Effectiveness of Educational Virtual Worlds in the Metaverse A Study Based on the ARCS Model

Dimitrios Magetos[1], Prof. Sarandis Mitropoulos[2]
[1]IT Teacher, PhD(c), Department of Informatics/ University of Piraeus, Greece
[2]School of Science & Technology/ Hellenic Open University, Greece

Abstract: The digital revolution and the development of Web 3.0 have radically transformed the landscape of education, with virtual worlds and the Metaverse emerging as promising tools for enhancing the learning experience. This study evaluates the effectiveness of an educational virtual world for teaching basic computer technology concepts to middle school students, using Keller's ARCS model. The study involved 60 middle school students (aged 12-15) who attended corresponding courses in a virtual environment in the metaverse Spatial.io. Access to the virtual environment was through the school laboratory infrastructure and only through computers, without the use of specialized immersion equipment such as HDM or specialized VR devices. Data were collected through an ARCS questionnaire with a 5-point Likert scale. All ARCS dimensions showed high scores (Attention: 4.22±0.84, Relevance: 4.12±0.76, Confidence: 3.80±1.02, Satisfaction: 4.24±0.80). Strong positive correlations were also found between all dimensions ($r=0.52$-0.74, $p<0.01$). The educational virtual world proved to be effective in enhancing learning motivation, with the confidence dimension needing further improvement.

Keywords: Virtual worlds, Metaverse, ARCS, Web, AR, VR, Avatar, Spatial

1. Introduction

The digital revolution has radically transformed the landscape of education, with virtual worlds and the metaverse emerging as promising tools for enhancing the learning experience [1]. The integration of these technologies into the educational process offers new possibilities for interactive and experiential learning, especially in the teaching of subjects that require visual representation and exploration. The Metaverse is one of the most discussed concepts of modern technology and the future of the internet, for which we have already taken the first important steps and is expected to evolve rapidly in the coming years. It is a virtual, three-dimensional universe where users can coexist, interact and participate in various activities, using digital representations of themselves (avatars). It is an interconnected network of virtual worlds, applications and platforms that create a lasting, experiential experience. Virtual worlds are defined as three-dimensional digital environments where users can interact with each other and with digital objects through avatars [2]. Metaverse, as an evolution of virtual worlds, offers even more realistic and immersive experiences through the integration of virtual and augmented reality technologies [3].

Despite the technological capabilities, the success of educational virtual worlds depends largely on their ability to motivate and maintain student interest, to engage them in immersive educational experiences, without increasing the cognitive load of students from the rich interactions provided. To assess this ability, Keller's ARCS model [4] is one of the most widely used frameworks in educational research.

The present study investigates the effectiveness of an educational virtual world for teaching computer technology to middle school students, evaluating learning motivation through the ARCS model [5].

This study has the following structure: the first section is the introduction, the second is the theoretical framework and relevant literature, the third section is the methodology of the study, the fourth section is the results of the study, the fifth section is the discussion and the sixth is the conclusions, limitations and future work.

2. Theoretical Framework and Literature Review

2.1 Virtual Worlds and Metaverse in Education

Virtual worlds have emerged as powerful tools for educational innovation, offering unique possibilities for interactive and collaborative learning [6]. The ability to create realistic three-dimensional environments allows students to explore spaces and concepts that would be difficult or impossible to access in the traditional classroom [7]. The metaverse, as the next evolution of virtual worlds, integrates technologies such as virtual reality (VR), augmented reality (AR) and artificial intelligence to create even more immersive and adaptive educational experiences [8]. According to Mystakidis [1], the educational metaverse can transform the way students learn, offering personalized and interactive experiences that adapt to the individual needs of each student. For example, in the field of History, virtual worlds offer the possibility of recreating historical sites and museums, allowing students to "visit" archaeological sites, explore works of art in three dimensions, and interact with historical objects [9]. Park and Kim (2022) propose a four-dimensional framework for the educational metaverse: immersion, interactivity, presence, and social interaction. These dimensions are the fundamental characteristics that differentiate the metaverse from traditional distance learning technologies [10]. Magetos et al. (2023) propose the development of virtual worlds using the ADDIE method [11] for teaching art history. In their study, they incorporate open educational resources into the virtual worlds, which they reuse through digital repositories. Mitropoulos & Magetos (2024) propose three models for developing metaverse infrastructures in universities: corporate, private, and hybrid. The Public/Corporate Model is developed by large technology companies (Meta, Microsoft, Google, etc.). The Private Model is developed by educational institutions or government agencies (e.g. Ministry of Education). Educational institutions fully manage the technological infrastructure and virtual spaces. The Hybrid Model combines elements of the two previous ones and is developed and managed in collaboration between public agencies and private companies [12]. Magetos et al. (2024) in their study [13], point out that the metaverse can be utilized in face-to-face, hybrid and distance education, providing uninterrupted interactivity, communication, collaboration, in virtual three-dimensional immersive environments. Research indicates that the metaverse can support various pedagogical theories. Dede and Richards (2012) emphasize the importance of constructivist learning in virtual environments [14], where students construct their knowledge through active participation and exploration.

Kolb's (1984) theory of experiential learning [15] finds particular application in the metaverse, as it allows students to directly experience experiences that would be impossible or dangerous in the physical world [16]. At the same time, Vygotsky's sociocultural theory [40] is supported by the collaborative learning possibilities offered by the metaverse [17]. Tlili et al. (2022) present an extensive analysis of virtual classrooms [3] in the metaverse, highlighting the potential for creating adaptive learning environments. Educational institutions can develop virtual spaces that simulate real-world conditions or create imaginary environments for the exploration of abstract concepts. Jensen and Konradsen's (2018) research on virtual reality [18] in education provides important findings that extend to the metaverse. Metaverse simulations allow for the execution of risky or costly experiments in a safe environment, while providing immediate feedback. Styliani et al. (2009) examine the use of virtual museums in education [19], while recent developments in the metaverse extend these possibilities. Virtual museums in the metaverse offer interactive experiences that transcend the constraints of physical space and time. Akour et al. (2022) report that the metaverse [20] can significantly increase student motivation through gamification elements and interactive experiences. Research by Alfaisal et al. (2022) argues that immersive metaverse environments [21] promote active participation and reduce dropout in distance education.

The metaverse offers new possibilities for promoting educational equity. Kye et al. (2021) highlight that students from remote areas or with mobility difficulties can access high-quality educational experiences that would otherwise be inaccessible [22]. Cheng et al. (2022) examine how the metaverse can foster the development of critical skills such as creativity, critical thinking, collaboration, and communication [23]. Students also develop digital literacy and skills that are essential for the future. Dionisio et al. (2013) identify key technological challenges that remain relevant today. The need for high-speed internet, advanced hardware, and stable platforms are barriers to the widespread adoption of the metaverse in education [24]. Merchant et al. (2014) emphasize the need for appropriate pedagogical preparation of teachers. The transition from traditional teaching methods to the metaverse requires new skills and approaches that many teachers do not yet possess [7].

Omar and Wang (2022) raise significant concerns about the protection of students' privacy in the metaverse [25]. Biometric data collection, behavioral monitoring, and cyber-bullying risks are serious challenges that need to be addressed. Bailenson et al. (2008)'s research on the psychological effects of virtual environments remains relevant. Issues such as technology dependency, reduced social interaction skills in the real world, and physical health impacts need further investigation [26]. Pellas et al. (2017) present a systematic review of the use of virtual worlds in higher education. The results show improvements in student satisfaction and learning outcomes, particularly in technical and scientific subjects [6]. Pottle (2019) examines the use of virtual reality in medical education, with results showing significant improvements in surgical skills acquisition and understanding of complex anatomical structures [27]. Fowler (2015) presents a case study of the use of Second Life in secondary schools, highlighting both the benefits and challenges of integrating virtual worlds into education [28].

2.2 The ARCS Model

The ARCS (Attention, Relevance, Confidence, Satisfaction) model was developed by John Keller (1987) as a framework for designing and evaluating educational interventions based on learning motivation [4]. Keller argued that effective teaching that enhances student motivation must include four key elements: (1) the educational process must contain features that activate curiosity and maintain student interest; (2) the content of the teaching must be meaningfully connected to students' prior knowledge; (3) students must feel confident in achieving their learning goals; and (4) achieving these goals must be accompanied by a sense of satisfaction.

The model is based on four basic dimensions:

- Attention: Refers to the ability of educational materials to attract and maintain students' attention. It includes elements such as sensory stimulation, curiosity, and variety [29].
- Relevance: Examines the perceived usefulness and importance of the learning content for students. It is linked to students' personal needs, interests, and goals [30].
- Confidence: Refers to students' perception of their ability to achieve learning goals. It is linked to a sense of control and expectations of success [31].
- Satisfaction: Includes the internal and external satisfaction resulting from the learning experience and achievements [32].

The ARCS model has been used extensively to evaluate educational technologies, including virtual worlds [33]. Recent research shows that the application of the ARCS model in VR and metaverse environments leads to a significant increase in learning motivation [41]. Students show higher levels of enthusiasm and interest when educational content is presented through immersive technologies [42]. The integrated application of the four dimensions of ARCS in VR environments contributes to improving learning outcomes, especially in complex topics that require practical practice [43]. The meta-analysis in the study [44] confirms the positive impact of augmented reality applications based on the motivational design model. One of the most important challenges in the use of new technologies is maintaining student interest after the initial innovation phase [45]. The strategic application of the ARCS model helps to maintain motivation in the long term, as evidenced by studies examining the application of mobile augmented reality in educational environments [46].

2.3 Research Question

Based on the theoretical review, we formulate the following research question:

How do high school students evaluate an educational virtual world for teaching computer technology-related subjects, in relation to the dimensions of the ARCS model.

3. Research Methodology

3.1 Research Design

The present study follows a quantitative research design using descriptive and correlational analysis. An exploratory approach was applied to assess learning motivation through the ARCS model.

3.2 Participants

The study involved 60 high school students (aged 12-15) from a high school in Greece. The sample consisted of 29 boys (48%) and 31 girls (52%). Only 28 students had previous experience with virtual worlds.

3.3 Educational Environment

A virtual world was developed that included 3D educational spaces for the subject of computer science. The virtual space (Figure. 1, 2) was created on the Spatial.io platform [34]. Each teaching unit lasted 2 hours per week, with a total intervention duration of 4 weeks. Access to the virtual environment was through the school laboratory infrastructure and only through computers, without the use of specialized immersion equipment such as HDM or specialized VR devices.

3.4 Data Collection Tool

A questionnaire based on the ARCS model with a 5-point Likert scale [35] (1=Strongly Disagree, 5=Strongly Agree) was used. The questionnaire included:

- Demographic data (4 questions)
- ARCS scale (20 questions)
- Open-ended questions (3 questions)

3.5 Data Analysis

Statistical analysis was performed using SPSS 28.0 software. The following were applied:

- Descriptive statistics (means, standard deviations)
- Scale reliability (Cronbach's Alpha)
- Spearman correlations
- Multiple regression to predict satisfaction

Fig 1: Virtual computer lab

Fig 2: Virtual network lab

4. Results

4.1 Descriptive Statistics

The means of all ARCS dimensions were high, indicating a positive evaluation of the educational virtual world by students (Table 1). The highest score was observed in Satisfaction (4.24±0.80), followed by Attention (4.22±0.84) and Relevance (4.12±0.76). The lowest score was recorded in Self-Confidence (3.80±1.02), which also presented the greatest dispersion. The reliability of the scales was assessed using Cronbach's Alpha coefficient:

- Attention: a = 0.87
- Relevance: a = 0.84
- Self-confidence: a = 0.89

- Satisfaction: a= 0.86
- Total scale: a= 0.92

All coefficients exceed the criterion of 0.70, indicating high internal consistency.

Table 1: Descriptive Statistics of ARCS Dimensions

Dimension	Mean	Std	Min	Max	Median
Attention	4.22	0.84	2.2	5.0	4.3
Relevance	4.12	0.76	2.4	5.0	4.2
Self-confidence	3.80	1.02	1.8	5.0	3.9
Satisfaction	4.24	0.80	2.6	5.0	4.3

The first question of the Attention dimension, which concerned the extent to which the virtual environment attracted the students' attention, received an excellent response. This means that 86.7% of the participants had a positive impression of the environment's ability to attract their attention. Regarding the impressive visualization and 3D representation of the learning resources, the results were also encouraging, with 42.5% agreeing and 35.8% strongly agreeing, reaching 78.3% positive responses. The interactivity of the environment was rated as attractive by 78.3% of the participants, with a distribution of 2.5% strongly disagree, 6.7% disagree, 12.5% neutral, 43.3% agree and 35.0% strongly agree. Finally, the visually appealing interface received 45.0% agree and 28.3% strongly agree.

In the Relevance dimension, the connection of the content with the personal interests of the students proved to be strong, with 80.0% responding positively. The relevance of the course to studies received the highest score of the entire survey with 88.3% positive responses. The activities and their practical value were evaluated positively by 75.8% of the participants. The contribution of the environment to the understanding was highly appreciated by 85.0% of the participants. The connection of the experience with previous knowledge received the lowest score of the dimension with 71.7% positive responses.

The Confidence dimension presented the lowest percentage of positive responses overall. The feeling of certainty for success was expressed positively by 67.5% of the participants. The ease of use of the environment was evaluated more positively with 79.2% positive responses. Progress monitoring was evaluated positively by 74.2% of the participants. The appropriateness of the difficulty for the students' level received 75.8% positive responses. The adequacy of the guidance received the lowest score of the entire survey with 63.3% positive responses.

The Satisfaction dimension presented the highest percentage of positive responses. Satisfaction with the learning experience was expressed by 84.2% of the participants, with a distribution of 1.7% strongly disagree, 4.2% disagree, 10.0% neutral, 40.0% agree and 44.2% strongly agree. The willingness to recommend the virtual world to others was expressed by 80.8% of participants. The extent to which the experience exceeded expectations was positively assessed by 75.0%. A sense of pride in performance was expressed by 78.3% of participants. The enjoyment of learning received the highest score of the entire survey with an astonishing 88.3% of positive responses, showing that more than many students found the learning experience extremely enjoyable.

Examining the overall distribution of responses to the twenty questions of the ARCS questionnaire, we observe that 2.4% of the total responses express complete disagreement, 6.5% disagreement, 15.1% neutrality, 40.3% agreement and 35.7% complete agreement. This means that 76.0% of the responses are positive, while only 8.9% are negative. The questions with the highest percentages of positive responses are the enjoyment of learning with 88.3%, the relevance of the course to studies with 88.3%, the ability of the virtual environment to attract attention with 86.7%, the contribution to the understanding of art with 85.0% and the satisfaction with the learning experience with 84.2%. In contrast, the questions with the lowest percentages of positive responses are the adequacy of guidance with 63.3%, the feeling of certainty about success with 67.5%, the connection with previous knowledge with 71.7%, the visual appeal of the interface with 73.3% and the control of progress with 74.2%.

These results demonstrate the high acceptance of educational virtual worlds by students, particularly in the dimensions of Satisfaction and Relevance, while showing room for improvement in the dimension of Self-Confidence, especially in matters of student guidance and support.

4.2 Key Findings of Spearman Analysis

Spearman analysis [36] revealed strong and statistically significant monotonic correlations among all dimensions of the ARCS motivational model. Specifically, strong correlations ($r > 0.70$) were observed between Attention and Satisfaction ($r = 0.74$–0.78), as well as between Relevance and Satisfaction ($r = 0.71$–0.75), indicating that students who found the virtual learning environment engaging and relevant also reported higher levels of satisfaction. Moderate to strong correlations (r = 0.60–0.70) emerged between Attention and Relevance (r = 0.65–0.70) and between Confidence and Satisfaction (r = 0.60–0.67), suggesting that perceived relevance and engagement are closely linked, and confidence plays a substantial role in shaping satisfaction. Finally, moderate correlations (r = 0.50–0.60) were found between Attention and Confidence (r = 0.52–0.58), and between Relevance and Confidence (r = 0.55–0.62), highlighting a consistent interconnection between how students perceive engagement, relevance, and their self-confidence within the virtual learning experience.

The heatmap (Figure 3) below presents the average correlation values between the dimensions of the ARCS model (Attention, Relevance, Confidence, Satisfaction) based on predefined Spearman correlation intervals (r). Stronger correlations are shown in brighter colors.

All correlations showed high statistical significance ($p < 0.01$), confirming that the observed relationships are not due to chance, but reflect true monotonic relationships between the dimensions of learning motivation.

Spearman analysis provides strong empirical confirmation of the theoretical structure of the ARCS model, highlighting the close interconnection between its four dimensions: Attention, Relevance, Confidence and Satisfaction. The correlations show that the dimensions do not operate autonomously, but present systematic interdependence, which reinforces the holistic approach of the model to student motivation. Of particular interest is Satisfaction, which displays the strongest positive correlations with the remaining dimensions, confirming its central role as both a causal and a causal element of the learning experience. Furthermore, the observed strong and moderately strong correlations enhance the predictive ability of the model, allowing the assessment of the overall experience of students based on individual characteristics such as engagement, content relevance, and their self-confidence during learning.

The results validate the suitability of the ARCS model as a tool for assessing the learning experience in educational virtual worlds. First, at the level of technological acceptance, the strong correlations between the dimensions suggest that the technological features of virtual environments —such as visualization, interactivity, and the sense of presence— translate directly and effectively into enhancing motivation for learning. Second, the multidimensional effect of the design of the environment is highlighted: the enhancement of a single dimension, such as Attention through improved visual-aesthetic stimuli, has the potential to positively affect the others —Relevance, Confidence, and Satisfaction— enhancing the overall educational effectiveness of the virtual world.

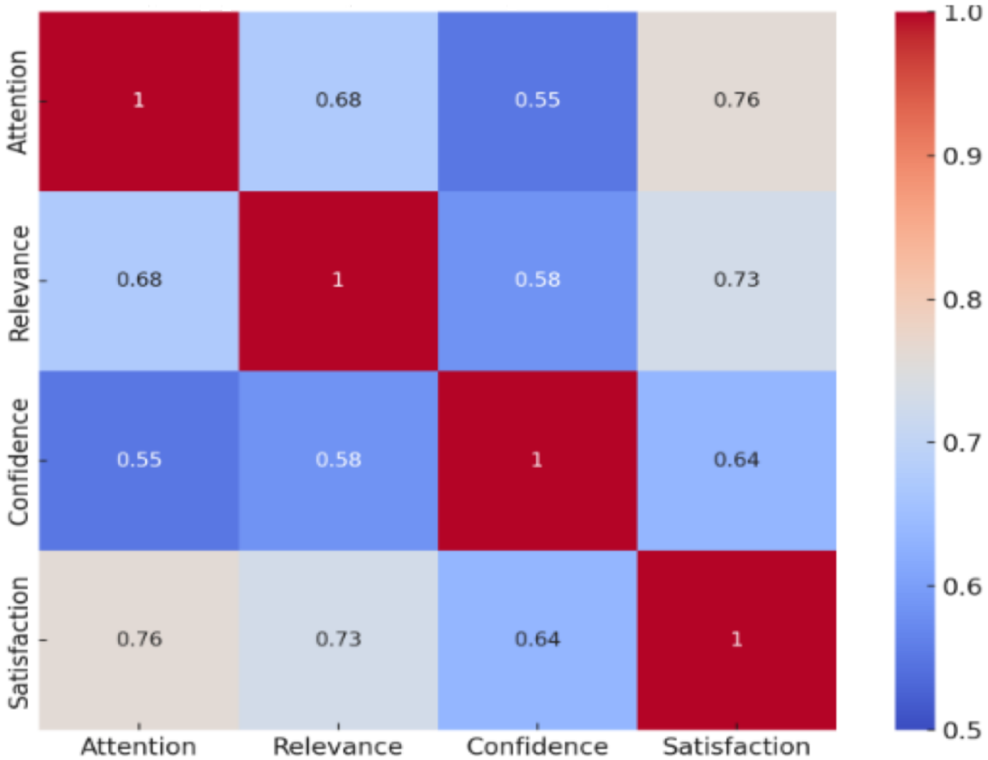

Fig 3: Heatmap correlations

4.3 Regression Analysis

The present study additionally applies multiple linear regression to predict the Satisfaction dimension, using three independent variables: Attention, Relevance and Self-Confidence. The proposed model:

(Satisfaction = b_0 + b_1(Attention) + b_2(Relevance) + b_3(Self-Confidence))

is based on the theoretical approach that user satisfaction with a system or application is influenced by specific psychological and cognitive factors.

The model exhibits extremely high explanatory power with $R^2 = 0.67$, indicating that 67% of the variance in Satisfaction is explained by the three independent variables. The overall statistical significance of the model is confirmed by the value $F(3,56) = 37.8$ with $p < 0.001$. This means that the probability that the model has arisen by chance is less than 0.1%, confirming the reliability of the results. The degrees of freedom (3.56) indicate a sample of 60 participants, which is considered sufficient for the application of multiple regression. Attention emerges as the strongest predictive factor with a coefficient $b_1 = 0.41$ and $p = 0.002$. This suggests that for every unit increase in Attention, Satisfaction increases by 0.41 units, holding the other variables constant. The high statistical significance ($p = 0.002$) reinforces the reliability of this relationship. The dominance of Attention highlights the importance of designing interfaces that attract and maintain user interest. Relevance presents an almost equally strong effect with a coefficient $b_2 = 0.38$ and $p = 0.005$. This shows that the perceived usefulness and relevance of the content to the users' needs has a direct and significant impact on their satisfaction. Despite having the smallest coefficient ($b_3 = 0.23$), Self-Confidence remains statistically significant ($p = 0.041$). This suggests that users' sense of competence and self-efficacy contribute to their satisfaction, although to a lesser extent than the other two factors.

The results are consistent with Keller's ARCS model, which is widely used in educational design. The present study provides empirical confirmation of the theoretical hypothesis that these dimensions are causally related to satisfaction.

5. Discussion

The results of the present study provide important evidence for the effectiveness of educational virtual worlds in teaching subjects such as basic computer technology concepts. High scores on all ARCS dimensions (>3.8/5) indicate that students positively evaluated the educational experience.

[1]. **Attention and Satisfaction:** The higher scores on the Attention (4.22) and Satisfaction (4.24) dimensions confirm the ability of virtual worlds to attract and maintain student interest. This is in line with previous studies highlighting the power of virtual reality in educational engagement [6].

[2]. **Relevance:** The high score on Relevance (4.12) indicates that students perceived the educational content as useful and relevant to their learning needs.

[3]. **Confidence:** The lowest score on Confidence (3.80) and the largest variance (1.02) highlight an area that needs improvement. This may be due to the complexity of the virtual environment and the need for technical skills that some students may not fully possess. This finding is consistent with the study by Huang et al. [38], who noted that confidence is often the most problematic dimension in technology-enhanced educational interventions.

The strong positive correlations between all ARCS dimensions (r=0.52-0.74) confirm Keller's theoretical hypothesis [29] that the dimensions of motivation are interdependent. The strongest correlation between Attention and Satisfaction (r=0.74) indicates that when students are attentive and actively involved, they tend to feel more satisfied with the learning experience.

The findings of the study have substantial practical implications for all stakeholders in the educational community. For educators, it is clear that virtual worlds can be powerful teaching tools, especially when they enhance students' self-confidence through structured guidance and support mechanisms. In addition, interactivity and experiential exploration emerge as key factors for enhancing students' Attention and Satisfaction. At the school policy level, it is clear that investing in Metaverse-type technologies [39] can yield significant pedagogical benefits, as long as it is accompanied by appropriate design for its proper pedagogical utilization. Finally, for creators of educational technologies, the study highlights the need for design that enhances Self-Confidence through graded, adaptive activities, while at the same time prioritizing the usability and universal accessibility of virtual learning environments.

The ARCS (Attention, Relevance, Confidence, Satisfaction) model, introduced by John Keller, is a powerful tool for designing motivation in teaching and is ideally suited to educational virtual worlds in the Metaverse. Virtual spaces offer unique opportunities to attract students' attention through impressive visualization, interactive scenarios, and experiences based on curiosity, surprise, and stimulus switching.

Interaction and gamification mechanisms can be utilized to activate interest and concentration, in line with the principles of the first ARCS dimension, Attention.

The Relevance dimension is enhanced by personalizing learning and connecting content to students' experiences or goals. Virtual worlds can incorporate realistic simulations, such as a laboratory or a work environment, creating a sense of authenticity. Students feel that learning is related to their experiences or what they will encounter in the future, which enhances their active participation.

Student self-confidence, the third dimension of the ARCS model, can be significantly enhanced through the graded challenges offered by the Metaverse. With a gradual increase in difficulty, guidance and continuous feedback, students gain the feeling that they can successfully meet the learning goals. A well-designed virtual environment can offer a controlled pace, visible progress points and reward mechanisms, thus building student self-confidence.

Finally, Satisfaction arises as a natural consequence of the previous dimensions and is reinforced by the sense of achievement, social recognition and rewards that can be integrated into the Metaverse environment. Successfully completing missions, obtaining digital distinctions and the possibility of collaboration enhance the positive learning experience. Overall, the ARCS model offers a holistic and practical framework for designing educational experiences within virtual worlds, making learning more engaging, meaningful, and effective.

6. Conclusion

The digital age requires the development of new educational approaches that will meet the needs of modern learners. Virtual worlds and the metaverse are presented as promising tools to achieve this goal, especially in subjects that require visualization and experiential exploration. The literature review reveals that the metaverse presents significant potential for education, offering immersive, interactive and accessible learning experiences. However, its successful integration into the educational process requires addressing significant technological, pedagogical and ethical challenges. Future research should focus on developing efficient pedagogical models, evaluating long-term impacts and ensuring the security and protection of students' data.

The present study contributes to the growing literature on the educational use of virtual worlds, providing empirical evidence for their effectiveness in education. However, the successful integration of these technologies into educational practice requires careful planning, appropriate teacher training, and continuous evaluation and improvement.

Despite the positive results, the study has some limitations. The sample size of 60 students, although sufficient for statistical analysis, is relatively small for generalizations to a larger population. The study examined the immediate response of students, without investigating the long-term effects on learning and retention of knowledge. The lack of a control group taught using traditional methods limits the possibility of comparing effectiveness. The data were based solely on student self-reports, without objective measures of learning.

Based on the findings and limitations of this study, we suggest the following directions for future research. Conduct randomized controlled trials with control groups to compare the effectiveness of virtual worlds with traditional teaching methods. Investigate the long-term effects on learning, retention of knowledge, and skill development. Combining self-reports with objective learning measures, such as knowledge tests and performance assessments. Applying the methodology to other subjects to explore the generalizability of the findings. Conducting interviews and observations to gain a deeper understanding of students' experiences. Researching the integration of new technologies such as artificial intelligence and augmented reality.

Future research should focus on addressing the limitations of the present study and exploring new dimensions of the educational use of virtual worlds. Only through systematic research and collaboration between researchers, educators, and technology companies will we be able to fully exploit the potential of these innovative educational tools.

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