Utilizing the Metaverse in Astrosociology: Examine Students' Perspectives of Space Science Education

Yahya Almurtadha
Metaverse Lab, Faculty of Computers and Information Technology, University of Tabuk, Kingdom of Saudi Arabia

***Abstract*—Big economic countries must invest in space skills to create a favorable business environment, particularly in KSA considering the present mindset in outer space. KSA's vast landmass is a tremendous asset that makes it the perfect position to provide space services throughout the Middle East and the world. Space science education is becoming increasingly important, requiring advanced technology and computational skills to benefit early-career scientists. The Ministry of Education in KSA has declared that students will take Earth and Space Sciences to prepare them for global competition. Traditional learning experiences seem to have little to no impact on students' conceptual understandings of the space science courses. The sociological interests of Generation Z serve as the foundation for modern Metaverse approaches. Students' comprehension and interest in studying space and the galaxy are increased by provided a simulation of space travel using metaverse technology. The major goal of this study is to underline the significance and usefulness of employing metaverse technology while creating a new space science curriculum to advance knowledge in the field of space scientific education. Another goal is to introduce the value of astrosociology in understanding how people might interact with one another in space. A voluntary survey was completed by 39 students prior to their training in the metaverse space simulation as part of this study. They then used the space simulation with careful observation. After that, they reply to a follow-up survey. The findings supported the suggestion that the metaverse should be included in space science curricula. A number of comments and interests also arise on the viability of space travel, social interaction, and the advantages of using the metaverse to research these issues.**

Keywords*—*Metaverse; space science education; astrosociology; virtual reality; space simulation

I. Introduction

Humans' desire to live in space is on the rise, after the topic was limited to scientific research bodies that are looking into sending astronauts to conduct research and explore space. This explains the tendency of many countries to include space science in their education curricula. Consequently, scientific curiosity arose by studying space science and the nature of social relations between humans in space. Astrosociology and space science are closely connected subjects that have many points of intersection. Understanding the physical environment of space, including the effects of radiation, microgravity, and severe temperatures on the human body, is now possible by space science. in the other side, astrosociology examines the relationship between outer space and society [1]. Space science examines the physical parts of space, such as celestial bodies and astrophysics, whereas astrosociology investigates the social, cultural, and behavioral aspects of human in space. Understanding human adaptability, creating space habitats, and the societal implications of discoveries define the link between the two professions. For instance, incorporating social and cultural factors into the design process can help astrobiologists and space scientists promote well-being, productivity, and social engagement. The integration of information and perspectives from both fields might enhance our comprehension of the difficulties, prospects, and social dynamics associated with space exploration. By exploring the literature, no previous research has addressed the use of the metaverse in simulating astrosociology studies. Therefore, the contribution of this study is to introduce astrosociology to the students. In addition, this study will investigate the role of the metaverse as the fastest, cost-saving, and most realistic technology for space living simulation for astrosociology scientists. Consequently, they can examine the theories of living in the space. The following subsections that follow will discuss both space science and astrosociology to prepare the reader for the aspects of this research. Next, details the background and similar research regarding space science and metaverse in the literature review section. The methodology section describes the metaverse-based space simulation and the environment of the proposed system. Finally, we discuss the experimental results, the effectiveness of the proposed system to the astrosociology field, and conclusion.

A. Space Science

Space science is the study of cosmic space beyond Earth. Space science education is becoming increasingly important in 21st century. Based on that necessity, the Ministry of Education in KSA has given its clearance for high school student to take four "Earth and Space Sciences" sessions each week. Earth and space sciences become a mandatory course to third-grade secondary students to prepare students for intercontinental rivalry by enhancing learning objectives. Hence, space science education is requiring significant call for a paradigm change [2] in collaboration with social science. However, there are a variety of motivations and challenges with space science education, including the following: 1) the social view: The development of space exploration, exploitation, and settlement activities is facing troubles by the absence of a social science-focused outer space curriculum. To fill the void, astrosociology is providing social scientific insights to the space community. It is a multidisciplinary field that focuses on the relationship between social life and outer space [2]. Astrosociology needs to get more acceptance and support from the space community in order to balance out the STEM fields [3]. 2) The economic benefit: Developing countries must invest in the skills and knowledge needed the space industry to ensure a favorable business environment. [1]. KSA's vast landmass makes it the perfect location to provide space services throughout the Middle East. 3) The high cost: Space travel is expensive. 4) Long time: The training and evaluation process for becoming an astronaut takes two years. Hence, as proposed by this study, the metaverse could be useful to help in solving these issues. The metaverse provides an inexpensive alternative for space travel by creating cyberspace without the need for expensive infrastructure. This lowers expenses and increases accessibility, encouraging collaboration among space enthusiasts, scientists, and researchers, and improving our understanding of the cosmos.

B. *Astrosociology*

Today, space exploration is a hot topic in many academic fields, from the scientific community to the humanities [4]. How can social scientists address problems in outer space? What do sociologists make of a human culture that explores and lives in space? The answers to these queries reveal the two-way influences of both space and society on human beings[5]. Because of this, a relatively new science called "astrosociology" has emerged, which studies human societies and their social, cultural, and behavioral aspects in space [6]. It looks at how space travel affects people as individuals and as a community, as well as possible social dynamics in alien surroundings. It seeks to offer a thorough grasp of the potential evolution and adaptation of human cultures within the framework of space travel. In general, astrosociology presents a distinctive perspective for analyzing the social consequences of space operations and can furnish significant understanding for decision-makers, scholars, and anyone attracted by humanity's post-Earth future. Therefore, this study is proposing to provide a simulation method—such as metaverse technology—that is simple, inexpensive, quick to implement, and immersive enough to give students a taste of what it is like to live in space while also allowing researchers to explore their perspectives on the subject.

II. Literature Review

The physical components of space science are enjoyable to both male and female students [7]. Nowadays students like to be informed about space science [7]. To support students understanding, experts employ technology and computers to precisely define and simulate objects in space. Space science courses can help early-career space scientists develop sophisticated computing skills [8]. Research has been done to evaluate the reliability and validity of space science awareness tools [9]. For example, some initiatives in teaching have been based on the International Space Station (ISS) [10]. The authors of [11] describe the results of Russian and international space missions as well as their proposals for future projects. Another study tested students to do space-flight scientific experiments on the International Space Station National Laboratory [12]. The research in [13] offers the results of a cutting-edge, university-based space program that created design concepts for astronaut health and wellness using the Project Based Learning (PBL) technique. Findings show that PBL improves academic achievement and student involvement but requires more time and effort from instructors than traditional methods [14]. The study in [15] discusses the development and implementation of an online tool to measure youth attitudes toward STEM areas and human spaceflight. Research on the educational impact of using space analog missions to educate at Vivalys Primary School has been conducted [16]. This helps to comprehend that experiments that aren't possible in a classroom environment should be given to students through virtual reality education [17].

A. *Metaverse*

Metaverse is a 3D immersion virtual ecosystem enables the user to integrate and feel almost real in the virtual world. Metaverse enables people to live and experience activities, sports and events in safe ways that they cannot in the real world because of their high cost or danger. The current Metaverse is "based on the social value of Generation Z that online and offline selves are not different" [18]. In its core, metaverse creates a fascinating, envisioned or real world where learners can not only view content but also engage with it directly. Metaverse can also take students to places they might not otherwise be able to visit, like space exploration, historical sites or even the human body. They may now explore and learn in previously impractical ways because to this. The metaverse, a virtual shared place formed by the merging of the physical and digital worlds, has the potential to transform a variety of disciplines, including education, medical, and entertainment. In education, students can benefit from augmented reality in critical thinking[19] and can immerse themselves in dynamic and engaging virtual worlds to get hands-on experience [20]. Medical students uses virtual reality learning performs better than the conventional learning method [21]. Results showed that learning with an augmented reality method was better to a paper-based approach in terms of learning accomplishment, pleasure of learning activities, and utility [22]. The metaverse opens up new avenues for people in the entertainment industry to interact, socialize, and take part in immersive events like virtual concerts and gatherings. According to a research, keeping existing customers is more practical and cost-effective than attracting new ones, therefore park owners and managers should make sure that visitors can easily utilize virtual reality and develop creative concepts and materials to boost satisfaction [23].

Due to the recent advancement in this contemporary technology, it is now feasible for scientists and students alike to explore the cosmos [24]. For example, the US space agency NASA is working to determine how metaverse technology may aid in space exploration studies [25]. Education using Metaverse is increasing team engagement, and saving redesign cost and time [26]. Metaverse is more effective for students and scientists to observe what is occurring in space than spending time there for weeks. The main limitation found from the similar research areas is that the astrosociology usage of the metaverse is still in its infancy, and several social, ethical, and technological issues require resolution. Thus, there is a reason for optimism regarding the metaverse's potential to improve education and research in space travel, cultural preservation, and social interaction as this study will investigate.

III. Methodology

The purpose of the study is to ascertain students' pre- and post-participation perceptions of life in space through a metaverse-based space simulation. Fig. 1, modified from the study in [27], illustrates the framework of the metaverse-based space simulation. It depicts that the metaverse-based simulation is simple to use, free, private, and aims inspiring. Therefore, students gain a good experience from using the metaverse as an engaging, instructive, and fun experience that introduces them to the marvels of the universe.

We followed the next steps as determined by Fig. 2 to help accomplish the project's objectives:

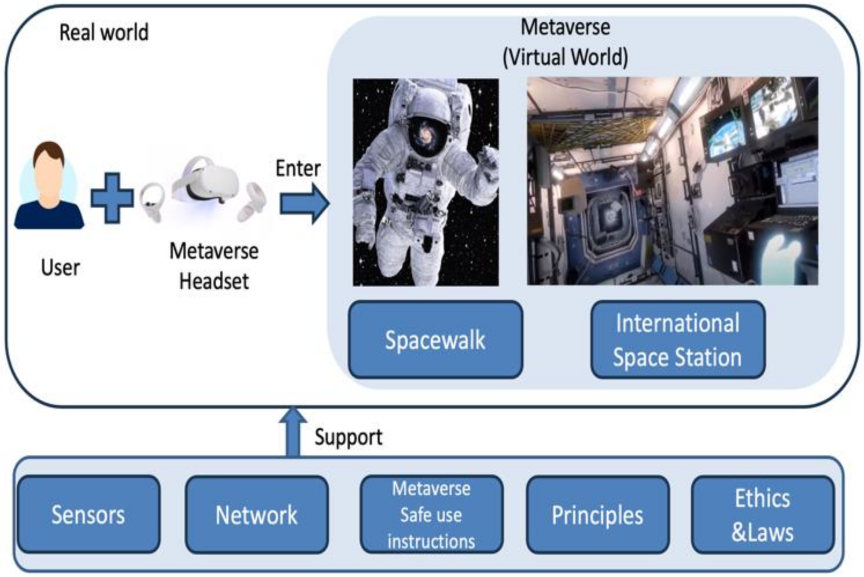

Fig. 1. Metaverse space simulation model.

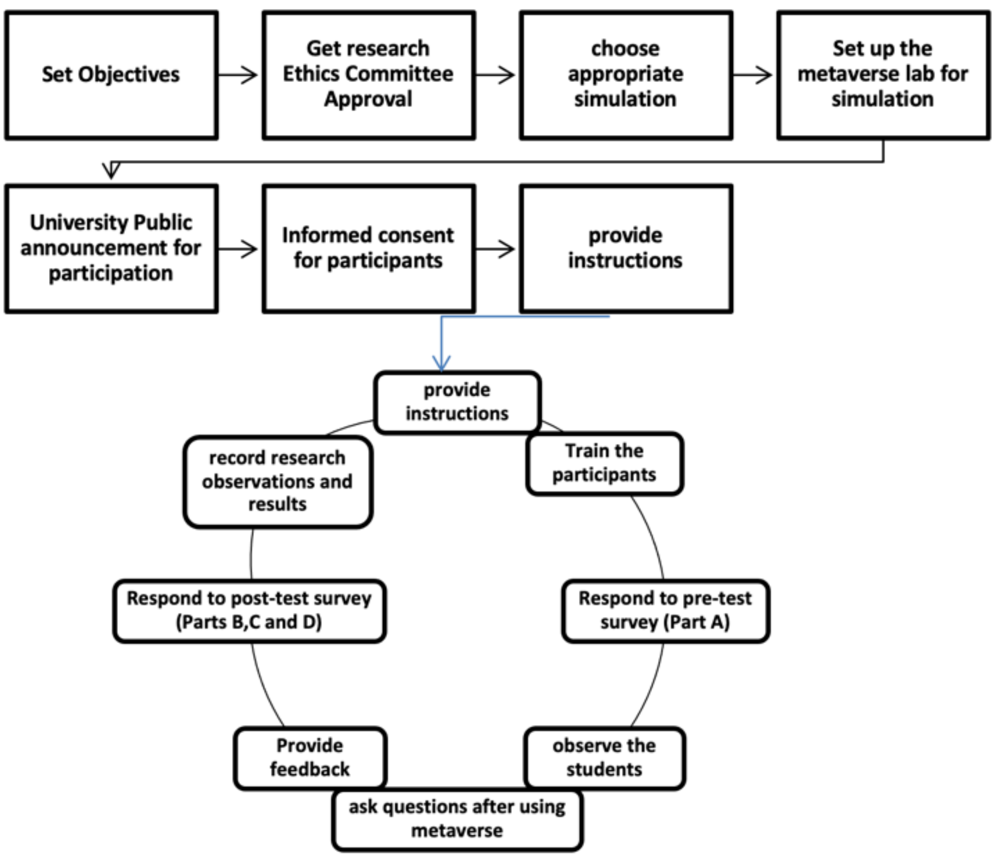

Fig. 2. Research methodology.

1) Identifying the key concepts and sub objectives that we want the students to understand. Sub objectives of this study are:

a) To highlight the significance and value of using metaverse technology for space science education.

b) To introduce students to the astrosociology, as well as to use the metaverse in astrosociology to better comprehend how humans could feel when living in space.

2) The University of Tabuk requires permission from the Local Research Ethics Committee (LREC) for studies involving students as participants. The committee requires the research investigator to:

a) Register at the National Committee of Bioethics (NCBE) database, pass the bioethics training, and get certified.

b) The researcher then can apply to the local research ethics committee by submitting their CV and a thorough study proposal including their objectives, sample size, data collection methodologies, description of personal information or any samples that might be collected, and how to secure these data. In addition, include a copy of the announcement materials for participation. Before students participate, they must be properly briefed; also, a consent form will be handed to them. The consent form discusses the study's goals, the number of visits required to participate, whether it is open to the public or only a select group, whether any personal information is required, how to ensure participant anonymity, any risks, location and safety considerations, the participant's right to leave at any time without penalty, and inclusion and exclusion rules. Then student who signs voluntary the consent form should be prepared to participate.

3) Choose the appropriate VR simulation: There are various VR simulations that can be used for space science education. we used Mission:ISS simulation as in Fig. 3 and Fig. 4 developed by Magnopus [28] run on Meta Oculus Quest 2 [29] which aligns with the research objectives.

4) Prepare the metaverse-based spacewalk simulation: The Metaverse lab is equipped with the research facilities and equipment needed to measure students' understanding of astrosociology using metaverse such as:

a) Meta Oculus Quest 2 Virtual reality headset (8 Devices): This is the most important piece of equipment needed. The headset is of high quality and capable of providing an immersive experience for the students.

b) Powerful Computer hardware (8 PCs): This includes a powerful graphics card, i9 processor, and 32GB RAM.

c) VR software: The VR software used to simulate spacewalk simulation of high quality and accurately represent the concepts.

d) Classroom space: The metaverse lab space is large enough to set up a room-scale play area, accommodate two students at a time, and allow them to roam freely while wearing the VR headset and following the safety guidelines.

Fig. 3. Snapshot of Mission ISS simulation: spacewalk [29].

Fig. 4. Snapshot of Mission ISS: Navigation inside ISS [28].

5) Asking pre-experiment questions: Before the students use the VR space simulation, we ask them questions to assess their understanding of the key concepts and research questions.

6) Provide instructions: Before starting the metaverse simulation, we provide clear instructions to the students on how to use the Oculus Quest2 headset safely and how to navigate the space simulation.

7) Observe the students: As the students are using the metaverse simulation, we observe their interactions and note any misconceptions or areas where they may need more clarification.

8) Ask post-experiment questions: We ask the students questions after they have done the metaverse space simulation to test their grasp of the major ideas and research objectives after experiencing the space simulation.

9) Provide feedback: Based on the observations and the students' responses, we provide feedback to help them improve their understanding of the material.

10)Repeat the process: To reinforce the learning, we may repeat the metaverse space simulation and assessment process.

*11)*Get conclusions and research results.

IV. The Experiments

The process for gathering data from various student groups is described below. A metaverse-based space simulation was prepared. Following that, a pre- and post-space simulation survey is answered by participants to gather information from students on their perspectives towards using the metaverse for space education. A descriptive survey (in four parts: A, B, C, and D) was used. The trainings and experiments were conducted in the metaverse lab at the University of Tabuk. 39 volunteer students responded and participated. No personal data was gathered. Part A test students' broad understanding of space science and astrosociology before using the metaverse space simulation. After participants completed ten multiple-choice questions in Part A, they are trained to use the metaverse simulation. Then they used the simulation for 20 minutes. After that they answered nine questions in part B. Part B discusses how students feel about spacewalk and ISS mission using metaverse space simulation and how they would interact with the space. Part C (10 questions) aims to test the System Usability Scale (SUS) [30] to evaluate whether this simulation is suitable for use in space science education. Part D (13 questions) aims to test the Igroup Presence Questionnaire (IPQ) [31] to assess their sense of presence and immersion while in virtual world.

V. Analysis

All the participants are students at university of Tabuk. They responded voluntarily to a public announcement in the main campus. We followed the bioethics committee's regulations, which required that each participant be briefed before participating and sign a consent form. No personal information was collected. They did not get any compensation for their participation. They were even told that they might exit the process at any moment, with no obligation. None of the 39 participants had used the space simulation before. 7% of them know about metaverse and have used it more than three times, 28.2% have used it fewer than three times, and the remaining 64.7% have never used it before. The next sections detail the results obtained from the pre- and post-test of the metaverse space simulation in addition to the SUS and sense of presence test.

A. Analysis of the Effectiveness of Metaverse in Space Science Education

We use descriptive statistic frameworks and data analysis methodologies to evaluate the results, which involves summarizing the data collected from the metaverse-space simulation using measures such as mean, and standard deviation. The aim is to provide an overview of the students' perception of how effected be if we use the metaverse in the space science education. In Part A questionnaire, all participants responded that they have never used the space simulation before. This ensures equivalent level of knowledge among all participants. Fig. 5 illustrate that most students after experiencing the metaverse-space simulation found the simulation has affected their knowledge of space science positively (SD=0.595, N=39) and recommended to use it for education (SD=0.339, N=39) as illustrated by Fig. 6. The scale of 3 in the figure refers to “agree”, 2 to “sort of” while the score 1 refers to “do not agree). SD stands for standard deviation, which measures how distributed the data is in comparison to the mean. A low standard deviation suggests that data is tightly grouped around the mean, whereas a high standard deviation shows that data is more spread out[32].

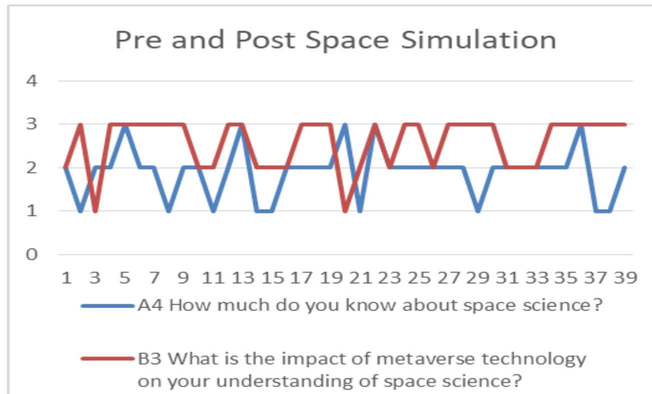

Fig. 5. Pre and post space simulation response regarding space science.

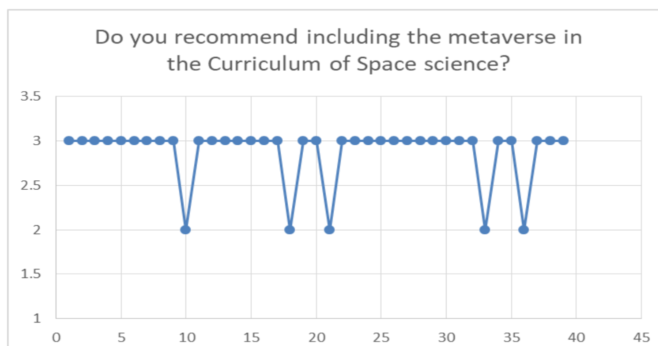

Fig. 6. Students’ recommendation for using metaverse in space science education.

B. Analysis of the Knowledge of Astrosociology

The second sub objective of this study is to introduce the astrosociology to the students. Pre-test participant responses indicate that all participants had no understanding of astrosociology. Following the metaverse simulation and conversation with each participant, there is a significant rise in their interest in learning more about astrosociology. Some even begin to wonder about the logistics of living in space and how humans would interact with one another. Table I illustrates the standard deviation and mean of the subjects' responses to astrosociology before and after exposure to space simulation. Fig. 7 shows that students’ awareness is increased after experiencing the space simulation.

TABLE I. PRE AND POST TEST STUDENTS' RESPONSE TO ASTROSOCIOLOGY KNOWLEDGE

Test	Test Topic	SD	Mean	N
Pre-Space simulation	Astrosociology kowledge	0.556	1.48	39
Post-Space simulation	Astrosociology Awareness	0.605	2.71	39

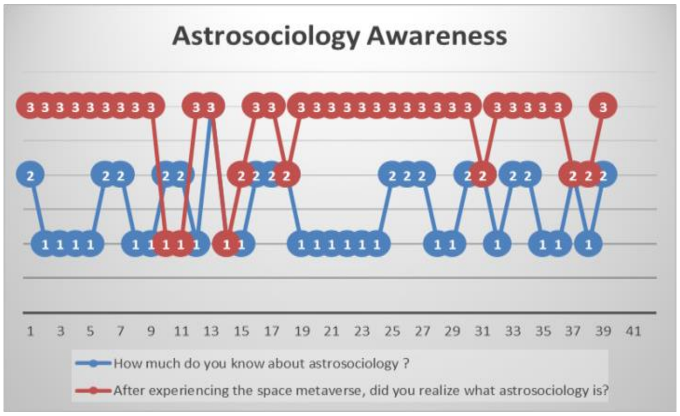

Fig. 7. Students'' response to astrosociology awareness: pre and post simulation.

C. Analysis of SUS and Sense of Presence Measurements

Participants in the metaverse space simulation also completed Part C of the questionnaire, which assessed the System Usability Scale (SUS) and the experience of presence and immersion in the virtual world. This survey was evaluated as a post-space simulation, and all 39 participants completed it. We use The System Usability Scale (SUS) to classify the ease of use of the site, application, or environment under examination. It consists of a 10-item questionnaire with five response scale for responders, ranging from strongly agreeing to strongly disagreeing [33]. After recording the results from participants, they should be normalized to a scale of 0-100. The SUS calculated value for the 39 participants was 69.14. This was greater than the average SUS score of 68 points. When translated to the adjective grading scale, this value equals "Good". As a result, the metaverse space simulation is considered suitable for use in practice.

Four metrics of presence may be determined by assessing the IPQ questionnaire items. The first is general presence (G), which measures complete presence in general. The second concept is spatial presence (SP), which relates to the perception of being physically present in a virtual world. The third metric is participation (INV), which evaluates both interest and involvement. The fourth metric is experiential realism, which assesses the subjective perception of reality in the virtual world [34]. Table II and Fig. 8 shows that general presence G exhibits the highest results (score=2.8, SD=0.37). Fig. 9 supports that by analyzing the students' response to the level of being actually in the space while using the simulation. Level of involvement in the simulation is the second highest result with (score=2.31, SD=0.53).

TABLE II. RESULT OF PRESENCE TEST

IPQ metrics	Avg Score	SD
G (General presence)	2.84	0.37
INV (Involvement)	2.31	0.53
SP (Spatial presence)	2.27	0.57
Real (experience of realism)	2.20	0.66

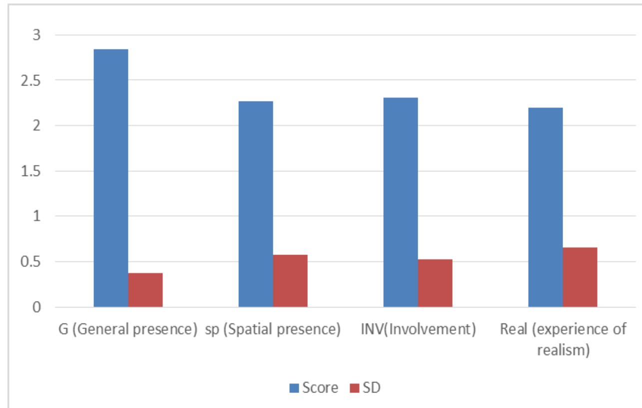

Fig. 8. Average result of response for IPQ Four metrics of presence.

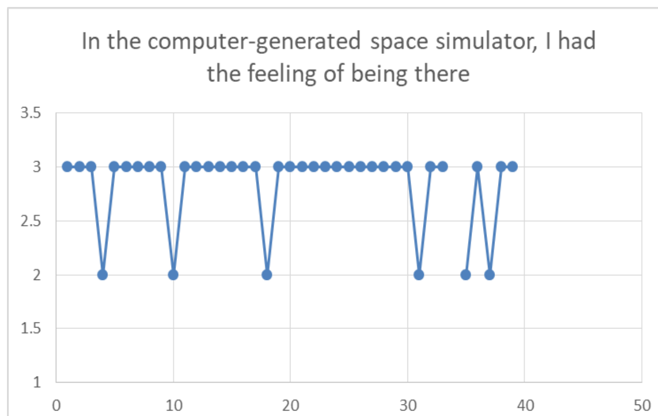

Fig. 9. General result of level of feeling of immersion in space simulation

VI. CONCLUSION

This study aims to support the university's priorities by promoting innovation and cutting-edge teaching methods via adding metaverse into the curriculum and promoting the astrosociology as a core component of the space science program. It will enhance students' understanding of space science, aligning with the university's research identity towards the space. This study concludes that the metaverse when adopted in the curriculum helps improved student performance, increased engagement, and knowledge retention, which can help students to secure future jobs and improve retention and graduation rates.

Furthermore, and upon discussion with students after experiencing the space simulation, we recorded the following conclusions: a) in recent times, the notion of the metaverse has earned noteworthy interest, especially in space science education. b) The metaverse can be utilized for education and outreach in astrosociology by developing immersive and interactive educational content about space exploration and the social dynamics of space living. This can raise public awareness and generate discussions on humanity's future beyond Earth. c) In terms of astrosociology, the metaverse can enhance immersive training and simulation experiences by building virtual settings that simulate space flight circumstances, and the conditions and difficulties of space flight. This might improve the skills, competence, and preparation for space missions. d)Furthermore, the metaverse may be utilized in astrosociology to promote social engagement by offering virtual spaces in which people can communicate and cooperate in space. This can reduce feelings of loneliness and encourage sociability in extraterrestrial environments. e) Finally, the metaverse can enhance study and cooperation in astrosociology by establishing virtual settings to perform experiments and collect data.

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Research Ethics approval: This study obtained the approval No: UT-353-179-2024 from the Local Ethics Committee following to the process of the National Committee of Bioethics (NBCE).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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