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Evaluating the Effectiveness of GIF-Based Methodology in Enhancing Geoscience Education Among Primary Education Undergraduates

Celia Campa-Bousoño [1] and Ángel García-Pérez [2,*]

[1] Department of Education, Universidad del Atlántico Medio, 35017 Las Palmas, Spain; celia.campa@pdi.atlanticomedio.es
[2] Department of Psychology, University of Oviedo, 33005 Oviedo, Spain
* Correspondence: garciaperangel@uniovi.es

Abstract: This study evaluates the impact of creating GIFs compared to traditional methodologies in teaching geology to undergraduate students in Primary Education, focusing on three key aspects: effectiveness in knowledge acquisition, motivation and interest in geology, as well as in information and communication technologies (ICTs). A total of 79 students participated, divided into two groups: one group utilized the research and creation of GIFs to learn geological processes, while the other group acquired this knowledge through traditional lecture-based classes. The study was conducted over a period of three months. The results indicated that creating GIFs was more effective than traditional methodologies for enhancing geological knowledge acquisition. No significant differences were observed in the interest in geology or ICTs between the two groups; however, students positively valued the GIF creation activity, describing it as an interesting and accessible experience with potential added value in teaching practice. These findings highlight the potential of GIFs as a dynamic and effective educational tool. The creation of GIFs can be integrated as an innovative complement to traditional methodologies, offering an attractive and practical alternative for teaching geological concepts.

Keywords: GIF-based learning; geoscience education; educational methodology; higher education

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1. Introduction

Science education plays a pivotal role in the holistic development of individuals, fostering critical thinking, the formulation of questions, argumentation, and an understanding of the natural world (Fernando Santos, 2017). However, in many educational contexts, science teaching faces significant challenges. Chief among these are a lack of student interest and the persistence of traditional methodologies that neither capture students' attention nor promote meaningful learning (Adak, 2017; Osborne & Dillon, 2008). In particular, geology, a fundamental branch of Earth sciences, has been marginalized due to insufficient curricular time and a lack of continuity in study plans. This has led to inadequate geoscience education for both students and preservice teachers (Calonge et al., 2014; Dodick & Orion, 2003; Fornós, 2018; Lacreu, 2018; Roca & Garcia-Valles, 2020; Zamalloa & Sanz, 2023). Consequently, geology has become largely overlooked (Pedrinaci, 2012), partly due to perceptions of the subject as difficult and uninteresting. This is reflected in low enrollment rates in geology courses and the perception among students that learning experiences in this discipline are irrelevant to their lives outside of school (Dawson & Carson, 2013; Lewis

& Baker, 2010; Mills et al., 2020). A clear example of this issue was evident during the eruption of the Spanish volcano Cumbre Vieja in 2021, where the dissemination of rumors and misinformation on social media, including tsunami warnings (Navarro et al., 2023), underscored the need for education in this field. Therefore, it is imperative to enhance geoscience education to enable students to better comprehend their environment and recognize the relevance of these processes in their daily lives and future (King, 2008; Orion, 2019).

Several studies have indicated that traditional teaching methods in earth sciences, typically centered on memorization and mechanical reproduction, are ineffective for fostering meaningful conceptual understanding (Occhipinti, 2025; Orion, 2019). Students often show persistent difficulties in grasping key processes such as rock formation and tectonic dynamics, attributable to the use of traditional teaching methods (Dolphin & Benoit, 2016; Frøyland et al., 2016). In contrast, an increasing body of research highlights the benefits of active learning methodologies, which have been shown to enhance student performance in science, improve retention rates, and reduce achievement gaps across diverse student populations (Dogani, 2023; Freeman et al., 2014; McConnell et al., 2017; Theobald et al., 2020). These approaches involve students in intellectually engaging tasks such as reading, writing, discussion, autonomous learning, inquiry, and the resolution of real-world problems (Dogani, 2023; Prince, 2004), thereby fostering higher-order cognitive skills, including analysis, synthesis, and evaluation, aligned with the upper levels of Bloom's taxonomy (Bloom & Krathwohl, 1956). Rooted in the principle that "learning to learn" constitutes a fundamental academic competency (Gargallo-López et al., 2023; Pirrie & Thoutenhoofd, 2013), active learning promotes deeper understanding through the critical assessment and transformation of basic information (Grabinger & Dunlap, 1995; Yang, 2008). These pedagogical models thus support meaningful learning by positioning students as active agents in the construction of their own knowledge.

Although the use of active methods is increasingly common in geoscience instruction (Huguet et al., 2020; Kober, 2015; López Núñez et al., 2020; Manduca et al., 2017; Pinto et al., 2021), many classrooms continue to rely almost exclusively on traditional lectures (Teasdale et al., 2017). In fact, some studies already pointed to the limited adoption and faculty awareness of active pedagogies, urging broader implementation across the discipline (Mosher et al., 2014; Pineda & Vergara, 2016). Educators often face systemic barriers such as insufficient training, lack of institutional support, and uncertainty about how to effectively implement these strategies (Baig & Yadegaridehkordi, 2023; Bonwell & Eison, 1991; Meng et al., 2023; Serrano Amarilla et al., 2022). Even when resources are available, the time and effort required to identify, adapt, and incorporate suitable activities into geoscience curricula remain a substantial obstacle (Henderson et al., 2011; Henderson & Dancy, 2007). Moreover, although numerous active learning strategies have been validated in other disciplines (Martinez & Gomez, 2025; Pratiwi et al., 2021), much of this literature remains unfamiliar to many geoscience instructors, limiting its practical application. As a result, the transition to more effective and sustainable instructional models often requires not only access to resources, but also long-term commitment and support. In this context, Information and Communication Technologies (ICT) are often positioned as tools that can facilitate the transition toward active pedagogies, but only when their integration is guided by clear instructional goals. ICT are not inherently transformative; in fact, when used simply to digitalize traditional practices, they risk reinforcing passive, teacher-centered learning (Barriga, 2008; Mampel Laboira et al., 2015). Their true educational value emerges when they serve as scaffolds for active, student-driven learning, enabling exploration, collaboration, and the production of knowledge. As Laurillard et al. (2018) explicitly argues, and Jimoyiannis (2010) also supports, technology reaches its pedagogical potential

when it facilitates iterative processes of design, feedback, and reflection, key dimensions in learner-centered and inquiry-based methodologies.

This perspective is central to the Technological Pedagogical Content Knowledge (TPACK) framework, which maintains that effective digital integration depends on a nuanced understanding of how content, pedagogy, and technology interact to support learning (Ertmer & Ottenbreit-Leftwich, 2010; Shernoff et al., 2017; Shafie et al., 2019). Likewise, the Technology Acceptance Model (TAM) emphasizes that educators' adoption of digital tools is shaped by their perceptions of ease of use and perceived usefulness (Davis et al., 1989). Therefore, for ICT to truly support active learning, they must be seen not merely as add-ons, but as integrated, pedagogically purposeful tools that enable learners to explore content through creation and inquiry.

These perceptions are particularly important when introducing new formats such as animations, simulations, or interactive platforms. If educators lack confidence in their ability to implement these tools effectively, or if they view them as too technically demanding or time-consuming, adoption rates will likely remain low, even when there is strong evidence supporting their pedagogical value. Given these circumstances, identifying simple and accessible resources that align with both the TPACK and TAM frameworks becomes essential in modern educational contexts, where visual communication plays a central role (Metze, 2020; Perales Palacios, 2007).

Among the wide range of ICT tools, Graphics Interchange Format (GIF) files stand out as particularly promising in geoscience education. These short, looping animations are especially suitable for representing dynamic geological processes, such as plate movements, rock cycles, or volcanic eruptions, in a clear and memorable way. Unlike complex simulations or lengthy videos, GIFs are easy to create, require minimal bandwidth, and demand little technical expertise, making them ideal tools for educators seeking effective resources without the burden of extensive training. In this sense, they fulfill the conditions identified by TAM: they are perceived as both useful and easy to use (Bakhshi et al., 2016; Gygli et al., 2016), which increases the likelihood of their adoption in real classroom settings.

From a TPACK perspective, GIFs also offer a concrete example of how technology can be meaningfully integrated into disciplinary teaching, allowing teachers to illustrate abstract concepts, reinforce explanations, and adapt resources to specific pedagogical intentions. For example, enhanced PowerPoint presentations incorporating GIFs and animations have been shown to increase student engagement and improve learning outcomes, particularly when aligned with curricular goals and instructional (Taculod & Arcilla, 2020). The particular value of GIFs becomes even more apparent when considering the inherent challenges of geoscience education, which include the spatial inaccessibility (due to depth or extent) and temporal inaccessibility (due to long durations or because they have already occurred) of many geological processes (Álvarez & García de la Torre, 1996). GIFs effectively address these challenges by illustrating complex processes that are difficult to observe directly or represent adequately through static images or textual descriptions alone.

Additionally, GIFs facilitate more interactive cognitive development of content by seamlessly integrating analog and physical processes with digital tools (Marín, 2011). While the creation of effective animations was once the exclusive domain of editors and audiovisual professionals, the advent of affordable software and accessible tools has democratized this practice (Stern et al., 2020), making animation creation increasingly feasible for educators. This democratization aligns particularly well with the preferences of current university students, who demonstrate significant interest in learning through audiovisual formats accessed via their mobile devices (Thomas, 2011). This inherent student interest can facilitate the integration of geoscience content into this format, allowing for effective presentation of

complex geological concepts through well-crafted and scientifically validated animations (Stern et al., 2020).

Several studies have investigated the use of GIFs in education, highlighting their capacity to enhance comprehension and information retention across various disciplines. For instance, Abgao (2023) revealed that high school students who used educational materials with GIFs to learn chemistry demonstrated better comprehension and retention of content compared to traditional online methods. Similarly, Henthorn (2023) found that incorporating GIFs into assignments in a first-year university writing course improved students' understanding of academic article structure and increased their engagement in academic discussions.

Additionally, research by Altintas et al. (2017) in Turkey showed that secondary education students found GIFs particularly useful for grasping mathematical concepts. Likewise, Bulbul (2007) noted that the creation of GIFs by university students could facilitate more effective learning in physics, emphasizing the ease of design and the underutilization of this educational resource. Guerrero Chinome and Genet Verney (2020) explored the use of GIFs in a research-creation project at an art and design school, providing an innovative perspective to the field. Furthermore, the study by Caeiro Rodríguez and Torres Pérez (2019) with primary education students in the subject of Plastic and Visual Education demonstrated that the creation of GIFs helped to better understand the contents addressed. These findings underscore the potential of GIFs as versatile and effective educational tools, capable of enriching the teaching-learning process across various contexts and educational levels.

Despite these promising results, previous research presents limitations that must be considered. Although there is a growing body of studies on the use of GIFs in education (Abgao, 2023; Altintas et al., 2017; Bulbul, 2007; Caeiro Rodríguez & Torres Pérez, 2019; Henthorn, 2023) none have focused on the training of future teachers. The vast majority focus on the passive use of GIFs, without involving students in their development and creation, or they did not empirically measure the actual acquisition of knowledge on the subject. Additionally, regardless of the educational level, none have addressed geological content. Finally, most studies have evaluated the effectiveness of GIFs in terms of immediate comprehension, without considering the impact on sustained motivation towards the sciences (Mayer, 2009). Based on the literature reviewed and the identified research gaps, this study aims to address the following research questions:

1. How does the use of traditional teaching methods compare to an approach based on the creation of GIFs in terms of fostering geological knowledge acquisition among future primary education teachers?
2. Do these future teachers consider GIFs a motivating and effective tool for improving their understanding of geology and increasing their interest in the use of ICT within active learning methodologies?

By investigating these aspects, this research seeks to contribute to the growing body of knowledge on innovative educational methodologies while specifically addressing the needs of teacher education programs.

2. Materials and Methods

2.1. Participants

The participants in this research, selected through a purposive sampling method, consisted of 79 students enrolled in the distance Primary Education degree program at a Spanish university. Owing to the virtual nature of their studies, the students originated from various geographical regions across Spain. The average age of the participants was 31.0 years, classifying them as young adults. All participants received detailed information regarding the study's objectives and procedures, and their informed consent was obtained.

Confidentiality of their responses was assured, and longitudinal tracking of each subject was conducted while preserving anonymity throughout all stages of the research.

2.2. Educational Methodologies

This research designed and compared two distinct educational methodologies for teaching geoscience content in the virtual Primary Education program. Both methodologies were applied to different groups of students, allowing for a rigorous evaluation of their effectiveness.

Traditional Methodology (TRA). The intervention was conducted in the course Experimental Sciences I: Natural Sciences, specifically within the didactic unit titled "The Planet Earth". This unit was developed over two theoretical-practical sessions with a total duration of four hours. The content was selected in accordance with the curriculum of the Natural, Social, and Cultural Environment knowledge area as established in Royal Decree 157/2022. During the sessions, content was delivered through PowerPoint presentations, followed by practical exercises and feedback between students and the instructor. The topics covered included an introduction to the course, the origin of the universe and Earth, and specific topics such as the Earth's internal layers, mantle convection currents, the theory of continental drift including the existence of Pangaea, and plate tectonics.

GIF Methodology (GIF). Innovative in its nature and predicated upon the creation of GIFs, this methodology was implemented within the course 'Didactics of Experimental Sciences'. This activity not only facilitated the creation of educational resources in the field but also contributed to the development of specific curricular competencies. Students received a simplified written guide and a brief oral explanation prior to the activity, which was to be completed autonomously within three months. The activity involved developing an educational digital resource in GIF format to illustrate a geological process. Participants could choose to represent (1) convection currents within plate tectonics or (2) the theory of continental drift, focusing on the distribution of continents from Pangaea to the present. Students had to research and obtain accurate scientific information, design at least five illustrative frames of the chosen process, and combine these frames into a GIF using free online programs. They were then required to theoretically describe the GIF content, supported by a variety of corroborated sources. Additionally, they had to reflect on the educational application of the GIF, justifying how this activity could facilitate the learning of scientific concepts and which aspects of active and constructivist pedagogy would be fulfilled, as addressed in Unit 4 "Methodology, resources, and materials for science. The scientific method in the classroom" of the course.

2.3. Procedure

This quasi-experimental pre-post study compared two pedagogical approaches for teaching geosciences to students in the Primary Education degree program in a virtual learning environment. Participants, previously assigned by the university to various courses, were divided into two groups: TRA and GIF. The intervention was carried out over a three-month period. The TRA group participated in theoretical-practical sessions in which geological content was presented and explained using PowerPoint presentations, with the instructor providing ongoing feedback throughout the sessions. The total duration of this intervention was approximately four hours. In contrast, the GIF group worked independently on the creation of digital educational resources (GIFs). No theoretical instruction on the geological processes to be represented was provided; instead, students received guidance on how to complete the task. Figure 1 offers an overview of the procedure and the interventions implemented for both groups.

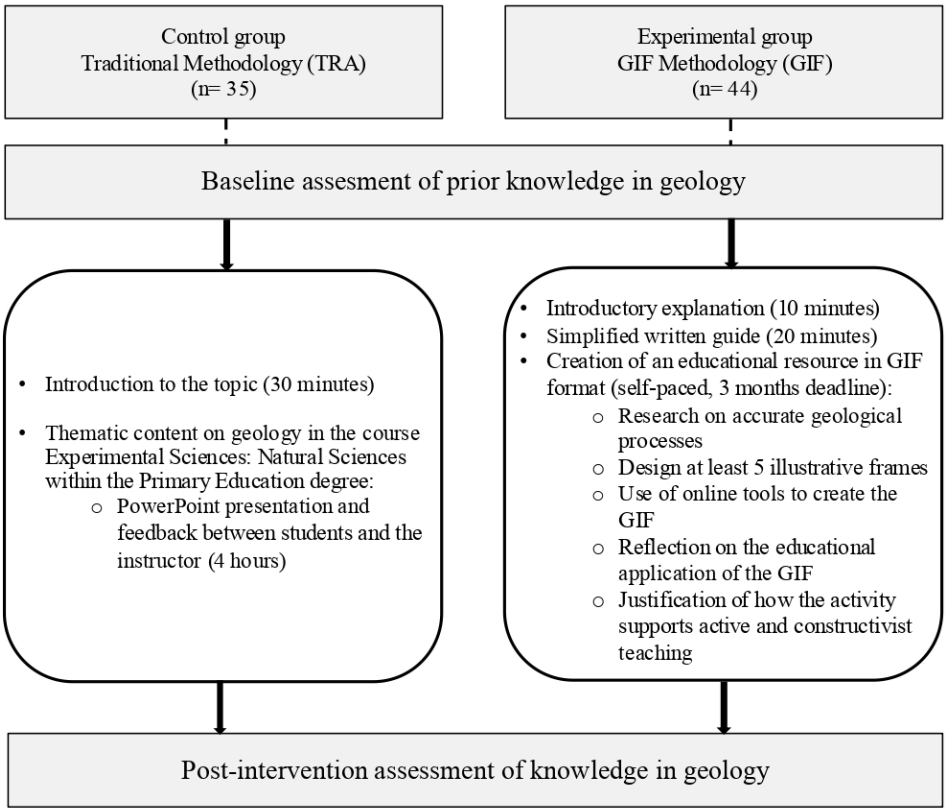


Figure 1. Procedure and interventions of the research.

To ensure correct participant identification while maintaining their anonymity, a "self-generated identification code" (SGIC, Audette et al., 2020) was used. The content of the pre- and post-intervention knowledge assessments was validated by two independent experts in the field. Additionally, the variables assessed were the same at both time points except for invariant ones (e.g., sex).

2.4. Variables

Participants completed a battery of sociodemographic and educational questions (ad hoc) such as age, sex, highest level of education achieved, and usual grades in biology and geology (i.e., pass, good, excellent).

Furthermore, various variables were assessed using a scale from 0 to 10 (where 10 represents the maximum value): (1) perceived level of geological knowledge, (2) motivation to learn, (3) interest in geology, (4) perceived digital skills, (5) interest in ICT, and (6) importance of ICT in the teaching-learning process.

Participants' actual level of knowledge was measured through a battery of questions with two types of responses: true/false (where they had to justify their response in writing) and multiple-choice (with four response options). The questions covered geological content they could address in creating the GIFs: (1) Continental drift and plate tectonics movement: how continents have shifted positions from the Pangaea era to the present, and the evolution of the positions of specific continents like Spain over geological time; and (2) Mantle convection currents and the Earth's layers: the role of convection currents in mantle dynamics and how these influence plate tectonics movement, as well as the organization of Earth's layers, from the crust to the core. The possible score range was from 0 to 8, where a higher score indicates greater knowledge about geological processes.

Finally, in the experimental group, the feasibility and usefulness of the GIFs were evaluated using a 5-point Likert scale (where 5 represents the highest level of agreement).

This evaluation covered: (1) ease of creating the GIF, (2) interest in the activity of creating the GIF compared to other academic activities, (3) effectiveness of the GIF as a resource for learning geological processes, (4) intention to use the GIF in future teaching practice, and (5) intention to use the GIF creation activity in future teaching practice. Additionally, information was recorded on the most challenging part of the activity (i.e., finding information, creating the frames, combining the frames).

2.5. Data Analysis

Descriptive and frequency analyses were used to characterize the variables included in the study. To analyze differences between groups at baseline, Student's *t*-test and χ^2 were used for continuous and categorical variables, respectively. To explore pre-post changes in learning, interest in geology, and interest in ICT based on the educational methodology, a mixed-model repeated measures (MMRM) approach was employed. Analyses were performed using restricted maximum likelihood and included unstructured data modeling. The intervention group was considered an invariant variable over time, while the other variables introduced in the models were treated as time-varying covariates. Motivation to learn, level of skill with ICT, importance attributed to ICT, interest in geology and age were introduced as covariates in some of the models. Effect sizes for the t-test, χ^2, and the estimators of the MMRM were calculated using Cohen's d, Cramér's V, and ηp^2, respectively. Analyses were conducted using SPSS 24® software (Inc., Chicago, IL, USA). Statistical significance for all comparisons was set at $p \leq 0.05$. In the MMRM analyses, with the current sample and assuming a medium effect size, the statistical power was 0.992.

3. Results

3.1. Sample Description

Table 1 presents the characteristics of the study sample. The sample consisted of 79 individuals, of whom 44 were in the GIF creation methodology group and 35 in the traditional methodology group. The average age of the sample was 30 years, with 87% being women, and nearly all participants had previously completed university studies (98.7%). In the course "biology and geology", they typically received a grade of "good" (67.1%), which partially contrasts with their self-assessed level of geological knowledge, which averaged 5.7/10. Their motivation to learn in general was 9.0 out of 10 points, while their interest in geology was 7.0 points. Regarding ICT, their interest was 8 out of 10 points, the importance they attributed to ICT as a vehicle in the teaching-learning process was 8.4, and their self-perceived level of digital skills was 7.8 points. Notably, there were no statistically significant differences in any of these variables between the groups forming each educational methodology ($p > 0.088$), except for age, with the GIF group being older ($p = 0.002$).

Table 1. Characteristics of participants by educational methodologies.

Characteristics	Total (n = 79)	GIF (n = 44)	Traditional (n = 35)	Statistical Test (df)	p-Value	Effect Size
Age (years) [a]	31.0 ± 6.7	33.0 ± 7.0	28.5 ± 5.4	$t_{76} = -3.213$	0.002	0.737
Gender (% women)	87.3	81.8	94.3	$\chi^2_{(1)} = 2.741$	0.098	0.186
Educational Level (%)				$\chi^2_{(2)} = 1.833$	0.400	0.152
Undergraduate	1.3	2.3	0.0			
Bachelor's	64.6	59.1	71.4			
Postgraduate	34.2	38.6	28.6			

Table 1. *Cont.*

Characteristics	Total (n = 79)	GIF (n = 44)	Traditional (n = 35)	Statistical Test (df)	p-Value	Effect Size
Grades in Biology and Geology (%)				$\chi^2_{(2)} = 3.249$	0.197	0.203
Pass	21.5	15.9	28.6			
Good	67.1	68.2	65.7			
Excellent	11.4	15.9	5.7			
Self-assessed Knowledge in Geology [a]	5.7 ± 1.6	6.0 ± 1.5	5.3 ± 1.6	$t_{77} = -1.729$	0.088	0.394
Motivation to Learn [a]	9.0 ± 1.1	8.9 ± 1.2	9.0 ± 1.0	$t_{77} = 0.570$	0.570	0.130
Interest in Geology [a]	7.0 ± 1.6	7.3 ± 1.8	6.8 ± 1.2	$t_{77} = -1.365$	0.176	0.311
Interest in ICT [a]	8.0 ± 1.6	8.1 ± 1.7	8.0 ± 1.6	$t_{77} = -0.322$	0.748	0.073
Importance of ICT in T-L [a]	8.4 ± 1.5	8.3 ± 1.6	8.5 ± 1.3	$t_{77} = 0.744$	0.459	0.170
Level of Digital Skills [a]	7.8 ± 1.4	7.8 ± 1.4	7.7 ± 1.4	$t_{77} = -0.096$	0.924	0.022

Note. *df* = Degrees of Freedom. ICT = Information and Communication Technologies. T-L = Teaching-Learning Process. [a] = Mean ± Standard Deviation.

3.2. Knowledge Level in Geology

The change in the level of geological knowledge before and after the use of educational methodologies is shown in Figure 2A. The group that used the traditional methodology increased their baseline knowledge from 5.1 (SD = 1.5) to 5.7 (SD = 1.4) post-intervention, while the GIF group improved their knowledge level from 5.7 (SD = 1.6) to 7.1 (SD = 1.1) after the GIF creation activity.

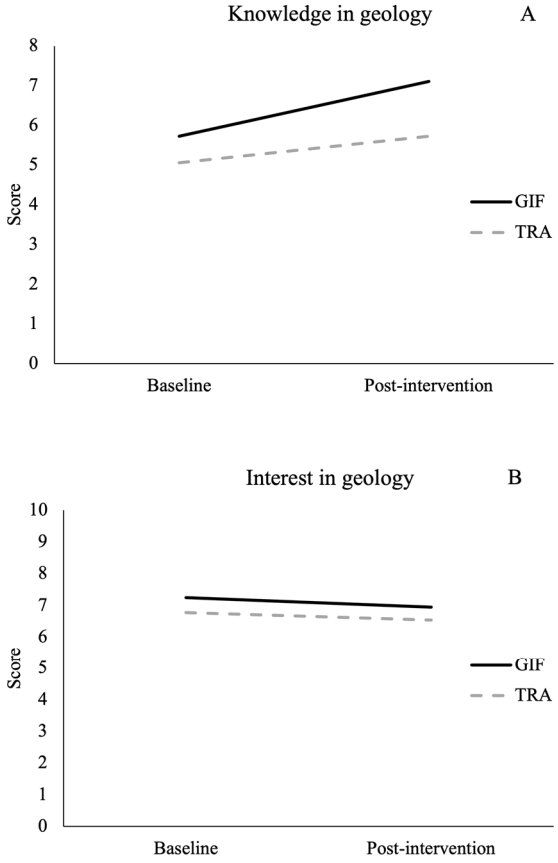


Figure 2. *Cont.*

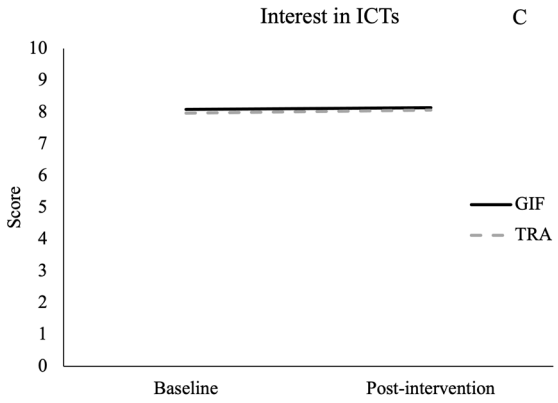


Figure 2. Pre-post changes in the study variables. (**A**) Knowledge in Geology; (**B**) Interest in Geology; (**C**) Interest in ICT.

The MMRM analysis (Table 2) indicated a significant increase in knowledge levels following the use of the educational methodologies ($EST_{\beta 1} = 1.906$, $t_{76} = 7.169$, $p < 0.001$), with a greater learning gain in geology observed in the GIF group ($EST_{\beta 3} = 1.201$, $t_{76} = 3.032$, $p = 0.003$). Additionally, the overall knowledge level was higher in the GIF group ($EST_{\beta 2} = 1.409$, $t_{76} = 5.101$, $p < 0.001$) compared to the traditional methodology group at baseline. Furthermore, the model included a covariate for interest in geology, showing that students with a greater interest in this science exhibited higher overall knowledge in the discipline ($EST_{\beta 4} = 0.146$, $t_{110} = 2.061$, $p = 0.042$).

Table 2. Results of the MMRM for knowledge level.

Fixed Effect	df_N	df_D	*F*	*p*	Effect Size
Time (β_1)	1	77	43.149	<0.001	0.354
Group (β_2)	1	76	8.769	0.004	0.103
Group × Time (β_3)	1	76	9.196	0.003	0.108
Interest in geology (β_4)	1	110	4.247	0.042	0.037
Age (β_5)	1	75	0.045	0.832	0.001

Note. df_N = Numerator degrees of freedom; df_D = Denominator degrees of freedom.

3.3. Interest in Geology

The change in interest in geology can be seen in Figure 2B. There is a slight decline in interest in geology following the use of the educational methodologies; however, according to the MMRM (Table 3), this decrease is not statistically significant ($p = 0.188$). There are no differences between the educational methodologies ($p = 0.993$), nor is there an interaction between time and the educational methodology ($p = 0.621$). The model introduced motivation to learn as a covariate, revealing that a high motivation to learn knowledge in general is associated with a greater interest in geology ($EST_{\beta 4} = 0.558$, $t_{262} = 8.427$, $p < 0.001$). Moreover, this was the only model in which age emerged as a significant covariate, with older participants showing greater interest in geology ($EST_{\beta 5} = 0.034$, $t_{254} = 2.223$, $p = 0.027$).

Table 3. Results of the MMRM for interest in geology.

Fixed Effect	df_N	df_D	*F*	*p*	Effect Size
Time (β_1)	1	81	1.763	0.188	0.021
Group (β_2)	1	181	0.000	0.993	0.000
Group × Time (β_3)	1	81	0.246	0.621	0.003
Motivation to learn (β_4)	1	263	71.016	<0.001	0.213
Age (β_5)	1	254	4.940	0.027	0.019

Note. df_N = Numerator degrees of freedom; df_D = Denominator degrees of freedom.

3.4. Interest in ICT

The evolution of interest in ICT after using the educational methodologies is shown in Figure 2C. In this case, as indicated by the MMRM (Table 4), interest in ICT remained generally unchanged ($p = 0.544$), with no differences between the methodologies after their use ($p = 0.911$). However, there was a relationship between interest in ICT and perceived skills in using these tools ($EST_{\beta 4} = 0.702$, $t_{257} = 13.818$, $p < 0.001$), and the importance attributed to ICT in the teaching-learning process ($EST_{\beta 5} = 0.394$, $t_{255} = 7.373$, $p < 0.001$), showing that high levels of these two covariates are related to a greater interest in ICT.

Table 4. Results of the MMRM for interest in ICT.

Fixed Effect	df_N	df_D	F	p	Effect Size
Time (β_1)	1	77	0.371	0.544	0.005
Group (β_2)	1	136	0.592	0.443	0.004
Group × Time (β_3)	1	77	0.013	0.911	0.000
Skills in ICT (β_4)	1	257	190.945	<0.001	0.426
Importance of ICT (β_5)	1	255	54.364	<0.001	0.172
Age (β_6)	1	255	0.003	0.957	0.000

Note. df_N = Numerator degrees of freedom; df_D = Denominator degrees of freedom.

3.5. Evaluation of GIFs as a Learning Resource

Of the 44 participants who created a GIF, 93% (41) chose to create a GIF about Pangaea, while only three students opted for convection currents. The difficulty attributed to creating the GIF was intermediate (3.4/5), with 15.9% finding it difficult, while half (47.8%) perceived it as easy. The majority stated that the most challenging part of the activity was creating and developing the frames (68.2%), followed by researching scientific information to create the frames (20.5%), and lastly combining the frames to create the GIF (11.4%).

Overall, participants rated the GIF as an effective tool for learning geological content (4.3/5), with 88.6% agreeing or strongly agreeing with this. Similarly, the majority (86.4%) would use this resource in their future teaching practice, with an average score of 4.6 out of 5. Participants also found it interesting to use an activity where their future students would design a GIF (4.6/5), with 84.1% agreeing with this. Finally, there was a high level of agreement that creating the GIF was more interesting than usual academic activities (4.3/5), with only 6.8% disagreeing.

4. Discussion

The results of this study provide a comprehensive view of the effectiveness of GIFs as an educational tool in teaching geology, particularly in the context of training future primary education teachers. The most relevant findings are discussed below.

Firstly, the independent creation of GIFs by participants was found to be more effective than traditional instruction delivered by an expert teacher in promoting geological knowledge acquisition. This finding is particularly significant, as it demonstrates that students who receive initial guidance can achieve higher levels of learning than those receiving direct instruction from a specialized teacher. The effectiveness of this methodology can be attributed to two main factors: the passive and active nature of the GIF creation process. The infinite repetition and visual representation of GIFs facilitate the illustration of complex geological concepts, which are often difficult to depict in static formats (Álvarez & García de la Torre, 1996; Ash, 2015). This visual and repetitive feature allows students to internalize and retain concepts more effectively. Additionally, the creative process of researching selected geological processes and developing GIFs involves active learning, which encompasses not only passive visualization but also research, information synthesis,

and the practical application of knowledge. Previous studies have shown that active, self-directed learning—such as simulating, researching, and creating educational materials—is an effective strategy for enhancing understanding and knowledge retention (Dorji et al., 2024; Guerrero Chinome & Genet Verney, 2020; Henthorn, 2023). This combination of active creation and repeated visualization supports not only immediate comprehension but may also facilitate long-term retention, aligning with multimedia learning principles (Mayer & Moreno, 2003).

Moreover, the ability to internalize complex processes through active participation is consistent with constructivist theories of learning (Kolb, 2014) and TPACK model (Angraini et al., 2023; Shafie et al., 2019), where students create their own understanding by actively engaging with content. By transforming abstract geological processes into tangible visual tools, students move beyond rote memorization to deeper, conceptual understanding—critical in subjects like geology, where temporal and spatial scales are challenging to grasp. This underscores the potential for GIF creation to foster long-term knowledge retention, a point that could be further explored in future studies with extended follow-up periods.

Another key finding was the lack of significant changes in students' interest in geology following the educational intervention, regardless of the methodology used. While GIF creation can be an effective teaching tool, it does not necessarily influence students' perceptions or interest in geology. This result may stem from various factors, including students' initial predispositions and the need for a more comprehensive and sustained approach to altering deeply rooted attitudes and perceptions (Dawson & Carson, 2013; Lewis & Baker, 2010; Mills et al., 2020). Additionally, changing subject-specific interest likely requires more prolonged or varied educational interventions that link geological concepts with students' everyday experiences. The creation of GIFs, while engaging, might not have been sufficient in this study to make geology appear more relevant to students' personal or professional lives. Integrating practical fieldwork or virtual simulations, such as augmented reality (AR) or virtual reality (VR), could offer more immersive experiences that boost interest in the subject (Pellas et al., 2020; AlGerafi et al., 2023). Future educational interventions should consider a multifaceted approach that combines technology-based tools like GIFs with real-world applications and interdisciplinary projects to foster genuine engagement with geosciences.

Notably, participants with a higher initial interest in geology demonstrated greater knowledge in the subject both before and after the intervention. This observation aligns with existing literature, which indicates that personal interest and motivation positively influence learning and knowledge retention (Orion, 2019; Occhipinti, 2025). Perception and interest in a subject are shaped by multiple factors, including prior experiences, the educational context, and the perceived relevance of the subject in daily life (Jameson et al., 2024; Snyder et al., 2015; Spearman & Watt, 2013; Urhahne & Wijnia, 2023). Therefore, while GIF creation can enhance understanding, it is crucial to design educational interventions that not only convey information but also cultivate a genuine interest in geology through practical experiences and relevant contexts. This is consistent with the idea that practical competencies and interdisciplinary learning are critical for addressing global challenges (King, 2008; Schijf et al., 2023).

Similarly, the study did not reveal significant changes in students' interest in ICT after the intervention. This finding suggests that GIF creation, although an innovative teaching method, does not substantially alter students' interest in ICT. According to our results, students with higher proficiency in using digital tools and who recognize their importance in education tend to be more motivated to use them. Therefore, the fact that students in this study already had a notable level of familiarity and comfort with ICT likely explains the lack of change in interest. This result is unsurprising given the widespread use

of ICT in modern society and particularly in higher education (Fernández-Rovira, 2022; Lloyd & Devine, 2012; Msafiri et al., 2023; Thomas, 2011). However, it is worth noting that ICT proficiency is not static, and future educators may benefit from training programs that develop more advanced skills in TPACK (Ertmer & Ottenbreit-Leftwich, 2010). This approach could better equip educators to integrate digital tools like GIFs into their teaching practices in ways that enhance learning outcomes while aligning with curricular goals.

It is important to note that students found the GIF creation activity more engaging than traditional academic activities and expressed a strong willingness to incorporate GIFs into their future teaching practices. This enthusiasm can be leveraged to promote more dynamic and interactive teaching methodologies that align with the learning preferences of newer generations (Buenaño-Barreno et al., 2021; Garbin et al., 2021; Stern et al., 2020; Thomas, 2011). Despite minimal training—consisting of a brief explanation and written instructions—students were able to successfully complete the GIF creation activity. Students' perception of the moderate difficulty of GIF creation suggests that, with appropriate training, this tool can be easily integrated into the curriculum without requiring extensive technical expertise. Furthermore, considering that students reported greater engagement, it would be useful to explore how combining GIF creation with other educational tools (e.g., interactive simulations or collaborative platforms) could further enhance both engagement and learning. This approach can foster the use of ICT as an enabler in teaching disciplines like geology, where technology and content are closely intertwined to enhance teaching and learning (Ertmer & Ottenbreit-Leftwich, 2010).

Although this study provides valuable evidence on the use of GIFs in geology education, it is important to acknowledge that the sample consisted exclusively of university students from a specific degree program, selected through purposive sampling. Moreover, the design is quasi-experimental, meaning that the groups were pre-existing and participants were not randomly assigned. This lack of randomization may introduce potential confounding variables and limits the ability to infer causal relationships. For this reason, in the main analyses we included as covariates those variables in which statistically significant differences between groups were found, in order to control for the limitations associated with the design. It is also worth noting that, due to the sample size, between-group tests (e.g., *t*-tests and chi-square tests) may suffer from low statistical power, which could limit the detection of true differences. All of these aspects introduces bias and limits both the representativeness of the results and the ability to generalize findings to other educational contexts. Additionally, extending the follow-up period to evaluate long-term knowledge retention and ongoing changes in student motivation would be beneficial. Another point to consider is that potential external factors—such as access to technological resources outside the university environment or additional support received by students—were not controlled. Finally, the study focused solely on GIF creation as an educational tool, without exploring other forms of animations or digital resources that could complement or enhance the findings. Future research could investigate how students might design their own educational ICT tools by incorporating emerging technologies such as augmented reality (AR), virtual reality (VR), or 3D modeling environments. Moreover, research could explore how artificial intelligence (AI) can be used not only as a teaching tool, but as a means for future educators to design and build their own ICT-based resources aimed at enhancing active methodologies in the classroom. Encouraging students to create these kinds of resources would not only reinforce content understanding but also promote digital literacy.

5. Conclusions

This study has demonstrated that creating GIFs as an educational tool can significantly improve short-term knowledge retention in university students. Participants who used

GIFs showed better content understanding and a greater willingness to actively engage in the learning process compared to traditional methods. Creating GIFs as a didactic resource proved to be an effective strategy for capturing students' attention and facilitating the understanding of complex concepts through dynamic visual representations. Moreover, the results indicate that GIFs can be a versatile and appealing tool that can complement traditional teaching methodologies, providing an innovative means for presenting information.

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References

Abgao, J. M. (2023). Effectiveness of using Graphics Interchange Format (GIF) in teaching chemistry. *IJCER International Journal of Chemistry Education Research*, *7*(2), 105–112. [CrossRef]

Adak, S. (2017). Effectiveness of constructivist approach on academic achievement in science at secondary level. *Educational Research and Reviews*, *12*(22), 1074–1079. [CrossRef]

AlGerafi, M. A. M., Zhou, Y., Oubibi, M., & Wijaya, T. T. (2023). Unlocking the potential: A comprehensive evaluation of augmented reality and virtual reality in education. *Electronics*, *12*(18), 3953. [CrossRef]

Altintas, E., Iigun, Ş., & Kucuk, S. (2017). Evaluation of use of Graphics Interchange Format (GIF) animations in mathematics education. *Educational Research and Reviews*, *12*(23), 1112–1119. [CrossRef]

Angraini, E., Zubaidah, S., & Susanto, H. (2023). TPACK-based active learning to promote digital and scientific literacy in genetics. *Pegem Journal of Education and Instruction*, *13*(2), 50–61. [CrossRef]

Ash, J. (2015). Sensation, networks, and the GIF: Toward an allotropic account of affect. In *Networked affect* (pp. 119–134). The MIT Press. [CrossRef]

Audette, L. M., Hammond, M. S., & Rochester, N. K. (2020). Methodological issues with coding participants in anonymous psychological longitudinal studies. *Educational and Psychological Measurement*, *80*(1), 163–185. [CrossRef]

Álvarez, R. M., & García de la Torre, E. (1996). Modelos analógicos en geología: Implicaciones didácticas. Ejemplos relacionados con el origen de materiales terrestres. *Enseñanza Ciencias de La Tierra*, *2*(4), 133–139.

Baig, M. I., & Yadegaridehkordi, E. (2023). Flipped classroom in higher education: A systematic literature review and research challenges. *International Journal of Educational Technology in Higher Education*, *20*(1), 61–87. [CrossRef]

Bakhshi, S., Shamma, D. A., Kennedy, L., Song, Y., de Juan, P., & Kaye, J. J. (2016). Fast, cheap, and good. In *Proceedings of the 2016 CHI conference on human factors in computing systems* (pp. 575–586). ACM. [CrossRef]

Barriga, F. D. (2008). Educación y nuevas tecnologías de la información:¿ hacia un paradigma educativo innovador? *Sinéctica*, *30*, 1–15.

Bloom, B. S., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals, by a committee of college and university examiners*. Longmans.

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom*. ASHE-ERIC Higher Education Reports. ERIC Clearinghouse on Higher Education, The George Washington University.

Buenaño-Barreno, P. N., González-Villavicencio, J. L., Mayorga-Orozco, E. G., & Espinoza-Tinoco, L. M. (2021). Metodologías activas aplicadas en la educación en línea. *Dominio Ciencias*, *7*(4), 763–780. [CrossRef]

Bulbul, M. S. (2007). Using gif (graphics interchange format) images in physics education. In S. A. Cetin, & I. Hikmet (Eds.), *Six international conference of the balkan physical union* (Vol. 899, pp. 481–482). American Institute of Physics.

Caeiro Rodríguez, M., & Torres Pérez, A. (2019). Experiencias visuales y cognitivas a través de GIFS en Educación Primaria. *Reidocrea*, *8*, 35–42. [CrossRef]

Calonge, A., Fermeli, G., Meléndez, G., & Martínez, J. A. (2014). Proyecto GEOschools: Reflexiones sobre la geología en la Enseñanza Secundaria Obligatoria GEOschools project: Teaching Geology in the Lower Secondary School level (ESO) in Spain. *Geogaceta*, *55*, 99–102. Available online: www.geogaceta.com (accessed on 10 February 2025).

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, *35*(8), 982–1003. [CrossRef]

Dawson, V., & Carson, K. (2013). Science teachers' and senior secondary schools students' perceptions of earth and environmental science topics. *Australian Journal of Environmental Education*, *29*(2), 202–220. [CrossRef]

Dodick, J., & Orion, N. (2003). Geology as an historical science: Its perception within science and the educational system. *Science and Education*, *12*(2), 197–211. [CrossRef]

Dogani, B. (2023). Active learning and effective teaching strategies. *International Journal of Advanced Natural Sciences and Engineering Researches*, *7*(4), 136–142. [CrossRef]

Dolphin, G., & Benoit, W. (2016). Students' mental model development during historically contextualized inquiry: How the 'Tectonic Plate' metaphor impeded the process. *International Journal of Science Education*, *38*(2), 276–297. [CrossRef]

Dorji, T., Subba, S., & Zangmo, T. (2024). De-mystifying the influence of PhET simulation on engagement, satisfaction, and academic achievement of bhutanese students in the physics classroom. *Journal of Science Education and Technology*, *33*, 892–909. [CrossRef]

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal Research Technology Education*, *42*(3), 255–284. [CrossRef]

Fernando Santos, L. (2017). The role of critical thinking in science education. *Journal of Education and Practice*, *8*(20), 160–173.

Fernández-Rovira, C. (2022). Motivaciones y tiempo de uso de las redes sociales por parte de los jóvenes españoles: Señales de adicción. *Anuario Electrónico de Estudios En Comunicación Social "Disertaciones"*, *15*(2), 1–19. [CrossRef]

Fornós, J. J. (2018). La enseñanza de la geología en la educación secundaria: Una cuestión problemática. Algunas observaciones en baleares. In J. Duque-Macías, & A. Paula Bernal (Eds.), *XX simposio sobre enseñanza de la geología* (pp. 83–94). Estudios Gráficos Europeos.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(23), 8410–8415. [CrossRef]

Frøyland, M., Remmen, K. B., & Sørvik, G. O. (2016). Name-dropping or understanding?: Teaching to observe geologically. *Science Education*, *100*(5), 923–951. [CrossRef]

Garbin, M. C., de Oliveira, E. T., & Telles, S. (2021). Active methodologies supported by interaction and communication technologies in higher education. *Global Journal of Information Technology: Emerging Technologies*, *11*(2), 47–54. [CrossRef]

Gargallo-López, B., Almerich-Cerveró, G., García-García, F.-J., López-Francés, I., & Sahuquillo-Mateo, P.-M. (2023). University student profiles in the learning to learn competence and their relationship with academic achievement. *Revista Española de Pedagogía*, *81*(286), 457–487. [CrossRef]

Grabinger, R. S., & Dunlap, J. C. (1995). Rich environments for active learning: A definition. *ALT-J*, *3*(2), 5–34. [CrossRef]

Guerrero Chinome, E. J., & Genet Verney, R. (2020). Palimpsesto urbano .gif _ Un instrumento de investigación creación. *Index, Revista de Arte Contemporáneo*, *10*, 212–230. [CrossRef]

Gygli, M., Song, Y., & Cao, L. (2016, June 27–30). *Video2gif: Automatic generation of animated gifs from video*. IEEE Conference on Computer Vision and Pattern Recognition (pp. 1001–1009), Las Vegas, NV, USA.

Henderson, C., Beach, A., & Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, *48*(8), 952–984. [CrossRef]

Henderson, C., & Dancy, M. H. (2007). Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics. *Physical Review Special Topics-Physics Education Research*, *3*(2), 020102. [CrossRef]

Henthorn, J. (2023). Using GIFs to position students as scholars. *Prompt: A Journal of Academic Writing Assignments*, *7*(1), 11–21. [CrossRef]

Huguet, C., Pearse, J., Noè, L. F., Valencia, D. M., Ruiz, N. C., Heredia, A. J., & Avedaño, M. A. P. (2020). Improving the motivation of students in a large introductory geoscience course through active learning. *Journal of Geoscience Education*, *68*(1), 20–32. [CrossRef]

Jameson, M. M., Sexton, J., London, D., & Wenner, J. M. (2024). Relationships and gender differences in math anxiety, math self-efficacy, geoscience self-efficacy, and geoscience interest in introductory geoscience students. *Education Sciences*, *14*(4), 426. [CrossRef]

Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development. *Computers & Education*, *55*(3), 1259–1269. [CrossRef]

King, C. (2008). Geoscience education: An overview. *Studies in Science Education*, *44*(2), 187–222. [CrossRef]

Kober, N. (2015). *Reaching students*. National Academies Press. [CrossRef]

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. Pearson Education Inc.

Lacreu, H. L. (2018). The Social Sense of Geological Literacy. *Annals of Geophysics*, *60*, 1–6. [CrossRef]

Laurillard, D., Kennedy, E., Charlton, P., Wild, J., & Dimakopoulos, D. (2018). Using technology to develop teachers as designers of TEL: Evaluating the learning designer. *British Journal of Educational Technology*, *49*(6), 1044–1058. [CrossRef]

Lewis, E. B., & Baker, D. R. (2010). A call for a new geoscience education research agenda. *Journal of Research in Science Teaching*, *47*(2), 121–129. [CrossRef]

Lloyd, K., & Devine, P. (2012). Psychometric properties of the Warwick–Edinburgh Mental Well-being Scale (WEMWBS) in Northern Ireland. *Journal of Mental Health*, *21*(3), 257–263. [CrossRef]

López Núñez, J. A., López Belmonte, J., Moreno Guerrero, A. J., & Pozo Sánchez, S. (2020). Effectiveness of innovate educational practices with flipped learning and remote sensing in earth and environmental sciences—An exploratory case study. *Remote Sensing*, *12*(5), 897. [CrossRef]

Mampel Laboira, L., Cortés Gracia, Á. L., & Alcalá Martínez, L. (2015). Imágenes sobre dinosaurios en libros de texto de Enseñanza Secundaria Obligatoria. *Didáctica de Las Ciencias Experimentales y Sociales*, *29*, 173–193. [CrossRef]

Manduca, C. A., Iverson, E. R., Luxenberg, M., Macdonald, R. H., McConnell, D. A., Mogk, D. W., & Tewksbury, B. J. (2017). Improving undergraduate STEM education: The efficacy of discipline-based professional development. *Science Advances*, *3*(2), 1–15. [CrossRef]

Marín, T. (2011). Experiencia de innovación docente GOUMH: Aprendizaje colaborativo en Bellas Artes con APPS de Google. In *Actas del congreso internacional de innovación docente* (pp. 1845–1859). Universidad Politécnica de Cartagena.

Martinez, M. E., & Gomez, V. (2025). Active learning strategies: A mini review of evidence-based approaches. *Acta Pedagogia Asiana*, *4*(1), 43–54. [CrossRef]

Mayer, R. E. (2009). *Multimedia learning*. Cambridge University Press. [CrossRef]

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychology*, *38*(1), 43–52. [CrossRef]

McConnell, D. A., Chapman, L., Czajka, C. D., Jones, J. P., Ryker, K. D., & Wiggen, J. (2017). Instructional utility and learning efficacy of common active learning strategies. *Journal of Geoscience Education*, *65*(4), 604–625. [CrossRef]

Meng, N., Dong, Y., Roehrs, D., & Luan, L. (2023). Tackle implementation challenges in project-based learning: A survey study of PBL e-learning platforms. *Educational Technology Research and Development*, *71*(3), 1179–1207. [CrossRef]

Metze, T. (2020). Visualization in environmental policy and planning: A systematic review and research agenda. *Journal of Environmental Policy & Planning*, *22*(5), 745–760. [CrossRef]

Mills, R., Tomas, L., Whiteford, C., & Lewthwaite, B. (2020). Developing middle school students' interest in learning science and geology through slowmation. *Research in Science Education*, *50*(4), 1501–1520. [CrossRef]

Mosher, S., Bralower, T., Huntoon, J., Lea, P., McConnell, D., Miller, K., Ryan, J. G., Summa, L., Villalobos, J., & White, L. (2014). *Future of undergraduate geoscience education: Summary report for summit on future of undergraduate geoscience education*. School of Geosciences Faculty and Staff Publications. Available online: https://digitalcommons.usf.edu/geo_facpub/1127 (accessed on 10 February 2025).

Msafiri, M. M., Kangwa, D., & Cai, L. (2023). A systematic literature review of ICT integration in secondary education: What works, what does not, and what next? *Discover Education*, *2*(1), 44. [CrossRef]

Navarro, J., Piña, J. U., Mas, F. M., & Lahoz-Beltra, R. (2023). Press media impact of the Cumbre Vieja volcano activity in the island of La Palma (Canary Islands): A machine learning and sentiment analysis of the news published during the volcanic eruption of 2021. *International Journal of Disaster Risk Reduction*, *91*, 103694. [CrossRef]

Occhipinti, S. (2025). Motivation for learning geosciences: The teaching-learning process—Analysis, evaluations, and proposals. In *Motivation in learning*. IntechOpen. [CrossRef]

Orion, N. (2019). The future challenge of Earth science education research. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), 3. [CrossRef]

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. The Nuffield Foundation.

Pedrinaci, E. (2012). Por una alfabetización científica. *Enseñanza de Las Ciencias de La Tierra*, *20*(1), 105–106.

Pellas, N., Dengel, A., & Christopoulos, A. (2020). A scoping review of immersive virtual reality in STEM education. *IEEE Transactions on Learning Technologies*, *13*(4), 748–761. [CrossRef]

Perales Palacios, F. J. (2007). Uso (y abuso) de la imagen en la enseñanza de las ciencias. *Enseñanza de Las Ciencias. Revista de Investigación y Experiencias Didácticas*, *24*(1), 13–30. [CrossRef]

Pineda, B. C. B., & Vergara, J. L. B. (2016). La península de Paraguaná: Un paisaje natural para la enseñanza de la morfología litoral en Ciencias de la Tierra. *Investigacióny Formación Pedagógica Revista del CIEGC*, *2*(4), 30–50.

Pinto, T., Dias, A. G., & Vasconcelos, C. (2021). Geology and environment: A problem-based learning study in higher education. *Geosciences*, *11*(4), 173. [CrossRef]

Pirrie, A., & Thoutenhoofd, E. D. (2013). Learning to learn in the European Reference Framework for lifelong learning. *Oxford Review of Education*, *39*(5), 609–626. [CrossRef]

Pratiwi, E. D., Masykuri, M., & Ramli, M. (2021). Active learning strategy on higher education biology learning: A systematic review. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, *6*(1), 75–86. [CrossRef]

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231. [CrossRef]

Roca, N., & Garcia-Valles, M. (2020). Trainee teacher experience in geoscience education: Can we do better? *Geoheritage*, *12*(4), 92. [CrossRef]

Schijf, J. E., van der Werf, G. P., & Jansen, E. P. (2023). Measuring interdisciplinary understanding in higher education. *European Journal of Higher Education*, *13*(4), 429–447. [CrossRef]

Serrano Amarilla, N., Cuetos Revuelta, M. J., & Manzanal Martínez, A. I. (2022). Systematic review: Flipped classrooms in the performance of undergraduate science students. *Journal of Science Education and Technology*, *31*(5), 594–604. [CrossRef]

Shafie, H., Majid, F. A., & Ismail, I. S. (2019). Technological pedagogical content knowledge (TPACK) in teaching 21st century skills in the 21st century classroom. *Asian Journal of University Education*, *15*(3), 24–33. [CrossRef]

Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education*, *4*(1), 13. [CrossRef]

Snyder, J. S., Schwiedrzik, C. M., Vitela, A. D., & Melloni, L. (2015). How previous experience shapes perception in different sensory modalities. *Frontiers in Human Neuroscience*, *9*, 594. [CrossRef]

Spearman, J., & Watt, H. M. G. (2013). Perception shapes experience: The influence of actual and perceived classroom environment dimensions on girls' motivations for science. *Learning Environments Research*, *16*(2), 217–238. [CrossRef]

Stern, R., Ryan, J., Wang, N., Ricchezza, V., & Willis, S. (2020). Geoscience videos and animations: How to make them with your students, and how to use them in the classroom. *GSA Today*, *30*(6), 42–43. [CrossRef]

Taculod, N. J., & Arcilla, F., Jr. (2020). Enhancing the academic performance and learning interest in biology of grade 10 students using expanded powerpoint instruction. *SMCC Higher Education Research Journal*, *2*(1), 57–81. [CrossRef]

Teasdale, R., Viskupic, K., Bartley, J. K., McConnell, D., Manduca, C., Bruckner, M., Farthing, D., & Iverson, E. (2017). A multidimensional assessment of reformed teaching practice in geoscience classrooms. *Geosphere*, *13*(2), 608–627. [CrossRef]

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E., . . . Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, *117*(12), 6476–6483. [CrossRef]

Thomas, M. (2011). *Deconstructing digital natives: Young people, technology, and the new literacies*. Routledge.

Urhahne, D., & Wijnia, L. (2023). Theories of motivation in education: An integrative framework. *Educational Psychology Review*, *35*(2), 45–80. [CrossRef]

Yang, Y.-T. C. (2008). A catalyst for teaching critical thinking in a large university class in Taiwan: Asynchronous online discussions with the facilitation of teaching assistants. *Educational Technology Research and Development*, *56*(3), 241–264. [CrossRef]

Zamalloa, T., & Sanz, J. (2023). Attitudes of secondary school students towards geology in Spain. *Research in Science & Technological Education*, *41*(1), 123–146. [CrossRef]

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