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The Impact of the Metaverse on the Programming Learning Motivation of University Students

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Abstract

Currently, educators are looking for new techniques in the teaching–learning process. Previous research has presented various teaching strategies designed to motivate students to learn. Existing research has focused on the use of spatial world design in elementary and secondary education settings. Therefore, it is essential to analyze how these immersive environments, designed and programmed by teachers, provide insights into the motivational perceptions of university students in teaching programming courses. This study employed a single-group, fixed-order, within-subject design ($N = 41$) to examine students' reported motivation after traditional instruction and a subsequent Roblox-supported activity and also to see if there is any difference in motivation when using Roblox, considering gender. The present study used the RIMMS to measure motivation. To analyze motivation using the teacher's material and Roblox, the Wilcoxon signed-rank test was used, and to analyze how gender affects it, the Mann–Whitney U test was used. The results revealed a statistically significant difference between both modalities ($Z = -2.264$, $p = 0.024$, $r = 0.354$, $N = 41$). With regard to gender, the results indicated no statistically significant difference between males ($N = 31$, Mean Rank = 21.60) and females ($N = 10$, Mean Rank = 19.15), $U = 136.500$, $Z = -0.567$, $p = 0.571$ (exact $p = 0.580$). The findings indicate that students reported higher motivation scores after the Roblox-supported activity than after the preceding traditional instruction. However, given the fixed-order design and the lack of formal measurement equivalence between the contextualized RIMMS versions, these differences should be interpreted as exploratory descriptive evidence rather than as evidence of an effect attributable specifically to Roblox.

Keywords: virtual worlds; Metaverse; motivation; programming

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1. Introduction

Learning a programming language is an important ability that allows students to develop 21st-century skills such as critical thinking and problem-solving [1]. In addition, programming helps students develop computational thinking skills [2]. However, teaching and learning programming presents well-documented pedagogical challenges [3,4].

In the literature, scholars and researchers continually develop new approaches to teaching and learning programming. In higher education, project-based learning, gamification-based learning, flipped classrooms, and collaborative programming are the most effective approaches for teaching programming [5,6]. Moreover, emerging technologies such as

augmented reality (AR), virtual reality (VR), and artificial intelligence (AI) are being used in teaching programming [5].

AR, VR, and AI are technologies that underpin the term "Metaverse", as they enable the design of immersive environments and facilitate real-time communication [7]. The Metaverse is a perpetual and persistent multi-user environment that unifies physical and digital reality [8]. Moreover, the Metaverse is a three-dimensional virtual world where avatars participate in activities across political, economic, social, and cultural domains [9]. Building on this immersive potential, researchers are increasingly using the Metaverse to create virtual environments designed for educational purposes [10]. However, further research is needed to assess its impact in different educational settings [11]. Virtual games are the closest applications to the Metaverse concept [12]. Therefore, virtual games are the most common platform for popularizing the Metaverse [9]. Digital games in education facilitate the development of 21st-century learners' skills [13]. Generally, "the research is clear; people do learn from games" [14] (p. 500). For this reason, many researchers and academics seek to incorporate digital games in the classroom. The game-based learning approach is important in computer science and has been used at the university level to teach object-oriented programming [15].

Researchers and educators commonly design the games at the university level to teach computer science [15]. The game creation process can be avoided by using commercial games. Commercial games free teachers from the need to become game developers or programmers to use them in schools [16]. Therefore, according to Kye et al. [17], it is necessary for teachers to understand the technical characteristics of each type of Metaverse and to design didactic activities that enable students to solve problems or develop projects collaboratively and creatively. The Metaverse provides service platforms, such as Roblox and Minecraft, for deployment [9]. Roblox and Minecraft are sandbox games that allow users to access virtual worlds and build and model their play environments [18].

Roblox provides a programmable environment that allows the creation of many in-game worlds [18]. Also provides a special tool for creating immersive experiences called Roblox Studio. Roblox Studio is a user-friendly environment where no programming skills are required to create simple virtual worlds [19]. In addition, Roblox Studio enables ubiquitous access to the experiences created on Roblox [19], as worlds can be played on computers, tablets, mobile devices, or video game consoles. Roblox has overcome critical barriers to the metaverse in education, such as the high technical and financial complexity of developing virtual environments and the use of poorly designed metaverse interfaces [20].

Some studies have examined the educational use of Roblox across different disciplines [21,22], educational levels and pedagogical purposes [23]. A systematic review of 40 studies identified uses of Roblox in areas such as STEM education, programming, mathematics, collaborative learning, and other educational contexts, and highlighted both its potential to enhance learning experiences and the need to develop more rigorous empirical research and well-grounded instructional designs [21]. Additionally, subsequent research has specifically explored Roblox's potential in higher education, demonstrating that its application at this educational level is a developing field of research [22,24].

Consequently, the research gap does not lie in the absence of studies on Roblox in education, but rather in the need to examine specific pedagogical configurations where a virtual environment developed by the teacher, and not by the student, is deliberately integrated into programming instruction and its relationship with student motivation is analyzed. This study represents a planned empirical extension of our broader research line regarding technology-integrated programming instruction. While our previous work evaluated motivational dynamics using Minecraft [25], the present study extends this knowledge base in two distinct ways. Empirically, it extends the empirical evidence on students' reported

motivation across different virtual-world platforms. Pedagogically and methodologically, unlike studies that utilize pre-built or commercial virtual spaces, the Roblox learning environment in this study was custom-built and directly programmed by the course instructor. This provides preliminary empirical insights into student motivational perceptions within a bespoke, teacher-developed immersive scenario in introductory programming, offering practical knowledge regarding the design feasibility and implementation dynamics of instructor-created virtual tools.

The present study uses the game-based learning approach proposed by Pho and Dinscore [26], which consists of designing learning activities that introduce concepts progressively and guide users toward an end goal. In this study, the teacher used Roblox to create a virtual world for teaching comparison, logical operators, and control structures in programming.

The study uses Roblox to measure students' motivation levels when learning about comparison, logical operators, and control structures, and contrasts these levels with those in traditional teaching. The main contributions of the paper are the following:

- An explanation of how the Roblox experience was designed to help university students in Mexico learn basic programming concepts, such as control structures, comparisons, and logical operators.
- The motivation level of Mexican undergraduates using Roblox is analyzed and evaluated.

Building on previous research in which teachers have focused solely on the spatial and visual design of virtual worlds [25], this study marks a key transition toward fully customized and programmed immersive environments in Roblox. Roblox functions as a comprehensive video game development engine. This transition makes it possible to implement customized mechanics, programmed by the teachers themselves and tailored to specific learning objectives.

The rest of the paper is organized as follows: Section 2 presents the Metaverse impacts on education. Section 3 shows the literature review. Section 4 explains the research design, the phases developed for practice with Roblox, and the instruments applied. Section 5 shows the results. Finally, Section 6 presents the discussion and conclusions.

2. Seven Ways the Metaverse Is Having a Positive Impact on Education

According to Lin et al. [27], the Metaverse can positively impact education in seven ways, as follows.

1. Visualization. Metaverse can help students visualize phenomena or structures that cannot be seen with the naked eye. For example, Abdinejad et al. developed an Augmented Reality (AR) application called ARChemy to help students understand molecular structures and chemical reaction mechanisms at the molecular level [28].
2. Reducing learning costs and risks. Experiments or laboratory practices are widespread in physics, chemistry, and medicine. With metaverse technologies, costs and risks can be reduced. For example, Gonzalez-Romo et al. used Virtual Reality (VR) for teaching microsurgical anatomy [29].
3. Not limited by time and space. Historical events can be recreated, and people worldwide can interact and overcome geographical limitations. For example, Rojas et al. implemented an educational platform using the Metaverse for engineering courses at four universities in Poland, Portugal, Germany, and Spain [30].
4. Prevention of academic misconduct. The Metaverse includes VR, AR, and emerging technologies such as 5G, Artificial Intelligence (AI), digital twins, blockchain, holography, and the Internet of Things (IoT) [31]. Blockchain technology can prevent academic misconduct and plagiarism in assignment assessments [32].

5. Personalization. Applying metaverse technologies to education creates an intelligent, interactive learning environment and enables personalized, intelligence-driven education [33]. For example, Yeganeh et al. propose the Multi-layered Immersive Learning Environment (Meta-MILE) model that integrates cutting-edge immersive technology, adaptive pedagogy, and robust security [34]. The model includes AI-driven personalization for a customized learning experience.
6. Immersive interactive experiences. In the Metaverse, students can use interactive artifacts provided to implement different learning scenarios. Students can use appropriate tools or artifacts for experiential learning and problem-solving activities [35]. For example, Bourdeau et al. used Minecraft Education Edition to teach Scrum [36]. Scrum is an agile framework for project management. The study involved 153 university students who applied the Scrum framework to realize a simulated project in Minecraft Education Edition.
7. Promote communication. Metaverses can more effectively convey nonverbal cues, such as facial expressions and glances, through digital presence, enabling effective collaboration and knowledge sharing [37]. For example, Chih-Ming and Ming-Yan designed a Jigsaw collaborative learning method implemented in the Metaverse (JCLM-MVS) for teaching programming [38]. Forty-eight elementary school students participated in the study. The Metaverse was used for peer-to-peer communication, and small-group discussion rooms were used for collaborative learning through desktop sharing and voice communication. Students indicated that using JCLM-MVS enabled them to get timely help from their peers.

3. Literature Review

Roblox is part of a new wave of virtual ecosystems and supports economies by enabling the exchange of virtual currency, digital objects, and user-generated content [39]. In the Metaverse, Roblox is one of the most important platforms. According to Wang et al. [40], the Metaverse has the following features: identity, friends, immersion, multiplatform, low friction, variety of content, economy, and security. All the features make Roblox an effective tool for undergraduates [22]. Roblox is not a game per se but a platform supporting thousands of user-created games [41]. The platform itself makes game creation easy for users.

In 2024, Roblox reached 380 million monthly active users [42]. Roblox is free and requires no subscription or license fee [22]. Roblox provides the so-called Roblox Studio as a game or experience editor. Unlike Minecraft, where the editor is the game itself [43], Roblox programming allows the development of tailored educational experiences adapted to specific learning needs and objectives [23].

Roblox in Education

Roblox can be used in educational settings, and the following describes some of the work that has been done in areas such as cultural heritage, electrical machines, English language instruction, mathematics, sculptural heritage, and entrepreneurship education.

Kang et al. [44] proposed the Virtual Art Museum Education Program (VAMEP) to improve art literacy by having students create a virtual museum in Roblox Studio. The study involved 15 students who used Roblox to create the Moonshin Art Museum (MAM). A paired *t*-test showed a difference in the knowledge level after the activities. Meier et al. [19] used Roblox to teach about sculptural heritage. The study involved 53 high school students who were asked to design a virtual environment depicting Santa Cruz de Tenerife's sculptural heritage. The results revealed that students considered

themselves capable of developing virtual worlds with Roblox and were more aware of the sculptural heritage.

In engineering, Yolal [45] presents a work that uses Ohm's law as a basis for developing a simulation of simple circuits in Roblox. Students did not evaluate the experience designed in Roblox. Another work in engineering was presented by Ho and Lee [23], who developed a Roblox experience to teach electrical machines. ChatGPT was used to optimize the client-side scripts for server-side implementation. Twenty-two undergraduate students participated in the study, and most found it attractive and valuable in improving their understanding of electrical machines.

Mustafa et al. [46] used Roblox for English language teaching. The qualitative study involved 60 students and four university-level teachers. Results obtained through observations, interviews, and questionnaires indicated that the Roblox experience was interactive, challenging, exciting, and fun. Also regarding English teaching and learning, Sinar et al. [47] used Roblox to teach digital literacy in English. Sixty-two high school students participated in the study. The results indicate an excellent perception of using Roblox as a learning medium to improve English multimodal literacy.

In the field of mathematics, the work of González et al. [48] presented the virtual world called "MatVers: El Metaverso de las Matemáticas", developed in Roblox, for teaching counting numbers and two-digit sums to first-grade elementary school students. The results indicate that Roblox can be an effective tool for engaging and motivating students in learning mathematics.

Wenzel et al. [49] used Roblox for entrepreneurship education for undergraduate students. Fifty-eight students participated in the 3D virtual world developed in Roblox, and 42 used 2D digital game-based learning media. The results show that students who interacted with the 3D virtual world reported significantly higher levels of accomplishment, challenge, competition, social presence, and playfulness.

As seen in the analyzed works, 8 studies used Roblox in education (see Table 1), and none addressed the programming field. Although there is a systematic review in the literature by Han et al. [21] on the use of Roblox in education, they note that some studies used Roblox in programming or Science, Technology, Engineering, and Mathematics (STEM). However, when analyzing the studies, they indicated that they used platforms other than Roblox.

Table 1. Summary of eight Roblox studies focused on education.

Author(s)	Subject to Learn	Sample	Learners	Assessment	Theory Base
Meier et al. (2020) [19]	Sculptural heritage	53	High school	Knowledge retention	Quantitative research
Mustafa et al. (2020) [46]	English language teaching	60	University-level	Prototipe perception	Qualitative research
Kang et al. (2022) [44]	Cultural heritage	15	College and graduate	Knowledge retention	Paired-sample Student's *t*-test
Yolal (2022) [45]	Ohm's law	N/A	N/A	Prototype presentation	Qualitative research
Ho and Lee (2023) [23]	Electrical machines	22	Undergraduate	Prototype perception	Mixed research
Sinar et al. (2023) [47]	English language	62	High school	Prototype perception	Percentages

Table 1. *Cont.*

Author(s)	Subject to Learn	Sample	Learners	Assessment	Theory Base
González et al. (2024) [48]	Counting numbers and two-digit sums	N/A	Elementary school	Prototype perception	Qualitative research
Wenzel et al. (2025) [49]	Entrepreneurship education	58	Undergraduate	Accomplishment, challenge, competition, social presence, and playfulness	Quantitative research
Our proposal (2026)	Computer programming	51	Undergraduate	Motivation	ARCS, Wilcoxon signed-rank test and the Mann–Whitney *U* test

4. Materials and Methods

This study employed a single-group, fixed-order, within-subject design (N = 41) to descriptively compare students' reported motivation following traditional instruction and a teacher-programmed Roblox activity.

The research questions guiding the present study are:

- RQ1. What levels of reported motivation do students exhibit after the traditional instructional condition and after the subsequent Roblox-supported activity, based on the ARCS dimensions?
- RQ2. Are there statistically significant differences in students' reported motivation by gender during the Roblox-supported activity?

4.1. Participants

The study sample consisted of 51 students enrolled in the Introduction to Programming course during the January–June 2025 semester. All 51 students participated in the traditional instructional activities and completed the first motivation measurement. Subsequently, 41 students participated in the Roblox-supported activity and completed the second motivation measurement, whereas 10 students did not participate in the Roblox activity and therefore did not provide a second measurement. The reasons for non-participation were not systematically recorded. Because the primary analysis required paired observations from both instructional conditions, the within-subject analyses were conducted using the 41 students with complete paired data. The 10 students who did not participate in the Roblox activity were retained for a supplementary participation-bias analysis based on their available baseline data. Specifically, their motivation after traditional instruction was compared with that of the 41 students who completed both instructional conditions. This analysis was conducted to assess whether observable baseline differences could help explain the reduction from the initial sample to the paired analytical sample.

4.2. Supplementary Participation-Bias Analysis

To examine the potential for participation-related bias, the 41 students with complete paired observations were compared with the 10 students who completed the traditional instructional condition but did not participate in the Roblox activity. The overall ARCS motivation score obtained after traditional instruction was compared between the two groups using the Mann–Whitney U test because of the small size of the non-participant group and the non-normal distribution of the motivation scores. The analysis was intended as a

baseline comparability check and did not treat the 10 non-participants as a control group. The primary within-subject analysis remained restricted to the 41 students who provided measurements under both instructional conditions.

4.3. Instruments

The Instructional Materials Motivation Scale (IMMS) is an instrument designed to measure motivation. IMMS is specifically defined for the ARCS model [50]. According to Keller [51], for a person to be motivated, four conditions must be met:

- Attention. The real challenge is to capture and maintain students' attention during the instructional session.
- Relevance. The course design should answer the question: Why should we learn this?
- Confidence. Teachers should encourage the development of confidence regardless of the factors that affect their expectations of success.
- Satisfaction. People should be more motivated if the task and reward are defined and an appropriate reinforcement schedule is used.

In the literature, the original IMMS or some modified versions have been used [52]. The study by Loorbach et al. [53] validated the 36-item IMMS. The results show that IMMS can be reduced to 12 items. Therefore, the new instrument was called the Reduced Instructional Materials Motivation Scale (RIMMS). The RIMMS instrument has been used for several metaverse studies, including augmented reality [54], virtual reality [55], and virtual worlds [25]. Therefore, the present study used the RIMMS to measure motivation adapted from Loorbach et al. [53].

The RIMMS items were contextually adapted to the instructional conditions analyzed: the traditional teacher-led approach and the Roblox-supported approach. The adaptation was carried out at the item-writing level, without modifying the motivational dimension. The wording reflected the materials, resources, or instructional characteristics students interacted with in each condition. Thus, the traditional version focuses on readings, exercises, illustrations, and other elements, while the Roblox version focuses on the virtual environment, 3D models, interactive elements, and other features. Because each version captures context-specific operational indicators tied to its respective environment, the two instruments do not share identical psychometric indicators and are evaluated strictly as descriptive, condition-specific motivational profiles.

The research consists of 4 stages: (i) thematic content, (ii) virtual world design and programming, (iii) materials design, and (iv) activity execution.

4.4. Thematic Content

Roblox does not allow users to execute code within the virtual world (VW), so interactive activities were designed and programmed. In this case, the teacher would be the developer or creator of the virtual world.

Taking the above as a reference, the authors of this research chose to create an experience in which the student is introduced to some elements of programming, considering the PSeInt pseudo-language, in particular, the syntax and flowcharts of the control structures, information on comparison and logical operators, and the resolution of exercises on conditional expressions. PSeInt is a tool to support beginning programmers. It is a simple pseudo-language in Spanish that allows students to focus on understanding computational logic.

4.5. Virtual World Design and Programming

When designing an experience in Roblox, a wide variety of ready-to-use resources are available. Figure 1 shows the available categories. Many of the resources were created by members of the Roblox community.

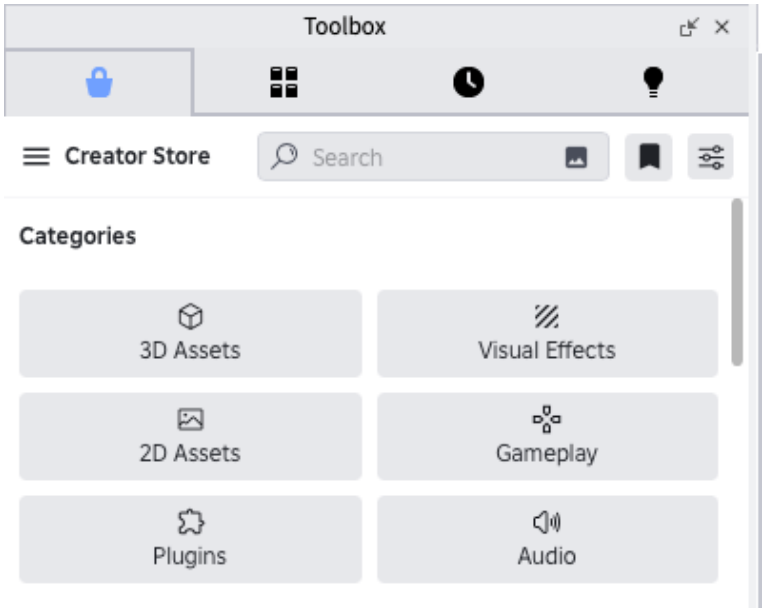


Figure 1. Roblox toolbox: categories of items available for incorporation into VW.

A virtual world was generated with a park theme using 55 3D models (8 benches, 4 garbage cans, 8 luminaires, 1 fountain, 17 trees, 11 slides, and 6 exercise panels). The virtual world presented students with information on control structures, comparisons, and logical operators in their surroundings. In addition, interactive models were integrated to perform exercises (see Figure 2).



Figure 2. Overview of the VW design created in Roblox.

The general experience involved guiding the student and presenting information about PSeInt in Roblox. For the exercises, students were instructed to solve expressions involving comparisons and logical operators; an example is shown in Figure 3. The student could generate a new exercise and practice with other values and operators.

Scripts using Roblox's Lua programming language were necessary to develop the exercises. The values and operators were generated randomly in each exercise. Therefore, it was necessary to design a graphical user interface in Roblox that would dynamically display exercises to the user. Figure 4 shows the user interface design, and Figure 3 shows an example with random values.

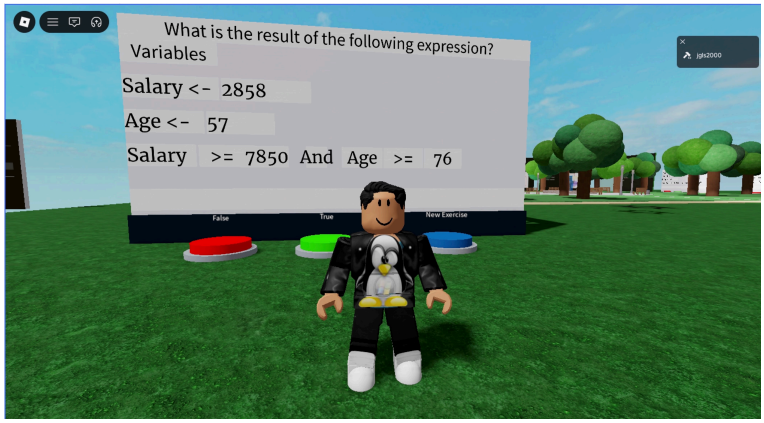


Figure 3. Example of an exercise regarding comparison and logical operators.

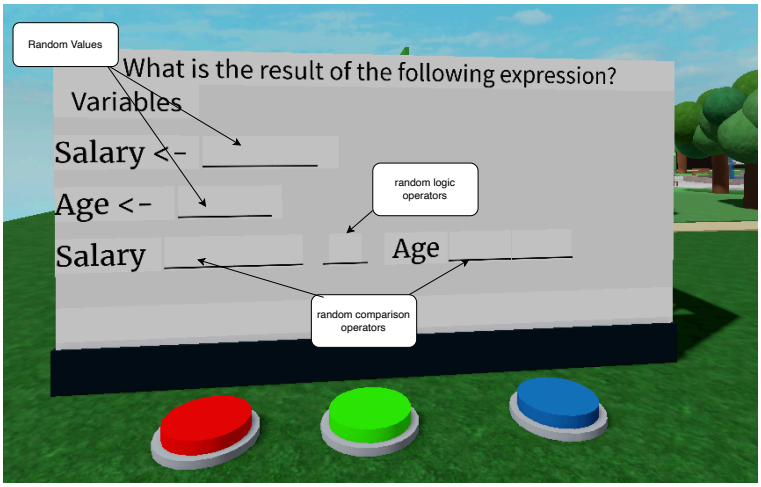


Figure 4. Graphical user interface exercises.

4.6. Materials Design

In the materials design phase, PowerPoint slides were made with information on the control structures, comparisons, and logical operators. Subsequently, the slides were converted to images and imported into Roblox Studio (See Figure 5).



Figure 5. Slides with information on the if-then conditional structure in Roblox.

4.7. Activity Execution

Figure 6 shows the activities performed in the study with Roblox. Each activity is explained below.

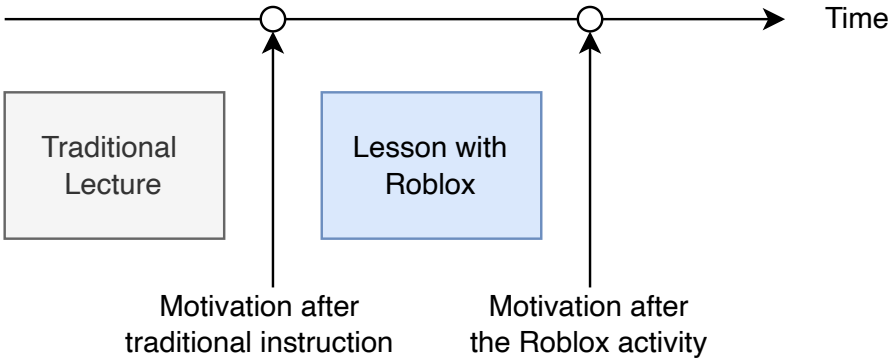


Figure 6. Instructional sequence and motivation measurement procedure.

4.7.1. Traditional Lecture

Before using Roblox, the students first took face-to-face classes with a teacher. The teacher explained control structures and conditional and logical operators in the traditional setting. Ten exercises using the PSeint environment were performed. After the classes, students were asked to answer the instrument to measure motivation.

4.7.2. Lesson with Roblox

The experience was published on the Roblox servers and made available to the students to use the VW created in Roblox and perform the immersive activity. Before the immersive activity, the teacher asked students to create an account and install Roblox on their devices (mobile or desktop). The teacher added all students as "friends" to access the VW. Figure 7 shows the students' avatars in the Roblox experience.

In the Roblox practice, the teacher guided the students through the activity and, through text chat, asked questions to the participating students. Students were asked to collaborate on the comparison and logical operator exercises. Many students sent screenshots of the computer solving the exercises (see Figure 8). At the end of the Roblox activity, students were asked to complete the motivation measurement instrument.



Figure 7. Students represented by avatars during the Roblox immersive activity.



Figure 8. Students solving exercises on conditional and logical operators.

5. Results

In this section, students' background in gaming and educational games and the results of the RIMMS instrument are presented. Subsequently, outcomes contrasting Roblox and traditional teaching are examined by gender and across the overall sample. The section concludes with the presentation of evidence concerning motivation levels evaluated via Wilcoxon signed-rank test.

5.1. Students' Background in Gaming and Educational Games

To establish the baseline digital profile of the sample and control for prior technological familiarity, participants were surveyed regarding their gaming frequency and previous exposure to video games used for educational purposes. 66% of the students had played video games and 49% of the sample had not used video games in educational environments.

5.2. RIMMS Instrument Results

The RIMMS results are presented in the following subsections, grouped by dimension, and the material provided by the teacher is compared using Roblox.

In each figure, the horizontal axis values represent the percentage of responses for disagree (left) and agree (right) relative to the neutral center point. The percentages shown on the right side of the figure correspond to the cumulative percentage of agreement responses.

5.2.1. Results for Attention

Most students agree that the quality, information organization, and interaction used in Roblox helped them maintain their attention (see Figure 9). During the Roblox activity, the students participated and interacted with the teacher. The teacher used the chat to ask questions about the content, and most students placed their avatars next to the teacher and wrote their answers. It is important to highlight that students were attentive to the indications.

Figure 10 shows the results on attention using the teacher's material. The students were not entirely convinced that the teacher's resources helped them maintain attention.

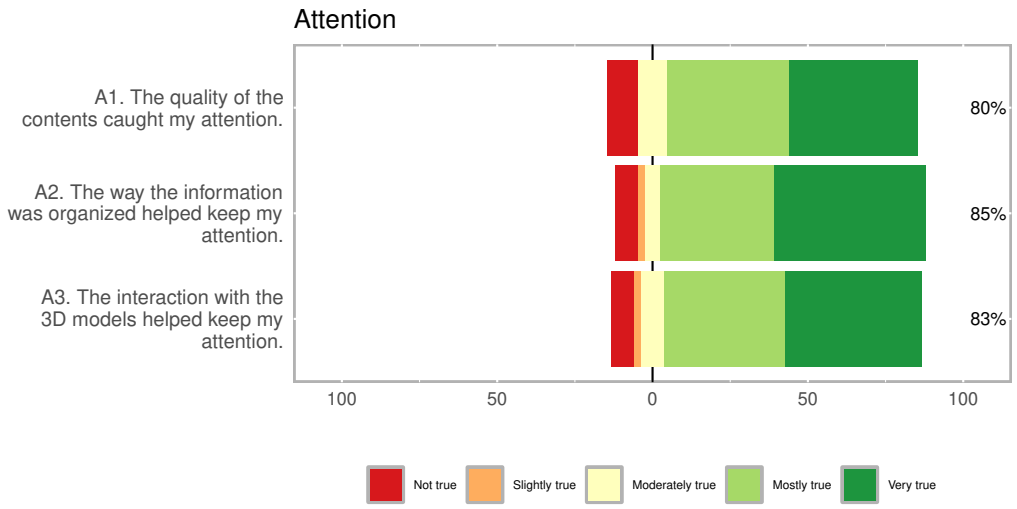


Figure 9. Results of the attention variable of the ARCS model using Roblox.

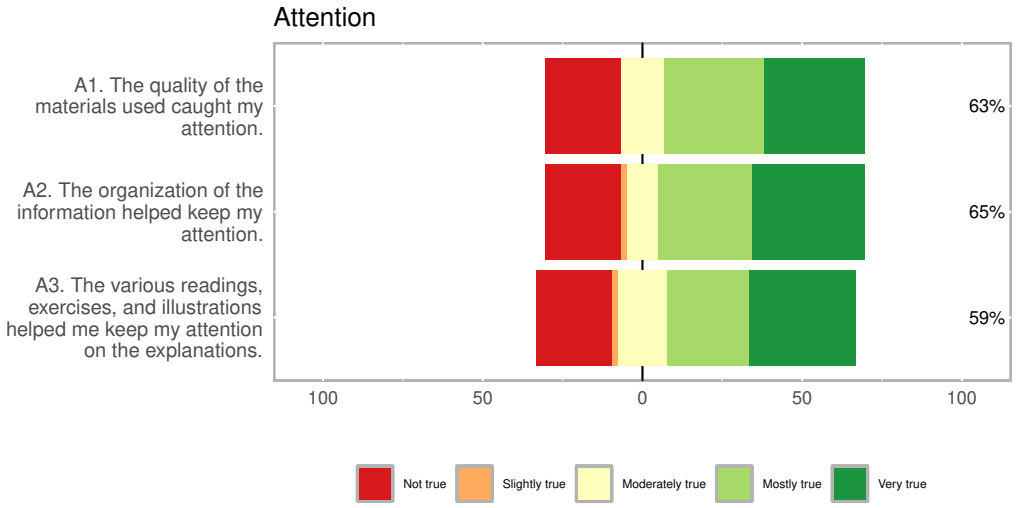


Figure 10. Results of the attention variable of the ARCS model using the teacher's material.

5.2.2. Results for Relevance

Students consider the content presented in Roblox relevant and valuable and indicate that it is worthwhile to delve deeper into the topic (see Figure 11).

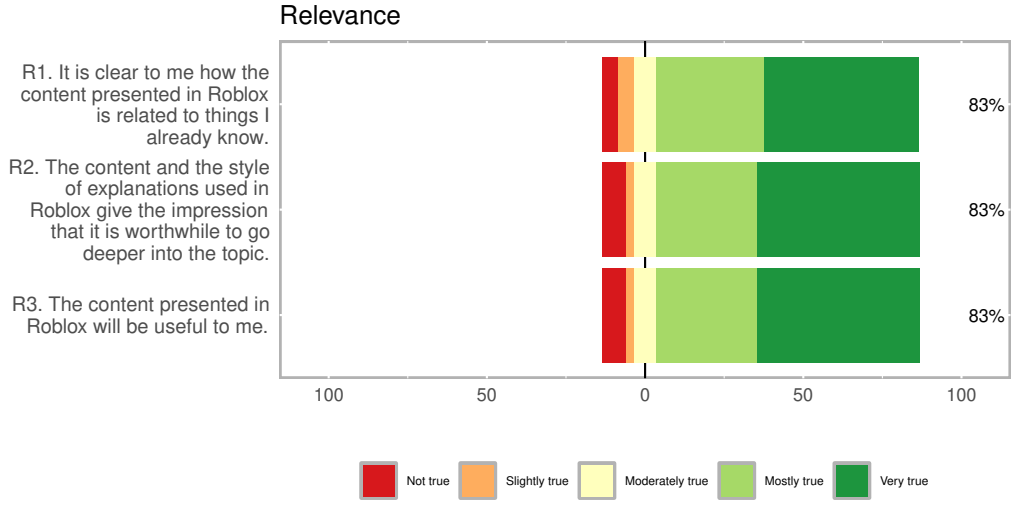


Figure 11. Results for the relevance variable of the ARCS model using Roblox.

Figure 12 shows the results on the relevance of the teacher's materials. Students agree that the content is useful and that going deeper into the topic is valuable. In contrast, students were not convinced that the teacher's material was related to topics they already knew.

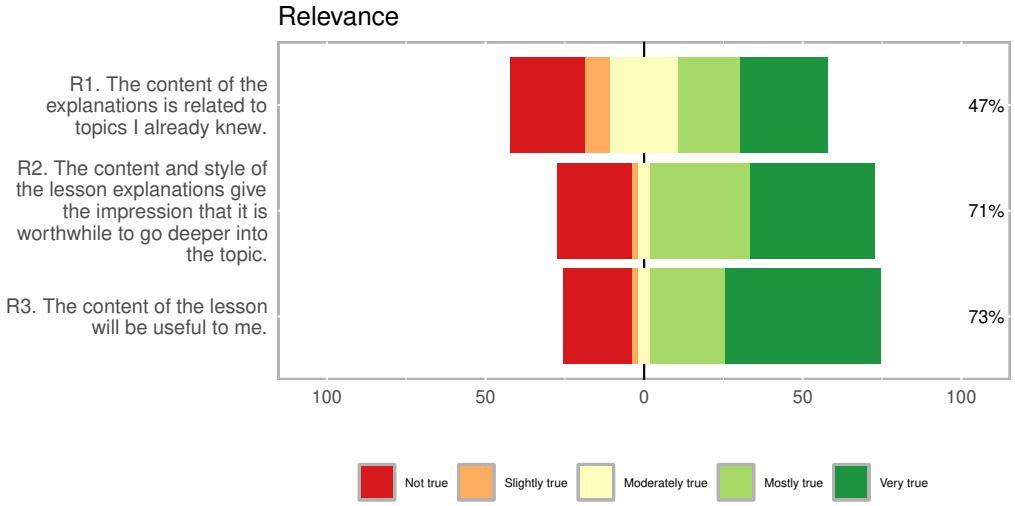


Figure 12. Results of the variable relevance of the ARCS model using teacher's material.

5.2.3. Results for Confidence

Figure 13 shows that students agree they could learn the content presented in Roblox, attributing this to the clarity of the explanations. On the other hand, students were not entirely convinced that they could pass a test on the topic.

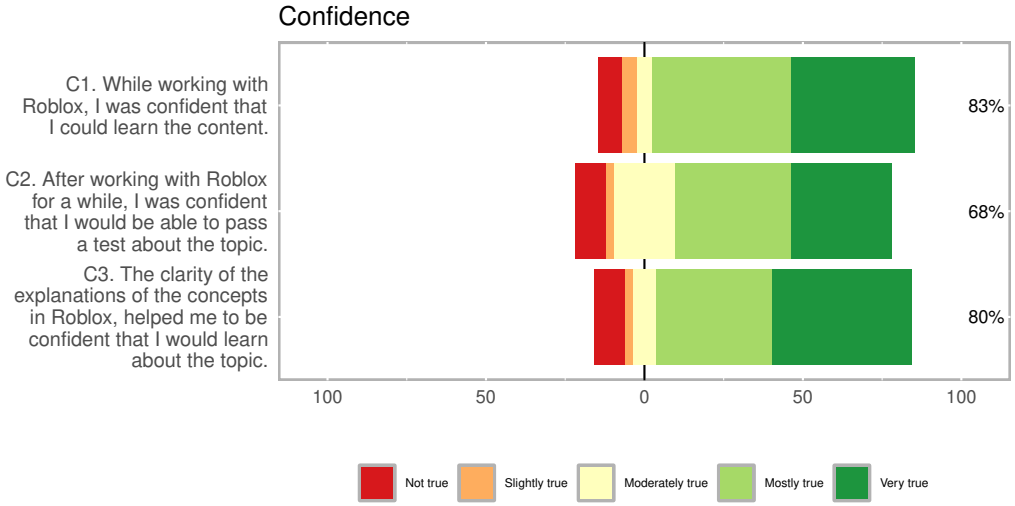


Figure 13. Results of the confidence variable of the ARCS model using Roblox.

Figure 14 shows the results corresponding to the teacher's material. 55% of students do not believe they would pass an exam on the subject. However, the students are confident that the clarity of the explanations and work in class would be conducive to learning and the correct application of the topics raised by the teacher.

5.2.4. Results for Satisfaction

Finally, the Satisfaction dimension is presented. Students agree that they liked working with Roblox, as they enjoyed the explanations (see Figure 15). Regarding the material offered by the teacher (see Figure 16), 39% of the students do not agree that they enjoyed the theoretical and practical learning provided by the teacher.

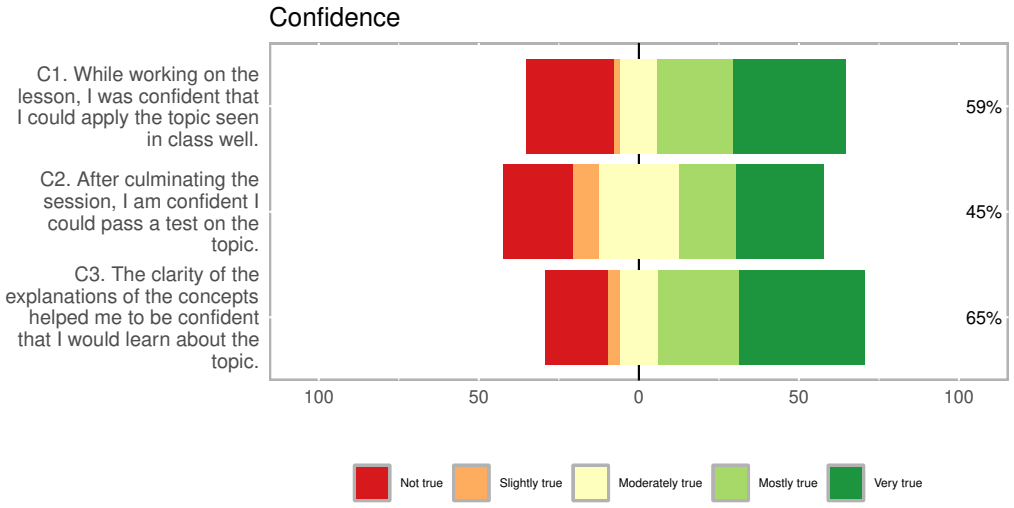


Figure 14. Results of the confidence variable of the ARCS model using the teacher's material.

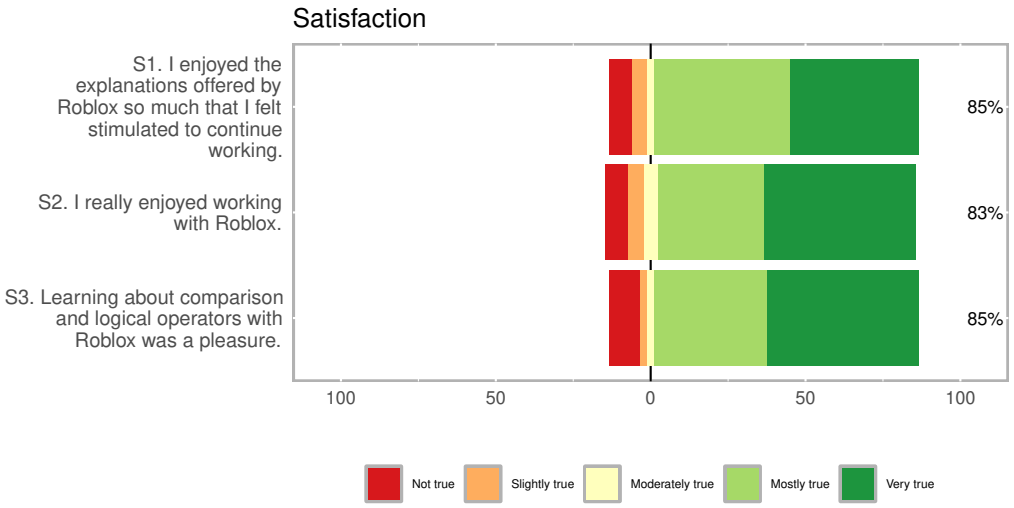


Figure 15. Results of the satisfaction variable of the ARCS model using Roblox.

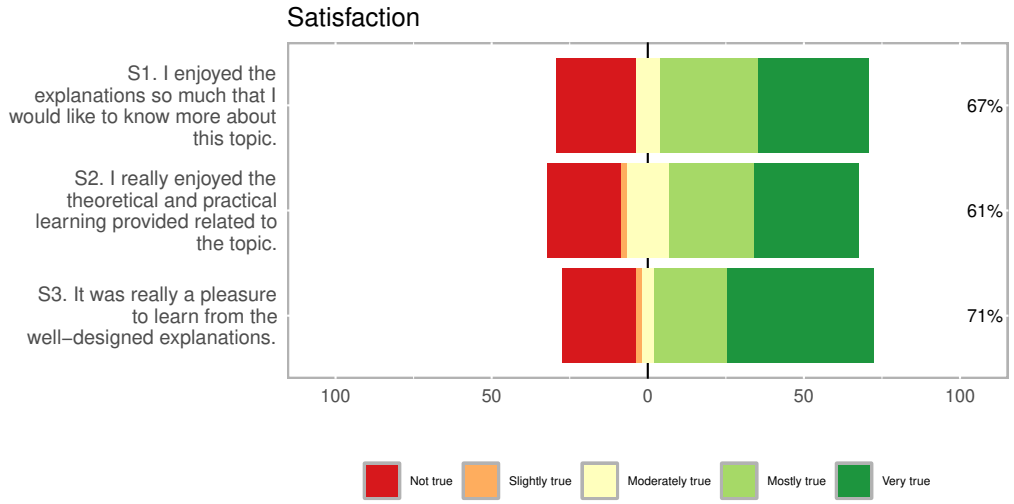


Figure 16. Results of the satisfaction variable of the ARCS model using the teacher's material.

5.3. Baseline Comparison Results

Of the 51 students initially enrolled in the course, 41 participated in both instructional conditions and provided complete paired measurements, whereas 10 students participated

in the traditional instructional condition but did not attend the Roblox activity. All 10 non-participants completed the first motivation measurement. To assess whether the students included in the paired analysis differed systematically from those who did not participate in the Roblox activity, the overall ARCS motivation score obtained after traditional instruction was compared between the two groups. The 41 complete cases had a mean ARCS score of 3.41 (median = 4.00), whereas the 10 non-participants had a mean of 3.78 (median = 3.92). The Mann–Whitney U test did not indicate a statistically significant difference between the groups (U = 199.000, Z = −0.142, p = 0.896), with a very small effect size (r = 0.020). This result does not establish equivalence between the groups; rather, they indicate that no statistically significant differences were detected in the available baseline motivation measure. Nevertheless, because the 10 non-participants did not provide a second measurement, the possibility of participation-related bias cannot be completely excluded.

5.4. Motivation Level Results with Roblox and Traditional Teaching by Gender

The measurement scale applied in Tables 2 and 3 for assessing motivation level was a 5-point Likert scale. In addition, the overall ARCS score was calculated by averaging the four individual factors evaluated during the tests.

The results by gender shown in Table 2 were obtained from a paired sample of 41 students who participated in both Roblox and traditional classes. Of the total sample, ten are female, and 31 are male. Males presented higher motivation levels (M = 4.23) than females (M = 3.63) when using Roblox. The plotted results are shown in Figure 17. To confirm that this difference is significant, the Shapiro-Wilk test was applied to both groups (females and males), which indicated that the data do not follow a normal distribution. Therefore, a Mann–Whitney U test was conducted to evaluate whether there were differences in motivation based on participant gender. The results indicated no statistically significant difference between males ($N = 31$, Mean Rank = 21.60) and females ($N = 10$, Mean Rank = 19.15), $U = 136.500$, $Z = -0.567$, $p = 0.571$ (exact $p = 0.580$). The effect size, calculated as $r = \frac{|Z|}{\sqrt{N}}$ with $N = 41$, was $r = 0.09$, indicating a small effect. Therefore, the observed difference in mean motivation scores should not be interpreted as evidence of a meaningful gender-related difference in students' reported motivation. These findings are limited to the present sample and Roblox-supported instructional activity and do not establish equivalence of motivational responses between gender groups. Given the unequal group sizes and the exploratory nature of this analysis, further studies with larger and more balanced samples are needed to examine whether gender-related differences in reported motivation are consistently observed across Roblox-supported programming learning environments.

Table 2. ARCS motivation results by gender of students participating with Roblox.

Variable	Men M	Women M
Attention (A)	4.22	3.73
Relevance (R)	4.29	3.80
Confidence (C)	4.11	3.43
Satisfaction (S)	4.28	3.57
ARCS	4.23	3.63

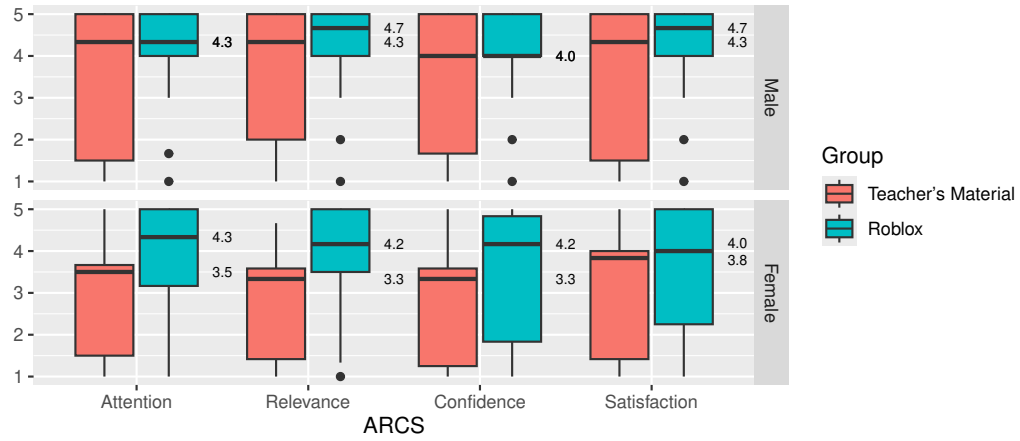


Figure 17. ARCS model results grouped by gender. The circles correspond to outliers.

5.5. Motivation Level Results with Roblox and Traditional Teaching Complete Sample

Finally, across the complete paired sample (n = 41), the results for each factor indicate that there are differences in students' motivation when using Roblox (see Table 3). The motivation level with Roblox (M = 4.08) is higher than the teacher's material (M = 3.41). Figure 18 shows the motivation after traditional instruction and after the Roblox activity.

Table 3. ARCS motivation results traditional instruction and Roblox activity.

Variable	Motivation After Traditional Instruction	Motivation After the Roblox Activity
Attention (A)	3.39	4.10
Relevance (R)	3.41	4.17
Confidence (C)	3.35	3.94
Satisfaction (S)	3.50	4.11
ARCS	3.41	4.08

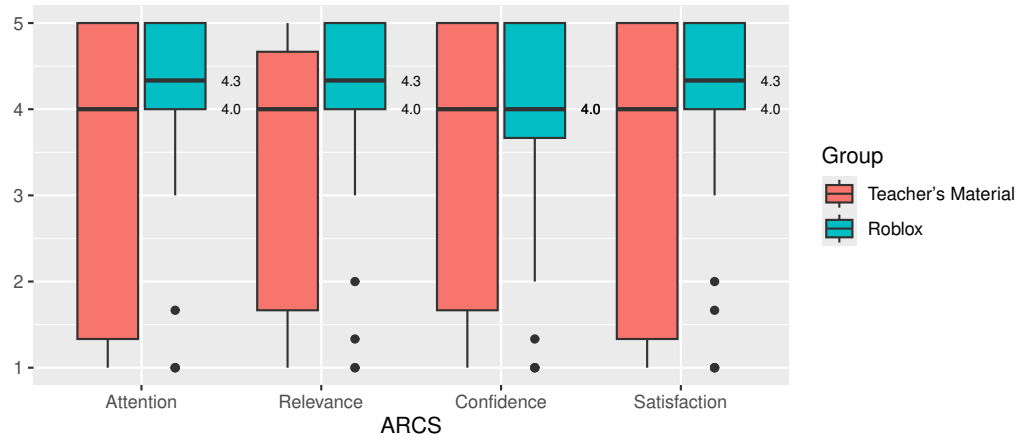


Figure 18. ARCS Model Results: Roblox and Teacher's Material. The circles correspond to outliers.

5.6. Wilcoxon Signed-Rank Test Results for Roblox Motivation Level

The Shapiro-Wilk test was applied to the four ARCS factors (Attention, Relevance, Confidence, Satisfaction) and the overall ARCS score, indicating that the data do not follow a normal distribution. Therefore, a Wilcoxon signed-rank test was conducted to compare motivation levels between the traditional modality and Roblox. The Wilcoxon signed-rank test was used to evaluate differences between the paired motivation scores. While this non-parametric test addresses non-normal distributional assumptions, it evaluates only

whether the paired scores differ statistically across the two measurement points; it cannot control for confounding variables arising from the fixed-order design, prior content exposure, teacher interactions, peer collaboration, immediate feedback, or differences in instructional format. In addition, the Wilcoxon signed-rank test was used as an exploratory comparison of the paired motivation scores obtained under the two contextualized instructional conditions. Because measurement equivalence between the two RIMMS versions was not established, this analysis does not constitute a confirmatory test of change in the underlying motivational construct. The results revealed a statistically significant difference between both modalities ($Z = -2.264$, $p = 0.024$, $r = 0.354$, $N = 41$). The observed effect size was of moderate magnitude according to Cohen's criteria. Specifically, a higher number of participants in Roblox reported greater motivation (n = 22, mean rank = 21.68) compared to the traditional modality (n = 14, mean rank = 13.50), while 5 participants showed no difference.

As a secondary, exploratory analysis, Table 4 shows the Wilcoxon signed-rank test results across the four ARCS motivation dimensions for the Roblox phase. To control the family-wise error rate due to multiple comparisons, p-values were adjusted using the Holm step-down procedure. After adjustment, statistically significant differences were retained only for Attention ($Z = -2.672, p = 0.008, p_{adj} = 0.024, r = 0.417$) and Relevance ($Z = -2.959, p = .003, p_{adj} = 0.012, r = 0.462$), both displaying moderate effect sizes. For Confidence ($Z = -2.188, p = 0.029, r = 0.342$) and Satisfaction ($Z = -2.062, p = 0.039, r = 0.322$), although moderate effect sizes were observed, the differences did not remain statistically significant after Holm adjustment ($p_{adj} = 0.058$ for both). Consequently, these dimension-level findings are interpreted as exploratory and do not provide confirmatory evidence of differences across all four ARCS dimensions.

Table 4. Wilcoxon signed-rank test results for the four dimensions of the ARCS model (Roblox).

Variable	Negative Ranks (*n*)	Positive Ranks (*n*)	Ties (*n*)	Test Statistic (*Z*)	*p*-Value	Holm-Adjusted *p*	Effect Size *r*	Interpretation
Atention	11	21	9	−2.672	0.008	0.024	0.417 [1]	Moderate effect; significant after Holm adjusted
Relevance	8	22	11	−2.959	0.003	0.012	0.462 [1]	Moderate effect; significant after Holm adjusted
Confidence	12	18	11	−2.188	0.029	0.058	0.342 [1]	Moderate effect; not significant after Holm adjusted
Satisfaction	11	18	12	−2.062	0.039	0.058	0.322 [1]	Moderate effect; not significant after Holm adjusted

[1] Effect sizes were calculated as $r = \frac{|Z|}{\sqrt{N}}$, where Z is the Wilcoxon statistic and N is the total number of observations.

6. Discussion and Conclusions

The Wilcoxon signed-rank test indicated a statistically significant difference between the scores recorded after traditional instruction and those recorded after the Roblox activity ($Z = -2.264, p = 0.024, r = 0.354$). However, because statistical testing cannot correct for the confounding factors inherent to the fixed-order design, this significant result reflects only a difference between the two measurement points and cannot be interpreted as evidence of a Roblox intervention effect. Consequently, regarding RQ1, while students exhibited higher motivation scores during the Roblox activity, the design limitations prevent

attributing this increase to Roblox. Furthermore, the novelty effect could have affected the results, as Marešová et al. noted that the VW should be used longer [56]. Although part of the sample reported previous gaming experience, this information does not establish familiarity with the specific Roblox educational environment. Therefore, a novelty effect cannot be ruled out.

Students reported high levels of attention during the Roblox-supported activity, particularly regarding the organization of information and interaction with 3D models. The interaction was possible as Roblox provides a more programmable environment for users to create their worlds [21]. In addition, students consider what they have seen in Roblox to be relevant and valuable, and would like to go deeper into the topic. Regarding satisfaction, students indicate that working with Roblox is very satisfying. Students were stimulated to learn more about how VWs are created in Roblox during the activity. It is important to note that students who use Roblox indicate confidence in passing an exam. On the other hand, students do not believe they can pass an exam using the teacher's material. In developing contexts such as Mexico, Roblox is a highly accessible platform because it does not require specialized hardware (such as VR headsets) to deliver virtual experiences. The use of Roblox may offer practical accessibility advantages because it can be accessed without specialized VR hardware and without licensing fees.

It must be explicitly noted that formal psychometric equivalence and measurement invariance between the adapted instrument versions across conditions were not evaluated. Because item wording was modified to reflect condition-specific instructional resources (e.g., 3D models in Roblox versus traditional readings), the two administrations do not measure identical operational indicators. Consequently, the Wilcoxon results should be interpreted as an exploratory comparison of students' reported motivation across two contextualized instructional experiences rather than as confirmatory evidence of change in the underlying motivational construct. The observed differences therefore cannot be interpreted as evidence that the Roblox activity itself caused an increase in motivation.

An additional analysis was conducted to examine whether the students included in the paired analysis differed systematically from those who did not participate in the Roblox activity. All 10 non-participants had completed the motivation measurement following traditional instruction, allowing a baseline comparison with the 41 students who subsequently participated in the Roblox activity. No statistically significant difference was detected in the overall ARCS motivation score between the two groups (U = 199.000, Z = −0.142, p = 0.896, r = 0.020). This finding provides no statistical evidence of an observable baseline difference in the available variables between complete cases and non-participants. However, they do not establish equivalence between the groups or rule out participation-related bias, because the 10 non-participants did not provide a second measurement and their motivation under the Roblox condition is therefore unknown. Accordingly, the primary paired analysis remains restricted to the 41 students who completed both measurements.

Regarding gender, using mean motivation levels as a reference, men (M = 4.23) show higher motivation than women (M = 3.63); however, the Mann–Whitney U test indicates no significant difference by gender with the effect size, calculated as $r = \frac{|Z|}{\sqrt{N}}$, corresponding to a small effect size ($r = 0.09$), which responds to RQ2. These results differ from those reported by Jo and Park, who indicated that men relieve boredom through the Metaverse [57]. However, as Leonhardt and Overå indicated, gender differences in video games are not necessarily a problem per se, as they may reflect gender-specific motivations and interests [58].

In summary, the findings indicate that students reported higher motivation scores after the Roblox-supported activity than after the preceding traditional instruction; these differ-

ences should be interpreted as exploratory descriptive evidence rather than as evidence of an effect attributable specifically to Roblox.

It is important to note that differences observed in motivation scores relative to the traditional phase must be interpreted with caution due to structural variations in item wording. Because each version of the instrument referenced condition-specific instructional resources, these comparisons serve purely descriptive purposes and do not establish psychometric equivalence across measurement points.

The present study deals with the following limitations:

- The study employed a single-group design without a control group.
- The sample was not randomly selected because it consisted of mandatory class groups assigned to the teacher.
- This study is subject to temporal limitations, as the intervention comprised only two sessions (traditional lecture and lesson with Roblox).
- The fixed order of instruction, non-controlled factors —such as order effects, novelty effect, prior content exposure, and instructional format variations— may contribute to the observed differences in student scores.
- A further limitation concerns participation in the second instructional condition. Although all 51 students completed the traditional instructional condition and its corresponding motivation measurement, only 41 participated in the subsequent Roblox activity, leaving 10 students without a second measurement. A comparison of the available baseline data did not identify statistically significant differences in overall motivation between the 41 complete cases and the 10 non-participants. Nevertheless, these analyses cannot rule out participation-related selection or attrition bias because the motivational response of the 10 non-participants under the Roblox condition is unknown. Consequently, the findings should be interpreted as applying to the students who completed both instructional conditions, rather than to the entire initial class sample.

Although the study has methodological limitations, these do not invalidate its findings, provided they are interpreted within the scope of its exploratory design.

In future research, it would be important to determine the effects of virtual worlds in other more advanced programming courses, higher-level subjects, and long-term studies. Furthermore, a larger sample of students and the incorporation of interactive exercises on control structures (conditionals and cycles) are proposed.

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Institutional Review Board Statement: Ethical review and approval were waived for this study by the Secretariat of Research of the Faculty of Accounting and Administration at the Universidad Autónoma de Nuevo León (Official Letter No. FACPYA-SI-NO-103/2025) because the research falls within institutional criteria for exempt educational research. The study was conducted strictly within an established higher education setting, involved standard educational practices and strategies regarding programming education, and posed no physical, clinical, or psychological risk to partici-

pants. Confidentiality, anonymity, and data protection measures were strictly maintained throughout the project.

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

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Abbreviations

The following abbreviations are used in this manuscript:

ARCS	The attention, relevance, confidence, and satisfaction model
AR	Augmented reality
VR	Virtual reality
AI	Artificial Intelligence
IoT	Internet of Things
Meta-MILE	Multi-layered Immersive Learning Environment
SCRUM	Agile framework for project management
JCLM-MVS	Jigsaw collaborative learning method implemented in the Metaverse
VAMEP	Virtual Art Museum Education Program
MAM	Moonshin Art Museum
MatVers	El Metaverso de las Matemáticas
STEM	Science, Technology, Engineering, and Mathematics
IMMS	Instructional Materials Motivation Survey
RIMMS	Reduced Instructional Materials Motivation Survey
VW	Virtual world

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