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- 1.- Percepciones de autoeficacia en docentes en formación en España: un estudio de caso de microenseñanza utilizando realidad virtual inmersiva // Self-efficacy beliefs in Spanish pre-service teachers: a microteaching case study using immersive virtual reality** 7  
María Esther Rodríguez-Gil, Bianca Manuela Sandu, Beatriz Santana-Perera
- 2.- Explorando tendencias sociales en las discusiones sobre cohousing y coliving en X(Twitter) mediante el uso de técnicas de PNL y de análisis de texto // Exploring social trends in cohousing and coliving discussions on X(Twitter) using NLP and Text Analysis Techniques** 25  
Rafael Sosa-Ramírez, Esteban Vázquez-Cano, Norberto Díaz-Díaz, Eloy López-Meneses
- 3.- Enmarcando las aplicaciones de IA generativa como herramientas para la cognición en educación // Framing Generative AI applications as tools for cognition in education** 42  
Marc Fuertes-Alpiste
- 4.- An Assessment of Technological Pedagogical Content Knowledge (TPACK) among Pre-service Teachers: A Rasch Model Measurement // Evaluación del conocimiento tecnológico pedagógico del contenido (TPACK) entre los profesores en formación: modelo de medición Rasch** 59  
Komarudin Komarudin, Suherman Suherman
- 5.- Rasch Measurement Validation of an Assessment Tool for Measuring Students' Creative Problem-Solving through the Use of ICT // Validación de una Herramienta de Evaluación Basada en el Modelo Rasch para Medir la Resolución Creativa de Problemas en Estudiantes Mediante el Uso de TIC** 83  
Farida Farida, Yosep Aspat Alamsyah, Bambang Sri Anggoro, Tri Andari, Restu Lusiana
- 6.- Influencia de la Realidad Virtual en el rendimiento académico en Educación Secundaria a través de un meta-análisis // Influence of Virtual Reality on Academic Performance in Secondary Education Through a Meta-Analysis** 107  
Juan José Victoria-Maldonado, Arturo Fuentes-Cabrera, José Fernández-Cerero, Fernando José Sadio-Ramos
- 7.- Tecnologías abiertas e inclusivas en la complejidad del futuro de la educación: diseño de modelo basado en investigación // Open and Inclusive Technologies in the Complexity of the Future of Education: Designing a Research-Based Model** 123  
María Soledad Ramírez-Montoya, Inés Álvarez-Icaza, Joanne Weber, Fidel Antonio Guadalupe Casillas-Muñoz
- 8.- El uso de ChatGPT en la escritura académica: Un estudio de caso en educación // The use of ChatGPT in academic writing: A case study in Education** 143  
Kevin Baldrich, Juana Celia Domínguez-Oller
- 9.- Inteligencia artificial: revolución educativa innovadora en la Educación Superior // Artificial Intelligence: innovative educational revolution in Higher Education** 159  
Virginia Villegas-José, Manuel Delgado-García
- 10.- Análisis de la competencia digital en profesores de educación primaria en relación con los factores de género, edad y experiencia // Analysis of Digital Competence in Elementary School teachers according to their socio-demographic factors and experience** 171  
Issac González-Medina, Eufrasio Pérez-Navío, Óscar Gavín Chocano



# Influencia de la Realidad Virtual en el rendimiento académico en Educación Secundaria a través de un meta-análisis

Influence of Virtual Reality on Academic Performance in Secondary Education Through a Meta-Analysis.

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## ABSTRACT

The integration of technology as an educational tool is essential across all educational stages. In this context, virtual reality has emerged as a powerful tool in recent years. Despite its prominence, there is limited research demonstrating its effectiveness in Secondary Education. To address this gap, a meta-analysis was conducted to explore and define the influence of virtual reality on the academic performance of secondary school students. The main results reveal a positive impact on academic performance, especially in short-term interventions, mirroring findings in other educational stages. However, the lack of clarity in the scientific literature regarding the overall impact of virtual reality interventions on students' academic performance in this specific stage is emphasized. This finding underscores the need for more detailed and conclusive research to better inform educational practices in the use of virtual reality in Secondary Education.

## RESUMEN

La integración de la tecnología como herramienta educativa es esencial en todas las etapas educativas. En este contexto, la realidad virtual ha emergido como una herramienta poderosa en los últimos años. A pesar de su prominencia, la investigación que demuestra su eficacia en la Educación Secundaria es escasa. Para abordar esta brecha, se llevó a cabo un meta-análisis con el objetivo de explorar y definir la influencia de la realidad virtual en el rendimiento académico de los estudiantes de secundaria. Los resultados principales revelan un impacto positivo en el rendimiento académico, especialmente en intervenciones de corta duración al igual que se muestran las investigaciones realizadas en otras etapas. Sin embargo, se destaca la falta de claridad en la literatura científica respecto al impacto general de las intervenciones con realidad virtual en el rendimiento académico de los estudiantes en esta etapa específica. Este hallazgo resalta la necesidad de investigaciones más detalladas y concluyentes para informar mejor las prácticas educativas en el uso de la realidad virtual en la Educación Secundaria.

## KEYWORDS · PALABRAS CLAVES

Virtual Reality; Information and Communication Technologies; Teaching; Secondary Education; Meta-Analysis  
Realidad Virtual; tecnologías de la información y de la comunicación; enseñanza; Educación Secundaria; Meta-Análisis/

## 1. Introduction

In contemporary society, the influence of technology is pervasive, shaping various elements through its advancements and the new tools it introduces. This ongoing technological evolution necessitates continuous adaptation across all fundamental societal aspects, a trend observed over recent decades and characterized by its perpetual nature (Ordoñez-Olmedo et al., 2021).

Educational institutions, including schools, are deeply embedded in this process of adaptation. Consequently, teachers must continually update their skills and knowledge in using new tools and methodologies to enhance their teaching capabilities (Campos et al., 2020). Among the various emerging technologies, immersive technologies hold significant promise within the educational domain. These technologies facilitate the creation of interactive 3D teaching experiences, which can significantly enhance the learning process (Ayala et al., 2020).

Immersive technologies, used for developing interactive 3D environments, are categorized based on the level of immersion they offer and the degree to which reality interacts with the virtual environment. The three primary types are augmented reality (AR), mixed reality (MR), and virtual reality (VR) (Moreno-Guerrero et al., 2021). Each of these technologies provides distinct levels of immersive experiences and interaction, offering unique opportunities for educational applications.

### 1.1. Augmented Reality

This technology combines virtual objects with the real environment in real time, enabling interaction between both through technological devices (Martínez et al., 2021). This tool stands out due to its motivational impact, introducing a new and innovative element into the classroom (Cabero et al., 2019). Augmented reality views learning as something that occurs through multiple pathways, emphasizing experimentation and research as fundamental elements. It highlights several key aspects, such as game-based learning, research-based learning, ubiquity, constructivism, contextualization of content, and the use of mobile devices as working tools (Cabero et al., 2019).

Despite its accessibility, augmented reality technology faces limitations primarily related to resource availability (Cadavieco et al., 2012). Unlike other technologies discussed in this study, augmented reality requires a mobile device with specific characteristics, typically high-end phones (Reyes, 2020).

### 1.2. Mixed Reality

With respect to mixed reality, we are not going to emphasize or explain in detail how it works. It is certainly a technology that is perceived as something innovative and with great possibilities. However, looking at the current scientific literature and establishing its possibilities and limitations, it can be seen how the economic factor is a differential factor that cancels out any possibility of action within an educational center (Rivera et al., 2021; Marín et al., 2023 and De Jesús and Ayala, 2021).



### 1.3. Virtual Reality

Virtual reality, as its name suggests, focuses on generating a completely virtual environment into which the user is immersed through an electronic device. One of the advantages of this tool is its adaptability. The use of virtual reality, regardless of the application, has a reduced adaptation process compared to other technologies, as it places the user in a specific environment that is quickly understood (Hwang et al., 2022).

In the educational field, virtual reality is having a significant impact due to its ease of use and the immersive experience it provides, making it a motivating and flexible tool for various educational purposes. For instance, a study by Huang et al. (2022) in higher education compared augmented reality and virtual reality, finding that while the level of learning was similar, motivation was higher with virtual reality.

Another study highlighting the impact of virtual reality in higher education is presented by Sheng et al. (2022), which explores the use of virtual reality in developing orthodontic studies.

Although these studies focus on virtual reality in higher education, it is necessary to analyze its potential use in secondary education, especially since most devices enabling this tool have a minimum recommended age of 13 years. Initially, it is important to note that most studies in this area focus on behavioral analysis, such as the work by Van Ginkel et al. (2020), which shows positive results from this perspective. However, there are no reviews or data that significantly demonstrate an impact on academic performance.

Given this conceptual delimitation, the present study aims to explore how virtual reality can be used to improve the academic performance of secondary school students. To this end, the following questions are presented:

R.Q.1 What are the salient features of the studies, including geographical and temporal distribution, most cited journals and authors, keyword analysis, sample selection procedures, cluster configurations, and sample characteristics?

R.Q.2 What are the characteristics of the intervention, taking into account its duration, setting, practices, strategies, techniques, resources, and activities?

R.Q.3 What evidence does the scientific literature provide on the efficacy of Virtual Reality and its impact on the academic performance of secondary school students?

## 2. Methodology

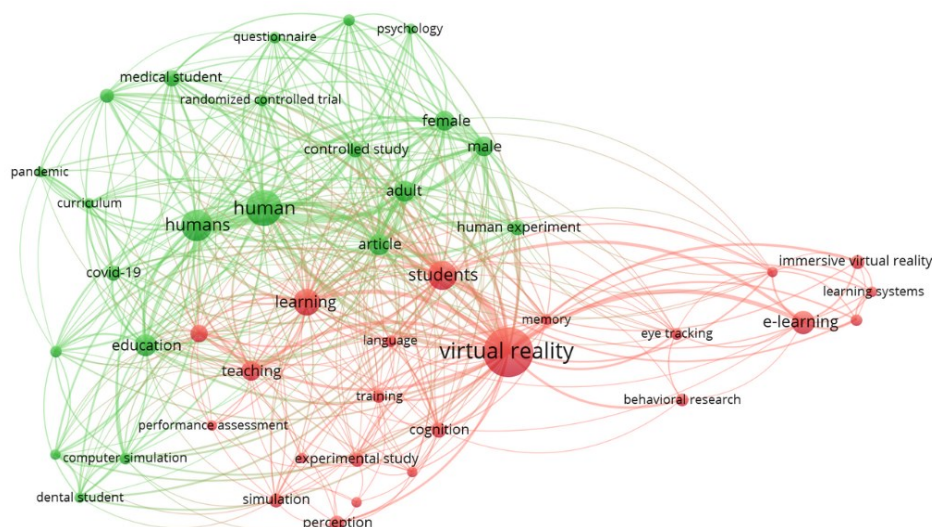
To create a search equation that meets the requirements of this meta-analysis, a keyword search was conducted to examine the impact of virtual reality on academic performance in a general sense, including specific subjects. Initially, two terms were identified, and their synonyms were searched in the ERIC Thesaurus, the European Thesaurus, and the European Education Thesaurus. This process led to the establishment of the following search equation: ("virtual reality" OR "VR" OR "virtual environment" OR "immersion" OR "immersive 360") AND ("academic achievement" OR "Academic Records" OR "Educational Indicators" OR "Grades" OR "Grading" OR "Test" OR "School Effectiveness" OR "Student evaluation" OR "student improvement"). Using this initial search equation, a preliminary search was conducted in both WOS and Scopus. The search was filtered to include articles from 2019, available in Spanish and English, categorized under

Education and Educational Research (Social Sciences in Scopus), and open access. This initial search was necessary due to the novelty of the subject matter, as the keywords used were not yet defined in the aforementioned thesauri. Therefore, it was important to collect the most relevant keywords currently in use.

From this first search, a total of 554 references were obtained, and an analysis of their keywords was performed, resulting in the following cluster diagram (Figure 1).

**Figure 1**

*Cluster's Flowchart*



From this search, we identified various aspects that could be refined to make the search equation more accurate. Terms such as e-learning, immersive virtual reality, teaching, learning, performance assessment, and computer simulation should be included, while terms like human experiment, eye tracking, behavioral research, and memory should be excluded, as they extend beyond the scope of this article.

Additionally, since the meta-analysis focuses on secondary education, relevant thesaurus terms related to this educational stage are incorporated. The refined search equation is defined as follows: ("virtual reality" OR "VR" OR "virtual environment" OR "immersion" OR "immersive 360" OR "e-learning" OR "immersive virtual reality" OR "computer simulation" ) AND ( "academic achievement" OR "Academic Records" OR "Educational Indicators" OR "Grades" OR "Grading" OR "Test" OR "School Effectiveness" OR "Student evaluation" OR "student improvement" OR "teaching" OR "learning" OR "performance assessment" ) AND ("Secondary School Students" OR "Adolescents" OR "Secondary Education" OR "Secondary Schools" OR "High Schools") AND NOT ( "qualitative study" OR "case study" OR "action research" OR "single subject design" OR "descriptive study" OR "correlational study" OR "case study" OR "human experiment" OR "eye tracking" OR "Behavioral research" OR " memory" OR ).

Using this search equation, automatic filters were applied in the aforementioned databases, specifying the following criteria: articles from 2019 to 2023 (covering the last five

years), articles only, because journal publications generally exhibit greater rigor and impact compared to books or conference papers. Additionally, the articles belong to the Social Sciences branch in Scopus and the Education Educational Research category in WOS, in line with the subject of this study. Only open access journal articles were selected to ensure the study's replicability. The languages were limited to Spanish and English, as these are of significant scientific interest and are familiar to the authors of this article.

Regarding the inclusion and exclusion criteria for the articles, four criteria were proposed (justified in Table 1): practical experience, conducted in secondary education, presence of a control group and an experimental group, and a clear relationship between the experience and academic performance.

**Table 1**

*Inclusion and exclusion criterio*

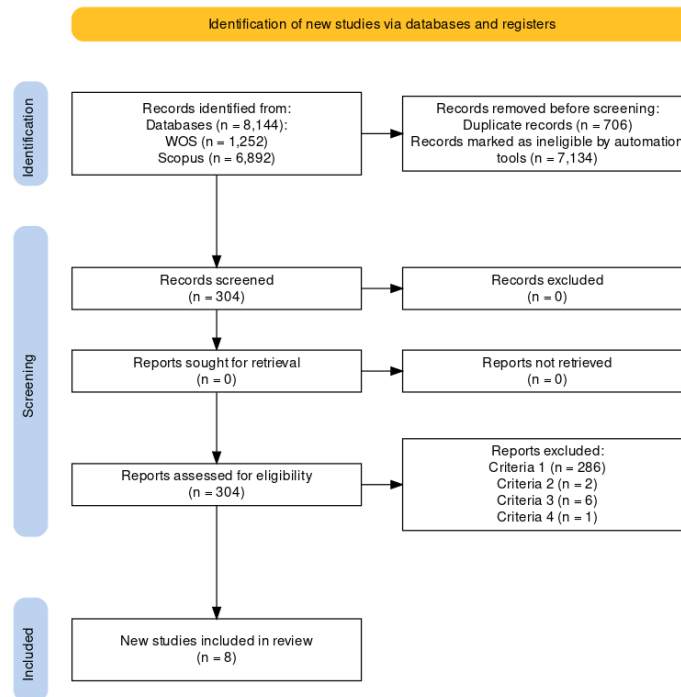
<b>Criteria</b>	<b>Justification</b>
Being practical experiences	The objective of the research is to see how experiences in secondary education influence academic performance, so correlational, descriptive, qualitative studies, etc... cannot be included in this review.
Done in Secondary Education	The study is focused on this stage, so studies with an older university population are out of the context of this research.
Research With Control and Experimental Groups	To ensure that virtual reality is a suitable tool, it is necessary to see how virtual reality influences and compare it with other tools to see if it is more or less suitable.
Focus on the relationship of virtual reality to academic performance	Other elements such as classroom management are being worked on using virtual reality. However, from the present study, academic performance is understood as the most differential factor when introducing a tool in the classroom or not.

Following the points established in the PRISMA guidelines as indicated by Page et al. (2021), the various criteria for conducting systematic reviews and meta-analyses are outlined throughout the document.

Accordingly, for the review and subsequent meta-analysis, the flow diagram for the selection of articles is defined as shown in Figure 2:

**Figure 2**

*PRISMA Flowchart*



### 3. Results

#### **R.Q.1. What are the salient features of the studies, including geographical and temporal distribution, most cited journals and authors, keyword analysis, sample selection procedures, cluster configurations, and sample characteristics?**

To begin with, an analysis of the included publications is conducted to observe how the topic is developing in the scientific literature. The study by Bibic et al. (2019) stands out as the most cited article, published in the *Journal of Chemical Education*. However, despite being the most cited, it does not have an overwhelming number of citations. This could indicate either a lack of interest in the subject or its limited impact, which warrants further investigation.

Additionally, although there is no clear trend in the most commonly used keywords, "Virtual Reality" appears prominently in studies by Setyowati et al. (2023), Christopoulos et al. (2023), and Jitmahantakul et al. (2019). The keyword "learning" is highlighted in studies by Setyowati et al. (2023), Huang et al. (2022), Jitmahantakul et al. (2019), and Hamamous et al. (2023).

This brief description underscores the relevance of the topic within the educational field. It shows that the key terms, as well as the most cited publications and journals, are often associated with psychological aspects such as learning, motivation, and behavior.

Regarding the selection of the sample, participants, and their characteristics, it is important to note that Secondary Education has been established as the developmental stage for this study. Consequently, all studies included have a sample of participants aged between 10 and 18 years. The samples were primarily selected based on access to

educational centers, ensuring that the groups were similar in terms of academic performance, with no statistically significant differences.

For the intervention, the groups were randomly assigned: one group received the virtual reality intervention, while the other group received a different type of intervention.

## **2. What are the characteristics of the intervention, taking into account its duration, setting, practices, strategies, techniques, resources, and activities?**

Regarding the use of Virtual Reality (VR) in Secondary Education, it is important to note that there is no clear protocol for such interventions. However, two main temporal categories of interventions can be identified.

The first category includes short-term interventions, lasting between 45 minutes and two hours. Studies such as those by Bibic et al. (2019), Jitmahantaku and Chenrai (2019), Tsivitanidou et al. (2021), Küger et al. (2022), Setyowati et al. (2023), Chu et al. (2023), and Hamamous and Benjelloun (2023) fall into this category. These interventions are predominant because they quickly demonstrate outcomes, with research indicating that even a brief intervention can lead to an improvement in students' grades and academic performance.

The second category consists of long-term interventions, which are particularly relevant as they show the prolonged effects of VR on academic performance. Examples include the studies by Mjenda et al. (2023) and Christopoulos et al. (2023), which involve interventions lasting a month and a half and incorporate various elements to assess their influence.

While there are no standard activities or tools universally used to develop VR interventions in higher education, the following is a list of tools and proposals derived from different research studies:

- The game Bug of a Pain video game in Virtual Reality for Android and virtual reality devices.
- Based on three key aspects: To become familiar with the geological environment in a virtual environment; to be able to observe geographical features and recognize them and to be able to analyze the different geographical points and to be able to see previous events that have caused the space in which it is located.
- Intervention divided into phases: 1 gathering information from traditional or textual media, 2 the use of virtual reality video games (focused on space) and 3 videos taken from the National Geographic Project Einstein's train paradox.
- 360 videos and images on the environmental impact on the Baltic Sea available for Android mobile devices.
- The method developed in: Borg and Gall (2003) and Dick and Carey's (2013) model
- Construction and Sketching 3D Figures

Finally, regarding the context in which the research is conducted, it is noteworthy that although all studies are carried out in Secondary Education, the contexts are diverse, spanning various regions across the world. Despite financial constraints, some studies have identified more economical alternatives for implementing virtual reality.

For instance, while Bibic et al. (2019) and Tsivitanidou et al. (2021) utilize more sophisticated VR tools with greater immersion capabilities, Jitmahantaku and Chenrai (2019) demonstrate the application of VR using simpler, more affordable devices like Google Cardboard. These devices are presented as cost-effective tools suitable for educational settings.

### 3. What evidence does the scientific literature provide on the efficacy of Virtual Reality and its impact on the academic performance of secondary school students?

A total of  $k=8$  studies were included in the analysis. The observed standardized mean differences ranged from 0.0691 to 2.6059, and most of the estimates were positive (100%). The estimated mean standardized mean difference based on the random-effects model was = 0.9519 (95% CI 0.2299 to 1.6740). Thus, the mean result differed significantly from zero ( $z = 2.5839$ ,  $p = 0.0098$ ) (Table 3).

**Table 3**

*Random-Effects Model (k = 8)*

Random-Effects Model (k = 8)						
	Estimate	se	Z	p	CI Lower Bound	CI Upper Bound
Intercept	0.952	0.368	2.58	0.010	0.230	1.674

Nota. Tau<sup>2</sup> Estimator: Restricted Maximum-Likelihood

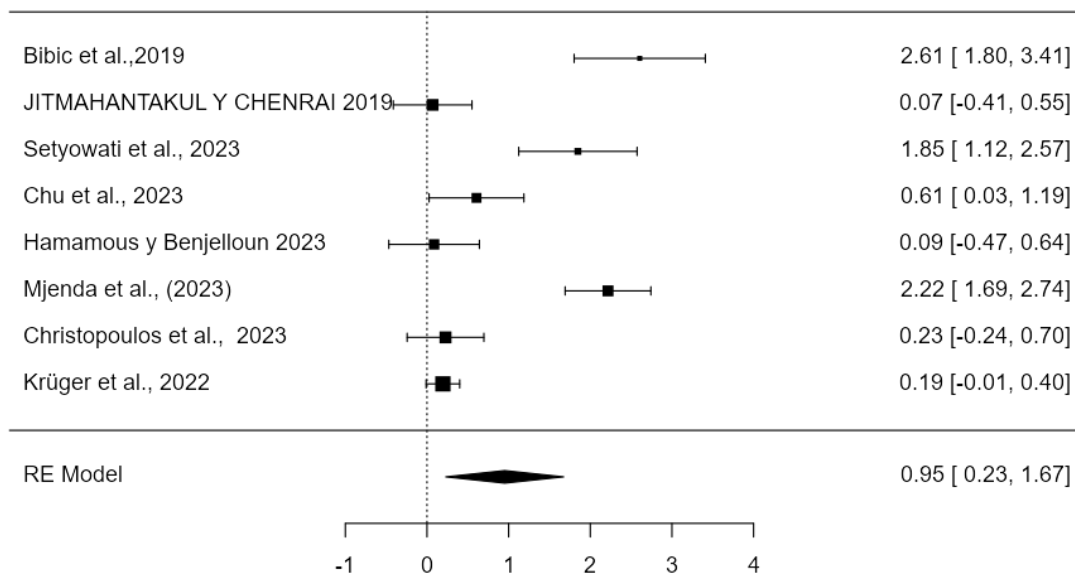
According to the Q test, the true results appear to be heterogeneous ( $Q(7) = 95.8119$ ,  $p < 0.0001$ ,  $\tau^2 = 1.0035$ ,  $I^2 = 94.6088\%$ ) (Table 4). A 95% prediction interval for the actual results is given by -1.1400 to 3.0439. Therefore, although the mean result is estimated to be positive, in some studies the actual result may be negative.



**Table 4***Heterogeneity Statistics*

Tau	Tau <sup>2</sup>	I <sup>2</sup>	H <sup>2</sup>	R <sup>2</sup>	df	Q	p
1.002	1.0035 (SE= 0.5801 )	94.61%	18.549	.	7.000	95.812	< .001

An examination of the residuals studied revealed that none of the studies had a value greater than  $\pm 2.7344$ , so there was no indication of outliers in the context of this model. According to Cook's distances, none of the studies could be considered overly influential (Figure 3).

**Figure 3***Forest plot*

The regression test indicated asymmetry in the funnel plot ( $p = 0.0289$ ), but not the rank correlation test ( $p = 0.0610$ ) (Table 6) (Figure 4).

**Table 5**

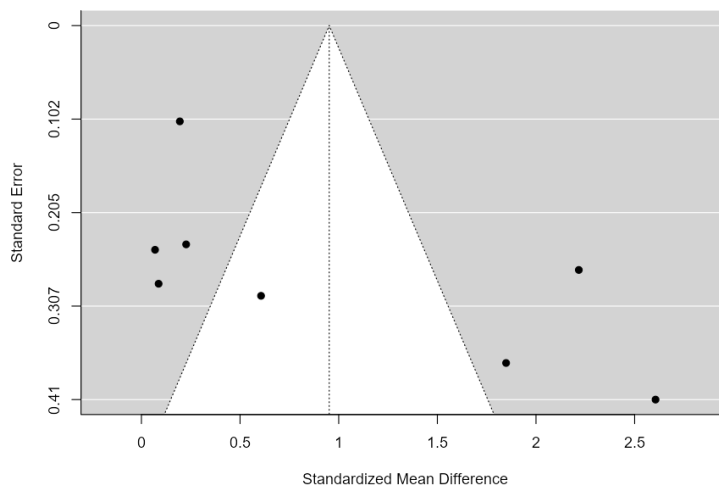
*Publication Bias Assessment*

Test Name	value	p
Fail-Safe N	225.000	< .001
Begg and Mazumdar Rank Correlation	0.571	0.061
Egger's Regression	2.185	0.029
Trim and Fill Number of Studies	1.000	.

Nota. Fail-safe N Calculation Using the Rosenthal Approach

**Figure 4**

*Funnel plot*



These results, however, cannot be taken into account as a reference when mentioning the results of virtual reality. On the part of the researchers, all possible aspects have been taken to eliminate the selection bias of the articles. Regarding the publication bias, it is important to mention that all the studies have a positive result that can be seen at a statistical level through the Egger's Regression test.

It can also be seen how there is an improvement in academic performance through the use of this tool, especially if we look at data such as IQ Lower Bound and IQ Upper Bound. However, although an improvement of 0.95 points above the mean is established, this result cannot be taken into account for future research because, as shown in Figure 4, the deviation of this result is very large.

## 4. Conclusions

The main conclusion of this study is that there is no clear evidence regarding the effect of VR on academic performance.

Throughout the study, it became apparent that a comprehensive review of the subject is needed at the scientific level. There are no specific keywords that facilitate the search for documents related to VR, making initial searches complex and resulting in low citation and referencing indices.

Regarding the interventions themselves, Tsivitanidou et al. (2021) and Bibic et al. (2019) stand out for their detailed explanation of the specific activities performed during the intervention. However, in many cases, it is challenging to identify which devices and specific tools were used in the interventions.

A notable methodological weakness across all studies is the selection of the sample. In the educational field, conducting experimental studies is challenging, as the structure of the educational system often necessitates a quasi-experimental design.

However, due to the limitations of access to the sample, in most cases the sample is low and insignificant, although the studies seek to ensure that the control and experimental groups are equivalent.

Finally, mention should be made of the data provided by the different studies. It can be seen that there is an improvement in the academic performance of secondary school students after the intervention with VR. However, estimating the value of this variation in academic performance is a complex task through a review of the literature, since the results given in the different interventions are certainly very variable. This is due to different aspects such as the time of intervention that is carried out, in which it is necessary to highlight Mjenda et al. (2023) and Christopoulos et al. (2023), the subject that is worked and how school performance is measured or how it is worked with the control group.

Compiling all the results and conclusions mentioned above, it is evident that scientific contributions relating virtual reality and academic performance are scarce. Furthermore, there is no specific methodology for developing experiences with virtual reality, which makes it difficult to extract conclusive data on the subject.

### 4.1. Limitations

The present study by methodology is understood as a purely theoretical study which, in spite of having empirical data, is not specific to it. This limitation directly affects the results presented, since they do not depend on the researchers who have carried out the research, but depend directly on the scientific literature.

Another limitation present in the review, related to the previous one and to what is stated in the conclusions, is the number of articles published on the subject, since the total number of articles selected has been reduced to 8 due to the lack of publications on this subject.

As a final limitation, it is important to point out that there is no validated intervention method for VR in Secondary Education, so that the works reviewed, despite rigorously covering most of the interventions, in many cases are difficult to replicate in the same context or in different contexts.

## 4.2. Future Research

Future research that may arise from this study is limited by the limitations that it has presented. Establishing, as future lines of research, the design of an intervention with virtual reality focused on secondary education. Another possible line of research for the future would be one similar to the present study in which the impact on academic performance is evaluated specifically in an area, subject or subject so as to show which subjects benefit most from this tool.

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