	Applied educational studies	Immersive VR teaching materials	Highlighted potential of immersive teaching materials to enhance engagement and intuitive learning experience.	Focused on material development and usability rather than cooperative learning outcomes.
This study	Quasi-experimental	Spatial.io metaverse	Significant improvement in cooperative learning and social skills.	Requires internet access and adequate digital literacy.

In terms of inferential analysis, the Mann-Whitney U test indicated that the control group's mean in the pre-test questionnaire was 18.44, while the experimental group's mean was 18.56. After implementing the educational metaverse program, the control group scored 12.56 and the

experimental group 24.22, showing a significant increase. In relation to the p-value, the results showed that $p > 0.05$ (0.988) from the pre-test while $p < 0.05$ (0.000) from the post-test, which validates the broad hypothesis that the implementation of an educational metaverse utilizing

interventional radiology enhances the cooperative learning of medical technology students in a Lima-based university.

From table I, the comparative analysis reveals that earlier studies conducted research on cooperative learning and

immersive technology independently. In the current study, however, both strategies have been used together through the use of metaverse in order to enhance cooperative learning in higher education.

TABLE II COMPARISON OF COOPERATIVE LEARNING SCORES BETWEEN CONTROL AND EXPERIMENTAL GROUPS

Measurement	Control Group (CG)	Experimental Group (EG)	p-value
Pre-test mean	18.44	18.56	> 0.05
Post-test mean	12.56	24.22	< 0.001

Table II shows that both groups had equal baseline scores. However, there was a significant rise in cooperative learning among students in the experimental group, whereas a decline

was recorded in the control group after the intervention, reflecting the significant impact of the intervention.

TABLE III DIMENSIONS OF COOPERATIVE LEARNING P-VALUES

No.	Dimension	Pre-test (p-value)	Post-test (p-value)
1	Positive interdependence	0.888	0.022
2	Interaction	0.888	0.006
3	Social skills	0.606	0.000
4	Heterogeneity	0.791	0.279
5	Group reflection	0.805	0.002
6	Evaluation	0.443	0.020
7	Tutoring	0.888	0.000

Note: Author's own calculations, $p > 0.05$ (not significant), $p < 0.05$ (significant).

As table III illustrates, the most dimensions that showed significant changes in the experimentally treated group were those other than heterogeneity, which did not achieve significance.

Fig. 2 depicts the comparison of cooperative learning scores pre- and post-intervention. The experimental group has shown a significant improvement after the implementation of metaverse, whereas the control group has shown a reduction in their scores.

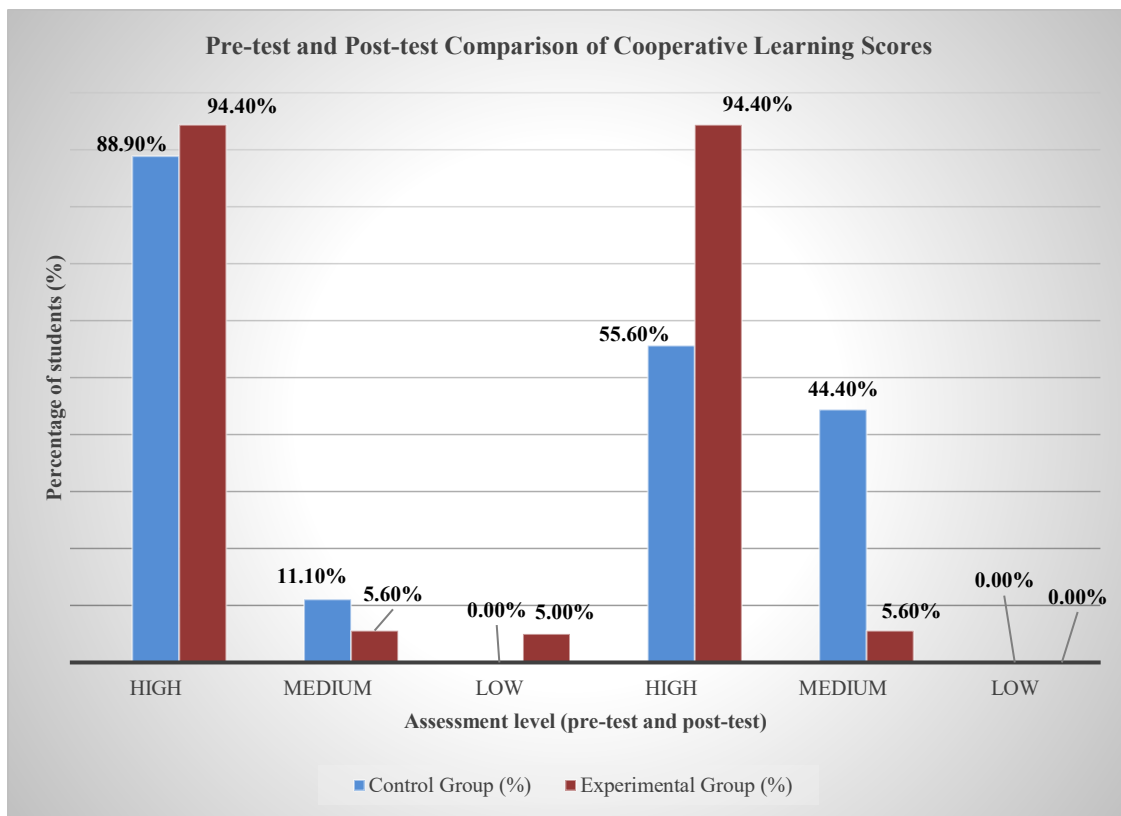


Fig. 2 Comparison of Pre-Test and Post-Test Cooperative Learning Scores Between Control and Experimental Groups



Fig. 3 Metaverse-Based Learning Environment on Contrast Injection in Radiology

Fig. 3 shows the virtual environment that was created using the Spatial.io software for conducting an educational session with the topic of contrast injection. The interaction between participants using avatars takes place, as well as the use of three-dimensional visualization of the material (vascular anatomy and organs) and presentation in the center containing the theory of the lesson.

V. DISCUSSION

The findings of the present research align with previous studies regarding the advantages of immersive technologies in medical education (Chen et al., 2025). According to the study conducted previously, virtual reality increases student participation and collaborative learning; which is in agreement with the considerable improvements made in cooperative learning in the current study (Wang et al., 2023). Furthermore, the results obtained showed that metaverse technology provides better learning experience for medical students (Huang et al., 2024). Nevertheless, the results obtained from both metaverse and traditional teaching were similar in this study (Rudolphi-Solero et al., 2025); yet, more improvements in cooperative learning have been seen in the current study among the metaverse group.

Theoretical results show that our outcomes correspond to the principles of cooperative learning, especially the principles of positive interdependence, interaction, and social skills (Chen et al., 2025). There was a statistically significant improvement in all these aspects, with p-values of 0.022, 0.006, and 0.000, which proves that an immersive environment is able to develop components of collaborative learning. This result corresponds to the results obtained earlier about the importance of interaction and participation in a virtual environment for enhancing student learning (De Gagne et al., 2023; Rudolphi-Solero et al., 2025).

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learning. This result corresponds to the results obtained earlier about the importance of interaction and participation in a virtual environment for enhancing student learning (De Gagne et al., 2023; Rudolphi-Solero et al., 2025).

As far as group organization is concerned, the approach that uses small groups (4 students), rotated during the process of working together on tasks is confirmed by the findings of the study, as the authors recommend small groups that facilitate better interaction and effectiveness in learning. This group structure promoted cooperation and enabled the students to work with different peers during the intervention, thus improving the processes of cooperative learning (Chen et al., 2025).

Despite the fact that the heterogeneity of group composition is a necessary component of cooperative learning, as it ensures the creation of cognitive conflict and allows for exchanging different opinions, no significant changes in this aspect have been noted ($p = 0.279$). Such results indicate that heterogeneity does not guarantee effective cooperation, especially in online conditions. The students encountered certain difficulties in working with peers at different academic levels, therefore, this fact makes one think about the necessity of using certain pedagogical techniques in order to ensure diversity (Cascante et al., 2016).

The practical importance of the findings involves the implementation of metaverse-based approaches in the framework of health sciences education (De Gagne et al., 2023). The findings show that platforms like Spatial.io can act as an efficient supplement to existing teaching techniques in terms of promoting cooperation, especially in cases when there is a lack of opportunities for clinical training. Thus, universities need to use such approaches to develop important collaborative skills required for professional development (Rudolphi-Solero et al., 2025; Wang et al., 2023).

The findings of this study directly support the research aim of examining the efficacy of a metaverse-oriented educational intervention in enhancing collaborative learning among university students. Statistical disparities were identified between the experimental and control cohorts, particularly concerning critical elements such as positive interdependence, interaction, social competencies, group reflection, assessment, and tutoring, indicating the metaverse's efficacy in enhancing cooperative learning results.

The above-mentioned results show that virtual environments have great potential for use in pedagogical activities related to cooperative learning in higher education institutions.

Limitations

First of all, the study is based only on one cohort of students studying interventional radiology, thus the applicability of the results of this research can be considered to be rather low due to the lack of external validity.

Secondly, it is imperative to note that the study involved rather a small sample of students, which also decreases its reliability. Furthermore, the utilization of the specific metaverse platform (Spatial.io) in this investigation may limit the applicability of the findings to other virtual learning environments with distinct characteristics (Kyriltsias & Michael-Grigoriou, 2022; Lewis et al., 2024; Park & Kim, 2022). The technical limitations such as unstable connection to the Internet of some of the participants could have also influenced the results obtained in the process of the research (Prakash et al., 2023; Radianti et al., 2020).

Thus, future research must have large and varied samples, involve different institutions, and use a longitudinal design to increase the generalizability of the results.

VI. CONCLUSIONS

This research assessed the efficiency of the metaverse educational intervention using Spatial.io in enhancing cooperative learning among radiology students. It was evident from the results that the introduction of the metaverse environment resulted in the improvement in the achievement of cooperative learning among the respondents when compared to traditional methods of teaching. Evaluation employing the Mann-Whitney U test revealed a notable disparity between the experimental and control groups subsequent to the intervention (post-test $p < 0.001$). The experimental group exhibited notable disparities across all facets of cooperative learning, encompassing positive interdependence ($p = 0.022$), interaction ($p = 0.006$), social skills ($p = 0.000$), group reflection ($p = 0.002$), evaluation ($p = 0.020$), and tutoring ($p = 0.000$). The findings clearly reveal that the metaverse environment plays a positive role in fostering collaborative learning processes in radiology education. Nonetheless, there was no statistically significant improvement found in the heterogeneity aspect ($p = 0.279$), which indicates that adoption of technology may not help in improving collaboration among diverse learners and thus needs to be accompanied with the right teaching methodologies. All in all, the outcomes reflect the promising application of immersive learning environments such as Spatial.io for health sciences education, especially under conditions when access to clinical practice is restricted. Future studies will have to include multi-center trials, longitudinal study designs, and comparisons between various metaverses in relation to their effects on academic performance, clinical skills, usability, and accessibility.

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