Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 9, 48-72
2025
Publisher: Learning Gate
DOI: 10.55214/2576-8484.v9i9.9769

Enhancing conceptual understanding in physics: An innovative interactive multimedia learning environment for teaching Newtonian gravity

Noureddine Echantoufi[1]*, Khalid El Khattabi[1], Mohammed Lamrabet[1], Hamza Fakhar[1], Lotfi Ajana[1]

[1]Laboratory for Scientific Innovation in Sustainability, Environment, Education, and Health in the Age of AI, École Normale Supérieure, ENS, Sidi Mohamed Ben Abdellah University, Fez, Morocco; noureddine.echantoufi@usmba.ac.ma (N.E.) khalid.elkhattabi@usmba.ac.ma (K.E.K.) mohammed.lamrabet@usmba.ac.ma (M.L.) hamza.fakhar@usmba.ac.ma (H.F.) lotaja@yahoo.fr (L.A.)

Abstract: This study investigates the impact of an Interactive Multimedia Learning Environment (IMLE) on students' comprehension of Newtonian gravity. A quasi-experimental design compared an IMLE-supported experimental group with a traditionally taught control group. Conceptual learning was assessed using the Newtonian Gravity Concept Inventory (NGCI), while motivation was measured via the Science Motivation Questionnaire II (SMQ II). Results showed significantly greater improvement in students' conceptual understanding of Newton's law of gravitation in the experimental group exposed to an IMLE, compared to the control group receiving traditional instruction. Paired samples t-tests indicated significant gains in NGCI scores within the experimental group ($p<0.001$). Independent t-tests confirmed that these gains were significantly higher than those of the control group ($p<0.001$). Additionally, ANCOVA showed no significant effect of gender on posttest performance, indicating that the benefits of IMLE were consistent across genders. Pearson correlation analyses highlighted significant positive relationships between NGCI posttest scores and all dimensions of science motivation, particularly grade motivation ($r=0.886$) and self-efficacy ($r=0.857$). These findings suggest that IMLE not only enhances conceptual learning but also positively influences student motivation in science education. Furthermore, they underscore the educational potential of incorporating interactive multimedia learning environments in the instruction of complex and abstract scientific concepts.

Keywords: *Conceptual understanding, Science motivation, Interactive multimedia learning environment, Moroccan educational system, Newtonian gravity, Physics education innovation.*

1. Introduction

Universal gravitation represents a fundamental concept in physics [1, 2] essential for explaining natural phenomena and supporting the development of scientific literacy among high school students [3, 4]. While the law of universal gravitation is mathematically straightforward, stipulating that the gravitational force between two bodies depends on their masses and the distance between them, it remains conceptually abstract for many learners. Effectively communicating these concepts poses enduring pedagogical challenges [5] particularly when relying on traditional, teacher-centered instructional methods [6].

Extant literature has identified persistent misconceptions among secondary school students regarding gravitational phenomena [7-9]. For instance, learners frequently interpret gravitational force as acting exclusively between large or massive bodies [10, 11], or are unable to adequately explain why objects accelerate toward the ground [12, 13]. These findings suggest a disconnect between formal instruction and conceptual understanding, particularly in topics related to Newtonian mechanics and

History: Received: 18 June 2025; Revised: 1 August 2025; Accepted: 6 August 2025; Published: 1 September 2025
* Correspondence: noureddine.echantoufi@usmba.ac.ma

gravitational interactions [14, 15].

In the context of the accelerating digital transformation of education, digital pedagogical tools are increasingly assuming a central role in teaching practices. Their significance is now widely acknowledged—not merely for their ability to modernize instructional strategies, but more significantly for their potential to enhance students' understanding of complex disciplinary content [16]. This potential is particularly relevant in the teaching of physics, where many concepts, such as Newton's theory of gravitation, remain abstract, non-intuitive, and difficult to grasp through traditional methods alone.

Amidst efforts to improve physics education, Interactive Multimedia Learning Environments (IMLE) have emerged as a promising pedagogical strategy. These environments promote active learning by providing personalized feedback, adaptive assessments, and interactive content, which collectively enhance student engagement and conceptual retention [17, 18]. Features such as self-paced video modules and interactive quizzes allow learners to revisit complex concepts, correct misconceptions, and regulate their own learning processes—benefits that are especially relevant for abstract scientific topics like gravitation.

Despite technological advancements in education, many students exhibit persistent difficulties in understanding basic concepts of gravitation [19]. This can be partly attributed to the absence of pedagogical strategies that effectively promote conceptual engagement and foster active cognitive engagement under investigation. Conventional instructional methods have demonstrated limited effectiveness in achieving lasting conceptual understanding [20].

In the Moroccan educational context, these difficulties are often compounded by limited access to updated instructional resources and technology-enhanced learning tools [21, 22]. In the 2022 assessment of the Programme for International Student Assessment (PISA), Moroccan students' performance in science scored significantly lower than the Organization for Economic Co-operation and Development (OECD) average. Recent studies have highlighted the conceptual challenges faced by Moroccan students in physical sciences, particularly in grasping Newtonian mechanics concepts, including gravitational force [23, 24]. These studies reveal that the majority of students do not possess a "Newtonian understanding" of force and motion. This misconception represents a major epistemological obstacle in physics learning, as it negatively influences how students interpret physical phenomena and solve problems related to motion. These findings emphasize the urgent need for developing and applying innovative strategies to address learning difficulties by exploring innovative instructional methodologies that incorporate technology-enhanced learning interactive environments to enhance students' understanding of abstract scientific principles.

In light of these challenges, the present study seeks to evaluate the impact of Interactive Multimedia Learning Environments (IMLE) in enhancing students' conceptual understanding of Newton's law of universal gravitation. Specifically, the study investigates whether the integration of IMLE into physics instruction leads to significantly improved learning outcomes compared to traditional teaching methods.

To achieve this goal, a quasi-experimental design was implemented, involving two student groups: an experimental group exposed to IMLE and a control group receiving conventional instruction.

The study seeks to address the following research questions:

- To what extent does the use of IMLE improve students' understanding of the law of universal gravitation compared to traditional instructional methods?
- Are there gender-based differences in students' understanding of Newton's law of gravitation, and how does the interaction between gender and IMLE use influence conceptual learning?
- What is the impact of IMLE on students' intrinsic and extrinsic motivation throughout the learning process?

Based on this framework, the study tests the following hypotheses:

H_1: Students taught using IMLE demonstrate significantly greater conceptual understanding of Newton's law of universal gravitation than those receiving traditional instruction.

H_2: There is a statistically significant difference in students' conceptual understanding of Newton's law of gravitation based on gender.

H_3: There is a statistically significant interaction between gender and the type of instruction (IMLE vs. traditional instruction) on students' conceptual understanding.

H_4: Students exposed to IMLE will report higher levels of intrinsic and extrinsic motivation compared to students in the control group.

By addressing these questions, the study aims to contribute to the body of empirical research on digital pedagogy in physical sciences. The findings are expected to inform educational policy, curriculum development, and instructional decision-making regarding the integration of IMLE in Moroccan secondary education.

2. Literature Review

2.1. Digital Technologies and Interactive Learning in Education

The current generation of students has grown up in a society where digital technology has already exerted a profound influence. Consequently, these technologies have consistently attracted the attention of the educational sector due to the potential opportunities they offer [25]. To more effectively meet contemporary educational demands, the quality of basic education must be enhanced. This includes fostering digital fluency, promoting equity in access to educational resources, cultivating critical thinking skills, supporting personalized and learner-centered approaches, and preparing students to adapt to rapidly evolving technologies in an increasingly digital and complex world [26-28]. This evolving landscape necessitates that individuals acquire a new set of competencies, often referred to as 21st-century skills. These skills encompass creativity and innovation, critical thinking, problem-solving, decision-making, learning to learn, metacognition, communication, collaboration, technological proficiency, and digital literacy [29, 30].

In response to these growing expectations, the integration of digital tools into teaching practices has become increasingly prevalent. Unlike traditional instruction, which often relies on passive transmission of knowledge, interactive media emerged during the Internet revolution of the 1990s and have since evolved alongside advancements in digital technologies such as smartphones, laptops, and high-speed internet. These developments have enabled the rapid growth of online platforms capable of supporting diverse educational functions, including virtual classrooms, content sharing, and online assessments [31]. Furthermore, such platforms facilitate the management of institutional daily operations, such as issuing digital grade reports, scheduling classes and exams, communicating with parents, and maintaining administrative records [32]. These capabilities have transformed the educational landscape by increasing accessibility, streamlining communication, and enhancing instructional efficiency in both face-to-face and remote learning environments [33].

Among various digital innovations shaping modern education, Interactive Multimedia Learning Environments (IMLEs) have emerged as particularly impactful. IMLEs are broadly defined as learning environments that engage users through input and provides responsive feedback. These environments can take the form of print, digital, or hybrid formats. At their core, IMLEs function as dynamic media through which information is not only transmitted but also co-constructed by learners. Social media, simulations, games, virtual reality, and mobile applications are among the most prevalent forms of interactive media that enhance user experience [34]. These platforms allow users to interact with individuals or organizations via textual, visual, and auditory channels. By offering dynamic, engaging, and immersive learning experiences that traditional methods often fail to match, educators can transcend the confines of the classroom, enabling students to explore complex concepts and systems through virtual experimentation. This practical approach not only deepens conceptual understanding but also promotes the development of critical thinking and problem-solving abilities [25, 28, 35].

Furthermore, interactive learning reconceptualizes knowledge acquisition, transforming learners from passive recipients into active participants in the educational process through direct engagement in activities, simulations, and interactive exercises [36-38]. The integration of such approaches not only

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 9: 48-72, 2025
DOI: 10.55214/2576-8484.v9i9.9769

enhances conceptual understanding but also aligns with contemporary pedagogical goals that emphasize student-centered learning and critical thinking. A key driver behind this shift has been the increasing availability and sophistication of digital technologies, which enable the transcendence of physical and temporal boundaries in education. These tools offer unprecedented opportunities for equitable access to high-quality, flexible, and efficient learning environments [39]. However, despite these promising developments, several real-world limitations must be acknowledged. The digital divide persists, as not all students have equal access to devices or reliable internet connectivity [40]. Moreover, many educators lack adequate training and preparedness to effectively integrate interactive technologies into their teaching practices [41]. Infrastructure constraints also pose significant challenges, particularly in rural or underfunded schools, where basic digital facilities may be entirely absent [42]. Addressing these barriers is essential to ensure that technological advancements in education lead to truly inclusive and equitable learning opportunities for all students.

The urgency of these educational transformations has been underscored by international assessments that highlight Morocco's critical position in terms of educational quality. Notably, the International Association for the Evaluation of Educational Achievement [43] and the Trends in International Mathematics and Science Study [43] have revealed deficiencies in teaching methods, pedagogical approaches, and teacher training. To address the limitations of traditional experimental approaches, numerous researchers have proposed solutions grounded in new information technologies [44]. It is within this context that Morocco launched the Morocco Digital Strategy 2030, aimed at reducing the digital divide by expanding Internet access—particularly in rural areas—and promoting digital literacy among youth and adults. The strategy also emphasizes the development of digital skills and investments in information and communication technology (ICT) infrastructure to create employment opportunities and drive economic growth through technological innovation.

In light of these evolving demands and initiatives, IMLEs represent more than just instructional tools; they constitute a comprehensive pedagogical approach that enhances student engagement, supports deeper understanding of complex concepts, and serves as a valuable complement to traditional classroom instruction. Both learners and instructors recognize the value of this form of e-learning, emphasizing its role as a valuable complement to traditional classroom instruction [45, 46].

2.2. Interactive Learning and Physics Education

In physics courses, significant emphasis is placed on the cognitive aspect of interactivity. For instance, simulations are particularly valuable in science education, as they provide students with the opportunity to visualize and experiment with phenomena that would otherwise be difficult to observe in a classroom setting. A quasi-experimental study conducted with 54 Grade 11 students in a high school in Ontario, Canada, compared the effectiveness of two teaching strategies employing distinct cognitive tools—interactive computer simulations and manipulations of concrete objects in a physics laboratory—for developing students' inquiry skills in mechanics [47]. Regardless of the cognitive tool used, the study revealed significant improvements in inquiry skill development; however, students in the computer simulation group exhibited greater gains in their inquiry skills test compared to the laboratory group.

Another recent study explored how physics inquiry-based learning, facilitated by PhET Interactive Simulations, influenced Malaysian secondary students' engagement with physics in a fully virtual setting during the COVID-19 pandemic [48]. The results indicate that the exclusive use of PhET Interactive Simulations negatively impacts students' attitudes toward inquiry-based physics learning in the context of fully virtual courses. Future research should explore integrating PhET Simulations with other online pedagogical content to provide more immediate feedback and enhance students' attitudes toward learning [48] their engagement in science courses, their interest in pursuing careers in physics or science, their learning outcomes [49], and their critical thinking and problem-solving skills [50].

Specific research on the teaching of the laws of physics has demonstrated that interactive simulations can lead to significant improvements in students' performance on conceptual physics assessments. By incorporating interactive elements, such as adjustable parameters (e.g., object mass or gravitational constant), students are able to explore various scenarios and observe the resulting effects on motion in real time [51]. These tools are adaptable to various learning styles, enabling students to manipulate variables and observe the effects of these manipulations in real time, which is particularly relevant for concepts like gravity, where forces and movements are not immediately visible. This enhances their understanding and engagement by translating abstract concepts, such as those in Newtonian mechanics, into tangible and accessible forms.

In the Moroccan context, a mixed-methods study of high school physics education revealed that digital simulations and Computer-Assisted Experimentation (CAEx) —defined as the use of computer-based tools and digital systems to support various stages of the experimental process, including data collection, analysis, modeling, and visualization — hands-on scientific experiments, enhancing, rather than supplanting traditional methods [52, 53]. The integration of CAEx significantly deepened students' conceptual understanding of physics, particularly Newton's law of universal gravitation, while promoting engagement through interactive tools.

Similarly, Computer-Aided Instruction (CAI), a related approach supporting self-directed learning, encourages students to independently explore scientific concepts [54]. However, Moroccan physics teachers face significant barriers to implementing hands-on experiments, including inadequate training, poor coordination between policymakers and educators, and shortages of functional laboratory equipment, with over 60% of laboratories facing maintenance issues [54]. By incorporating digital simulations, schools can address some of these challenges, improving student learning outcomes and highlighting the value of technology in education [55]. Furthermore, Information and Communication Technology (ICT) offers innovative, interactive learning tools that enhance student engagement and understanding of scientific concepts in Moroccan physical science education [56].

2.3. The Role of Interactive Videos

Interactive videos have become a significant educational tool in the digital era, offering dynamic and engaging learning experiences that often surpass the effectiveness of traditional instructional methods [38]. By integrating visual and auditory elements with interactive features—such as embedded questions or reflective activities—these tools promote deeper cognitive engagement and support active learning processes [57]. One of their most notable advantages in physics education is their capacity to foster deeper conceptual understanding. Traditional physics instruction often relies on lectures and textbook explanations, which may fail to fully engage students or assist them in grasping abstract concepts. Unlike conventional approaches, interactive videos can simulate real-world scenarios, enabling students to visualize and manipulate variables within a controlled environment [58]. This hands-on experience is especially important in physics, where understanding principles such as motion, force, and energy requires not only theoretical knowledge but also intuitive insight. Through such simulations, students are better able to connect abstract theories with observable physical behaviors.

Empirical studies further support the pedagogical value of interactive videos. A study that employed interactive video using H5P revealed that 55% of students reported increased motivation compared to traditional online activities. Furthermore, teachers observed that the interactive video positively impacted student participation and motivation [59]. Moreover, another study examining the use of interactive video vignettes to teach Newton's Second and Third Laws demonstrated that the use of interactive videos significantly enhanced students' conceptual grasp of these laws [60]. Notably, they were able to correct common misconceptions and develop a more nuanced comprehension of the underlying principles after interacting with the content.

Given that gravity is a foundational concept in physics and is often challenging for students to understand due to its abstract nature, interactive videos have proven to be a highly effective instructional tool for teaching this topic [61]. These videos offer dynamic visualizations that illustrate how gravitational forces operate across different contexts, making complex ideas more accessible and intuitive [62]. Additionally, embedded quizzes provide immediate feedback, reinforcing learning and promoting deeper engagement. This active exploration supports the development of a robust conceptual understanding, enabling learners to visualize the relationships between variables and their outcomes—an insight that is often difficult to achieve through traditional teaching methods. For example, simulations of planetary motion and free-fall experiments allow students to experience the effects of gravity dynamically, fostering a more intuitive and concrete grasp of the concept.

2.4. Misconceptions about Gravity

Research in science education, particularly concerning students' representations, highlights critical insights into scientific learning processes. Learning does not commence from a blank slate: students possess pre-existing conceptions and ways of interpreting scientific phenomena prior to instruction [63]. Consequently, the aim of teaching extends beyond merely imparting new knowledge to actively reshaping learners' prior conceptions. This principle aligns with the constructivist framework, an educational approach derived from the work of Jean Piaget [64], which posits that learning involves the active construction of knowledge.

By incorporating the social dimension of learning, as emphasized by Lev Vygotsky from the 1960s onward [65], a socio-constructivist perspective emerges, underscoring the significance of cooperative and collaborative interactions among learners. Drawing on these two theoretical frameworks—constructivist and socio-constructivist—particular attention has been devoted to distinguishing between the general aspects of the concept of "force" and the specific nature of the "gravitational force". Existing scholarly literature has consistently highlighted students' difficulties in fully understanding the concept of force [66]. When confronted with conceptual questions about gravity, they tend to focus on its causes, effects, and magnitude, rather than on the more abstract and overarching principles that define the idea of force [67].

The misconceptions identified among students include the beliefs that gravitational force acts only on heavy objects, gravity does not influence objects in water, continuous motion requires a continuous force, speed and motion are equivalent, and inertia is the force that maintains an object's motion [68]. In a study that used a stratified sample of 627 ninth-graders from a district in Kerala, researchers found that most students had misunderstandings about 34 different physics concepts, including gravity [69].

A study on assessing students' ability to identify the direction of gravitational force revealed the difficulties learners have in understanding the concept of directionality [70]. Questions in this area explore scenarios such as an object resting on a large body's surface or situations involving multiple objects. The "Gravity as a Force" domain examines students' understanding of the magnitude of gravitational force and how it depends on mass and distance [71, 72]. The "Independence from Other Forces" domain aims to address common misconceptions, such as confusing gravitational force with other forces like Earth's magnetism, rotation, and air pressure [73]. Students also face difficulties when calculating the weight (gravitational force) of an object near the Earth's surface and comparing it to the gravitational force in other contexts. Another misconception is about the existence of a limit for the force of gravity: some students believe that gravitational force ceases at the edge of the atmosphere [74].Consequently, physics concepts are often complex and abstract, leading to widespread student misconceptions and learning difficulties [75].

In the Moroccan educational context, the concept of gravity is introduced for the first time to students in the first year of secondary school (equivalent to 10th grade or "2nde" in the French system), as outlined in the national physics curriculum defined by the Moroccan Ministry of National Education. This introduction occurs during the very first mechanics lesson, titled Universal Gravitation, where students are taught about Newton's law of gravitational force. The concepts and formulas presented in this lesson serve as foundational knowledge for understanding the motion of planets and artificial satellites, which are covered in greater depth in the second year of the baccalaureate.

A study on physics education in Morocco, focusing on the teaching of specific concepts, including Newton's gravitational force, reveals deficiencies in educational quality, with students demonstrating a poor understanding of the concept of gravitation [23]. The persistence of misconceptions, particularly

ISSN: 2576-8484
Vol. 9, No. 9: 48-72, 2025
DOI: 10.55214/2576-8484.v9i9.9769

concerning the concept of gravitational force, is notably strong among Moroccan students, even after formal instruction, indicating a significant resistance to change [76]. Furthermore, many physics teachers do not emphasize the chapter on gravitation, as it is the first topic covered in high school physics. This lack of focus, combined with traditional methods of presenting the concept, highlights the conceptual difficulties and misunderstandings that students often experience [77].

3. Materials and Methods

3.1. Framework

The integration of interactive multimedia resources in teaching the concept of gravity is grounded in the Cognitive Theory of Multimedia Learning [78], developed by Mayer [79]. This theory posits that learning becomes more effective when information is presented in a multimodal format by combining simultaneously text, images, sound, and engaging both the visual and auditory channels of human memory as seen in Figure 1.

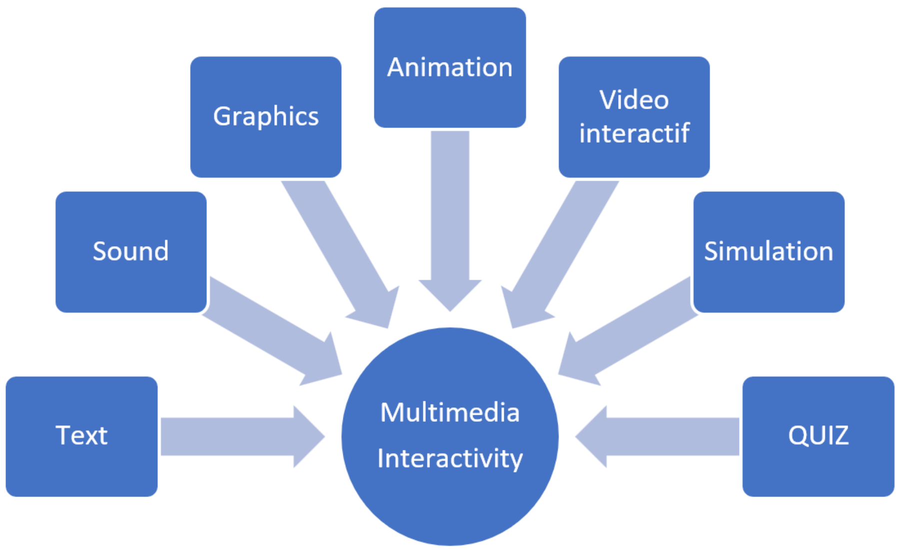

Figure1.
Multimedia interactivity process for interactive learning media environment.

Mayer outlines four fundamental assumptions:

- Dual Channels: Human memory processes information through two distinct channels—visual and auditory.
- Limited Capacity: Each cognitive channel has a limited capacity for processing information at any given time.
- Active Processing: Learning is an active process in which learners construct knowledge by selecting, organizing, and integrating information into their existing mental schemas.

Newly acquired knowledge and skills must be stored in long-term memory in order to be retrieved and applied to new tasks.

From this approach, the use of an IMLE such as animations, interactive videos, simulations, and quizzes in teaching Newton's law of universal gravitation offers several key benefits: It enables students to visualize abstract physical phenomena , such as the mutual attraction between two bodies (gravitational force); It supports cognitive anchoring by synchronizing verbal explanations with visual representations; It enhances student engagement through active interaction with the learning content.

This theoretical framework thus justifies the use of interactive digital resources within the experimental learning sequence, relying on a multimodal approach aligned with Mayer's principles of coherence, redundancy, and contiguity.

3.2. Research Design

This study adopted a quantitative research approach, employing a quasi-experimental design with a non-randomized control group and a pretest-posttest framework. This investigation utilized pre-existing groups to evaluate the effectiveness of an interactive multimedia learning environment on students' conceptual understanding of Newton's law of gravitation.

The sample of this study comprised two groups: an experimental group that engaged with an IMLE during the introductory unit on Newton's Universal Gravitation, and a control group that received traditional instruction without the interactive digital content. As detailed in Table 1, this methodological approach facilitated a systematic comparison of students' conceptual understanding of Newton's gravitational force before and after the intervention, thereby providing empirical evidence for the pedagogical value of the IMLE.

To evaluate prior conceptual knowledge, a pretest using the Newtonian Gravity Concept Inventory (NGCI) was administered to both groups, with particular emphasis on the experimental group. This initial assessment aimed to establish baseline levels of understanding regarding Newtonian gravitation. Following a three-week instructional period incorporating interactive multimedia content, a posttest based on the same NGCI instrument was conducted.

In addition, to assess the impact of the IMLE on students' motivation toward science learning, the Science Motivation Questionnaire II (SMQ II) was administered exclusively as a posttest to the experimental group. This allowed for an evaluation of students' motivational engagement specifically after exposure to the interactive learning environment, focusing on dimensions such as intrinsic motivation, extrinsic motivation, career motivation, self-efficacy, and grade motivation.

Table 1.
Quasi-experimental research design.

Groups	**Pretest**	**Treatment**	**Posttest**
Experimental group	Applied	No treatment	Applied
Control group	Applied	Receiving treatment	Applied

3.3. Participants

A total of 80 first-year high school students from the scientific stream of a public educational institution in Fez, Morocco, participated in the study. The sample included 38 female students and 42 male students, aged between 15 and 16 years. None of the participants had previously taken a specific course on the topic; all were beginning their first physics lesson, titled "The Universal Gravitational Force," drawing on knowledge gained from prior schooling and personal experiences. The first group, designated as the control group (CG), followed traditional instruction and comprised 40 students, including 22 female students and 18 male students. The second group, identified as the experimental group (EG), consisted of 40 students, including 16 female students and 24 male students. The experimental group engaged in the same course within a multimedia room equipped with 20 computers, where two students shared a computer and learned using interactive resources such as simulations, interactive videos, and quizzes. Both groups received instruction on the concept of gravity over three sessions.

Participants were assigned to two groups of comparable size and homogeneity, as detailed in Table 2, without randomization. The study was conducted in a natural educational context, minimizing disruption to students' learning and enhancing the real-world applicability of the findings. To ensure the validity of comparisons, all respondents were selected from the same school and shared the same academic level and background knowledge in science.

Table 2.
Frequency distribution of gender.

Gender	Groups		Total	Percentage (%)
	CG	EG		
Male students	18	24	42	52.5
Female students	22	16	38	47.5

This study was approved by the ethics committee, comprising the Regional Directorate of Education of Fez and the Parents' Association of the involved institution, in accordance with the ethical regulations in force in Morocco. All participants provided informed consent prior to their inclusion in the study.

3.4. Data Collection Instruments

For assessing student learning and the effects of instructional interventions, the Newtonian Gravity Concept Inventory (NGCI), developed and validated by Kathryn Williamson and Shannon Willoughby, was selected to assess undergraduate students' conceptual understanding of gravity. This instrument examines students' comprehension across a range of contexts—including on and around Earth, throughout the solar system, and in hypothetical scenarios—with the aim of identifying common conceptual difficulties about gravity [80]. The NGCI consists of 26 multiple-choice questions that probe students' understanding of gravity in four conceptual domains: gravity as a force, directionality, independence from other forces, and behavior at certain thresholds.

The test was given to both groups; each one of these groups took the test twice, as a pretest and as a posttest. The internal consistency of the instrument was assessed using Cronbach's alpha statistic. The value obtained for the full set of 26 items was 0.72, aligning with the values reported in previous studies [74, 81]. According to Taber's research, α values between 0.7 and 0.8 are regarded as acceptable, satisfactory, and sufficient by various scholars [82]. This finding reaffirms the established reliability in the test and demonstrates its applicability to the study.

To assess students' motivation, a validated tool, the Science Motivation Questionnaire (SMQ II), consisting of 25 items, was used to measure five sub-dimensions of motivation to learn science in an IMLE: intrinsic motivation, extrinsic motivation, the relevance of science learning in relation to personal goals, self-efficacy, and grade motivation [83]. The SMQ II questionnaire was translated into French and adapted to the context of our study while retaining the phrasing of the original questionnaire and maintaining the same factors identified in the initial study.

Data collection was conducted using a five-point Likert scale ranging from 1 ("Strongly Disagree") to 5 ("Strongly Agree"). To ensure the accuracy of the translation, a back-translation was performed by a bilingual French-speaking expert. Finally, the items were presented in random order to minimize any potential bias related to the sequence of items. The internal consistency of the items in the SMQ II motivation questionnaire was assessed using Cronbach's alpha coefficient as detailed in Table 3.

Table 3.
Reliability analysis of SMQ II sub-dimensions.

No.	Dimension motivation	Number of items	Cronbach Alpha
1	Intrinsic Motivation	5	0.817
2	Extrinsic Motivation	5	0.829
3	Career Motivation	5	0.841
4	Self-efficacy	5	0.923
5	Grade Motivation	5	0.898

These values indicated a high level of internal reliability for the instrument used to measure motivational variables associated with the integration of an Interactive Multimedia Learning Environment (IMLE) into the teaching and learning process. A Cronbach's Alpha coefficient above 0.7 for each sub-dimension reflected satisfactory internal consistency, suggesting that the items in the instrument measured the same underlying motivational construct reliably.

3.5. Research Materials

Gravity represents an invisible phenomenon that often remains difficult to conceptualize mentally for students. In this context, this study aims to address the challenges encountered by learners in understanding Newtonian gravity. The objective is to propose an innovative pedagogical approach designed to enhance students' conceptual understanding of this abstract concept in physics.

To meet this educational challenge, we used iSpring Suite 11 software, an e-learning development tool, to design and structure an IMLE in the form of a web-based application. This application is accessible online as well as offline via a local network in a multimedia room equipped with 20 computers to teach Newton's law of gravitational force, as illustrated in Figure 2.

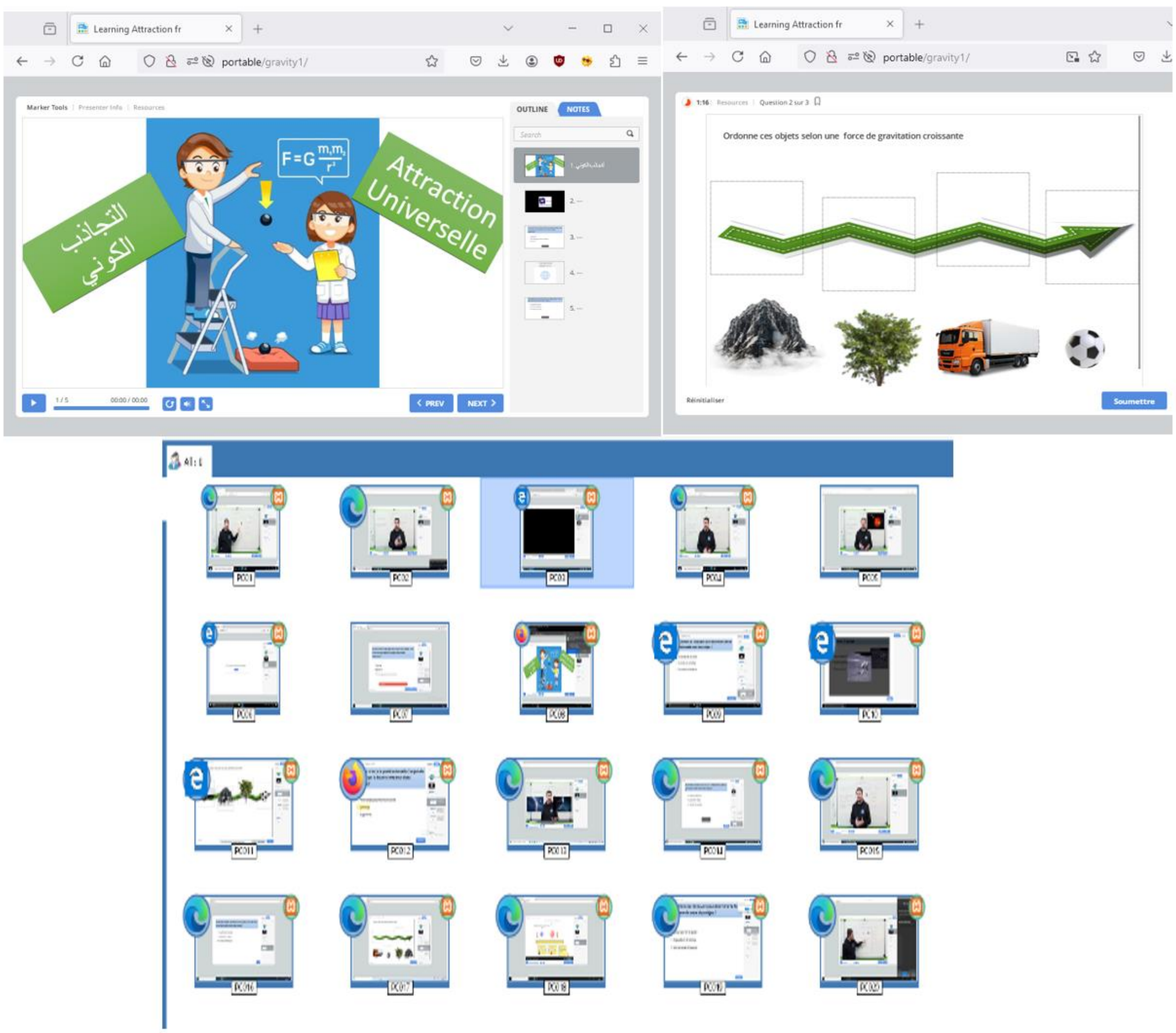

Figure 2.
A screenshot showcasing courses integrated with an IMLE.

The application integrates various interactive elements intended to promote cognitive engagement and facilitate knowledge acquisition:

- Interactive video capsules provide immediate feedback to students on their comprehension.

ISSN: 2576-8484
Vol. 9, No. 9: 48-72, 2025
DOI: 10.55214/2576-8484.v9i9.9769

- Guided scenarios encourage students to formulate hypotheses while exploring dynamic animations illustrating universal attraction between celestial bodies.
- Through integrated PhET simulations, students can test and validate their hypotheses by manipulating variables such as mass, distance, and force. This enables them to observe the direct effects of these parameters on gravitational attraction, analyze results, and draw informed conclusions. This interactive and progressive process plays a crucial role in building a deep and lasting understanding of the concept of gravity.

Interactive exercises and summative assessments offered at the end of each session allow for evaluating the knowledge acquired by learners and adjusting, if necessary, their learning pathways, as shown in Figure 3.

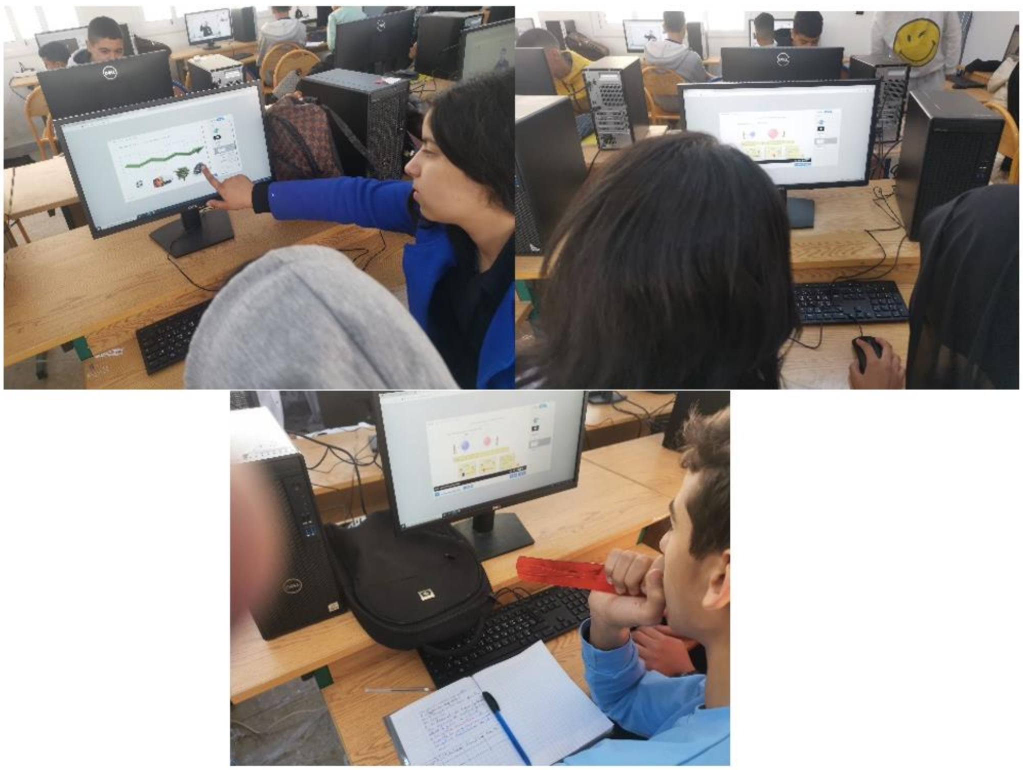

Figure 3.
Feedback from questions assesses conceptual knowledge.

The digital resources integrated into this IMLE are aligned with the official Moroccan physics curriculum. They were originally developed by the Ministry of National Education and made available via the TelmidTICE.ma platform during the COVID-19 pandemic, as part of continuous remote learning initiatives. Their integration into the IMLE aims to enrich the learning experience by combining validated educational content with innovative interactive modalities.

In our context, the pedagogical validity of the web application integrating the IMLE content was rigorously evaluated by a panel of five experts:

- One instructional designer validated the design of the learning scenarios, ensuring alignment between learning objectives, activities, and assessments. He also verified the structure, ergonomics, accessibility, interactivity, and overall learning logic of the platform.
- One developer reviewed the technical usability and accessibility of the interface, ensuring a smooth and intuitive experience for users.

ISSN: 2576-8484
Vol. 9, No. 9: 48-72, 2025
DOI: 10.55214/2576-8484.v9i9.9769

- A group of three teachers, each with over 14 years of experience in teaching physics, assessed 10 items related to the quality of the platform's interactive content. To measure the level of agreement among evaluators, the method of inter-rater reliability using Holsti [84] was applied.

The result showed a percent agreement of R=80%, indicating a good level of consistency among expert judgments. This broadly validates the web application in terms of its structure, content, and educational relevance within the learning process.

Finally, a usability test was conducted prior to the start of the intervention with the experimental group, in order to evaluate the application's accessibility and user-friendliness from both the students' and the teacher's perspectives.

3.6. Research Procedure

The first phase of the intervention consisted of assessing students' prior knowledge through a pretest. The Newtonian Gravity Concept Inventory (NGCI) was administered to both groups to establish a baseline for comparing their levels of conceptual understanding of Newtonian gravitation before the intervention. The experimental group received instruction that integrated an IMLE, delivered in a multimedia lab under the supervision of the physics teacher. The same teacher also provided traditional instruction on the same content to the control group in a conventional classroom without the use of interactive resources. Students did not encounter technical difficulties, as they were already familiar with computer use due to the inclusion of "Computer Science" as a subject starting from middle school in Morocco. They worked in pairs, one pair per computer. The teacher provided a printed guide explaining how to navigate the digital environment and outlined the pedagogical objectives of the session.

The intervention was structured around a four-phase learning cycle, grounded in constructivist and experiential learning approaches, according to Kolb [85] and Kolb [86]. The structured steps of the instructional sequence are:

3.6.1. Concrete Experience: Phase of Practice and Action

Students are exposed to real-world problem situations related to gravitation. Short videos and simulations are used to activate prior knowledge and stimulate inquiry. An interactive video illustrating gravitational phenomena—such as falling objects and orbital motion around the Moon—is viewed to contextualize the learning experience.

3.6.2. Reflective Observation: Phase of Reflection

In this phase, students critically examine their experiences and reflected on the situations they encounter. A guided brainstorming session explores gravitational effects, accompanied by embedded true/false quizzes within the interactive videos aimed at identifying and correcting common misconceptions about gravity. The integration of the PhET Gravity Force Lab simulation allows students to confront pre-existing misconceptions interactively, thereby reinforcing conceptual understanding. As a central component of experiential learning, this stage promotes a deeper analysis of prior knowledge and skills, facilitates critical transformation, and supports the development of new conceptual frameworks.

3.6.3. Abstract Conceptualization: Phase of Thinking

This phase involves the construction of mathematical and conceptual understanding of Newton's universal law of gravitation. Students draw conclusions from hypotheses, general concepts, and theoretical principles developed during the earlier stages. They aim to generalize their observations and integrate them into a broader conceptual framework. Through guided interactive videos and simulations, particularly the PhET Gravity Force Lab activity, students explored how gravitational force varies with mass and distance. These activities allow them to manipulate variables, observe effects, and relate these phenomena to underlying physical laws. In addition, solving numerical problems in pairs strengthens this theoretical understanding by encouraging practical application of the studied concepts.

3.6.3. Active Experimentation: Phase of Transfer and Demonstration

During this phase, students are encouraged to apply gravitational concepts in contextualized scenarios. They complete summative assessment tasks, including multiple-choice questions and reflective prompts. Learners synthesize their acquired knowledge and mobilize it in new contexts through peer discussions, which enhance their scientific communication skills and active learning experiences.

This process not only represents a new concrete experience but also marks the beginning of a new learning cycle, consistent with Kolb [85] model of experiential learning.

At the end of the three-week instructional period using an IMLE, a posttest was administered using the same NGCI instrument. This step aimed to assess whether students' conceptual understanding had improved and whether they were now capable of reasoning scientifically when confronted with gravity-related problem situations.

Finally, the motivation questionnaire (SMQ-II) was administered at the conclusion of the final session. This tool assessed the level of motivation in the experimental group following the IMLE-based intervention.

3.7. Data Analysis

The data collected in this study were analyzed using the statistical software SPSS 24.0. An independent samples t-test was employed to compare students' mean scores on the Newtonian Gravity Concept Inventory (NGCI), a conceptual performance test, between two distinct groups, in order to determine whether the observed difference was statistically significant. Inferential statistics were used to test the formulated hypotheses. The null hypothesis was rejected when the statistical significance (p-value) of the test was below the critical threshold set at 0.05, and accepted otherwise.

The Shapiro–Wilk test was conducted to assess the normality of the data distribution, followed by Levene's test to evaluate the homogeneity of variances. The independent samples t-test was used during the pretest phase to verify the initial comparability between the experimental and control groups, and again during the posttest to compare the average scores of the two groups after the intervention. A paired samples t-test was applied to assess the performance changes in the experimental group before and after learning within the IMLE.

To examine the potential influence of gender on students' conceptual understanding of Newton's law of universal gravitation within the IMLE, an Analysis of Covariance (ANCOVA) was conducted. The NGCI posttest score served as the dependent variable, while gender (male vs. female) was treated as the independent variable. This statistical method allowed for a more precise estimation of the effect of gender by adjusting the post-intervention scores based on initial performance levels.

Prior to conducting the ANCOVA, the main assumptions—normality, homogeneity of variances, and homogeneity of regression slopes—were carefully verified and found to be satisfied. Finally, a Pearson correlation analysis was performed to explore the relationships between the different sub-dimensions of students' science motivation and their conceptual understanding of physics, measured by their posttest scores on the NGCI.

4. Results

To address our first research question regarding the effect of IMLE on students' improvements in conceptual understanding, a statistical analysis was conducted after verifying the prerequisite conditions, including data normality and homogeneity of variances between the groups. The pretest and posttest scores refer to the students' performance on the Newtonian Gravity Concept Inventory (NGCI), which was used as the instrument to assess the conceptual understanding of Newton's law of gravitation. The Shapiro–Wilk test statistic for the normality of the pretest scores was $p=0.078$ for the experimental group and $p=0.091$ for the control group. The p-values for the pretest scores of both the experimental and control groups exceeded the significance level (α=0.05), indicating that the pretest data for both groups were normally distributed. Regarding the posttest scores, the Shapiro–Wilk test yielded a p-value of 0.115 for the experimental group and 0.590 for the control group. These p-values were also greater than the significance level (α=0.05), indicating that the posttest data for both the experimental and control groups were normally distributed.

After conducting the normality test, a homogeneity of variance test was performed to assess the uniformity of the data. Levene's test for homogeneity was employed for this purpose, as shown in Table 4. Levene's test for equality of variances on the pretest scores yielded F=2.158, p=0.146. Since the p-value (0.146) was greater than the significance threshold of 0.05, we did not reject the null hypothesis, indicating that the variances between the two groups were equal. Similarly, for the posttest, Levene's test resulted in F=0.129, p=0.721. As the p-value (0.721) also exceeded 0.05, the assumption of equal variances was considered valid, and the analysis proceeded under the assumption of equal variances.

4.1. Independent T-Test Calculation

After confirming the normal distribution of the data and the homogeneity of variances between the two groups, an independent samples t-test was conducted to compare the means of the two groups on the pretest, as shown in Table 4, to assess whether the control and experimental groups were initially equivalent.

Table 4.
Independent samples t-test comparing NGCI achievement scores.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Pretest	Equal variances assumed	2.158	0.146	-4.249	78	0.000	-1.775	0.417	-2.606	-0.943
	Equal variances not assumed			-4.249	70.523	0.000	-1.775	0.417	-2.607	-0.942
Posttest	Equal variances assumed	0.129	0.721	-14.079	78	0.000	-7.925	0.562	-9.045	-6.804
	Equal variances not assumed			-14.079	77.037	0.000	-7.925	0.562	-9.045	-6.804

The results revealed a statistically significant difference in pretest means between the experimental and control groups, t (78) = -4.249, p < 0.001. This initial discrepancy suggests that the groups were not equivalent before the intervention, which could potentially influence the interpretation of posttest results. To account for this initial disparity, an Analysis of Covariance (ANCOVA) was performed after verifying the assumption of homogeneity of regression slopes in the Group × Pretest interaction test. This analysis examined the effect of the instructional method (experimental group vs. control group) on posttest scores from the Newtonian Gravity Concept Inventory (NGCI), while controlling for pre-existing differences measured at pretest. The results are presented in Table 5.

Table 5.
ANCOVA: Tests of between-subjects effects with posttest as the dependent variable.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1282.387a	3	427.462	69.417	0
Intercept	1204.087	1	1204.087	195.536	0
Group	191.63	1	191.63	31.119	0
Pretest	13.279	1	13.279	2.156	0.146
Group * Pretest	21.115	1	21.115	3.429	0.068
Error	468	76	6.158		
Total	20447	80			
Corrected Total	1750.387	79			

Note: a. R Squared = .733 (Adjusted R Squared = .722).

The results revealed a statistically significant main effect of group, $F(1,76)=31.119$, $p<0.001$, indicating that students who received instruction through the IMLE (Interactive Multimedia Learning Environment) achieved significantly higher posttest scores than those who were taught using traditional methods, even after controlling for pretest performance. Additionally, the pretest included in the model as a covariate, did not have a statistically significant effect on posttest scores, $F(1,76) = 2.156$, $p=0.146$. This suggests that initial variance in pretest scores alone does not account for the differences observed in post-intervention outcomes.

Furthermore, the interaction between group and pretest (Group × Pretest) was marginally significant, $F(1,76)=3.429$, $p=.068$, indicating a potential slight variation in the intervention's effect depending on students' initial levels. However, since this interaction remained above the conventional significance threshold ($p > 0.05$), the assumption of homogeneity of regression slopes is considered acceptable.

Finally, the overall model was statistically significant, $F(3,76)=69.417$, $p<0.001$, with a coefficient of determination (R^2) of 0.733, indicating that the model explains 73.3% of the total variance in posttest scores.

4.2. Paired-Sample T-Test

To address our research question: "Does the use of interactive media in teaching significantly improve learners' performance in understanding Newtonian gravity?", a paired-sample t-test was conducted to check whether there was a significant difference between the means of pretest and posttest for the EG in conceptual gravity. The results of the paired t-test, conducted to assess changes within each group from pretest to posttest, are presented in Table 6.

Table 6.
Paired-sample T-test analysis result.

		Paired Differences					t	df	Sig. (2-tailed)
		Men	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
CG	Posttest - Pretest	5.900	2.629	0.415	5.059	6.740	14.192	39	0.000
EG	Posttest - Pretest	12.050	3.289	0.520	10.998	13.101	23.171	39	0.000

For the Control Group (CG): The mean difference between the posttest and pretest scores is 5.900, with a standard deviation of 2.629 and a standard error of 0.415. The 95% confidence interval for this difference is [5.059, 6.740]. The t-statistic is 14.192 (df=39, $p=0.000$). With a p-value below 0.05, the results demonstrate a statistically significant improvement from pretest to posttest for the control group, this outcome is anticipated, as the pretest was conducted prior to the initiation of the course on Newton's gravitational force. The control group's scores increased significantly due to a learning effect.

For the Experimental Group (EG): The mean difference between the posttest and pretest scores is 12.050, with a standard deviation of 3.289 and a standard error of 0.520. The 95% confidence interval is [10.998, 13.101]. The t-statistic is 23.171 (df=39, p=0.000). The p-value, also below 0.05, indicates a significant increase in scores for the group that engaged in learning using an IMLE. The increase is more pronounced in this group, which can be attributed to the potential of an interactive multimedia learning environment to boost learner engagement and foster a deeper understanding of the concepts taught (Newton's gravitational force).

In conclusion, the integration of an IMLE in the teaching of Newtonian gravitation had a significant positive effect on the performance of the experimental group, significantly greater than that observed in the control group receiving traditional instruction.

4.3. Gender Effect

To address our research question, "Is there a difference in the understanding of Newtonian gravity between male and female students, and how does the interaction between gender and the Interactive Multimedia Learning Environment (IMLE) influence the conceptual comprehension of Newton's law of gravity among Moroccan high school students?", a one-way ANCOVA was employed.

This method compared the group that used an IMLE with the group that followed traditional instruction on Newton's law of gravitation. The use of a one-way ANCOVA relies on four key assumptions:

4.3.1. Normality of the Data

The normality assumption of the residuals was assessed through the Shapiro-Wilk test during the independent t-test analysis. The results indicated a normal distribution ($p > 0.05$), thereby confirming the validity of this assumption. Consequently, the model was deemed to meet the requirements for conducting ANCOVA.

4.3.2. Homogeneity of Variances

A one-way ANCOVA assumes homogeneity of variances across groups. The non-significant results of Levene's test, as shown in Table 7 ($F(1,78)=0.008$, $p=0.931 > 0.05$), indicate that the assumption of homogeneity of variances was met for the cognitive reserve posttest after controlling for the pretest effect.

Table 7.
Levene's test of equality of error variances.

Dependent Variable: Posttest			
Levene Statistic	**df1**	**df2**	**Sig.**
0.008	1	78	0.931

4.3.3. Linearity Between the Covariate and the Dependent Variable

The assumption of linearity between the covariate (pretest) and the dependent variable (posttest) was examined using a scatterplot accompanied by the regression line, as shown in Figure 4.

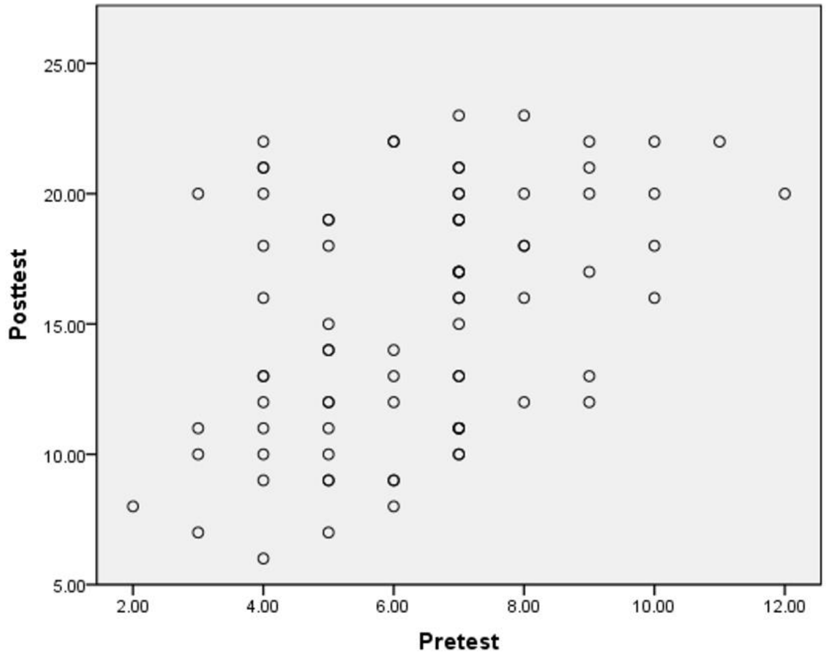

Figure 4.
Scatterplot showing the linear relationship between pretest and posttest scores.

The distribution of points indicates an overall linear relationship, with no marked curvilinear trend. The regression line follows the central tendency of the data, and no systematic deviations were detected. Therefore, the assumption of linearity is considered satisfied, supporting the use of the pretest as a covariate in the Analysis of Covariance (ANCOVA). This validates the appropriateness of employing ANCOVA to test the effect of gender.

4.3.4. Homogeneity of Regression Slopes

As shown in table 8, the assumption of homogeneity of regression slopes was tested by including an interaction term between pretest scores and gender in the ANCOVA model. Since this interaction effect was non-significant ($F(1, 76) = 0.000$, $p=0.983>0.05$), the assumption was considered satisfied, confirming that the relationship between the pretest scores (covariate) and the posttest scores was linear. In simpler terms, the relationship between the pretest and posttest scores is consistent across both groups, which is a key condition for the validity of the ANCOVA.

ANCOVA was conducted to examine the effect of gender on posttest scores of the Newtonian Gravity Concept Inventory while controlling for pretest scores, as shown in Table 8.

Table 8.
ANCOVA analysis of effect of gender scores on the NGCI test.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	330.378[a]	3	110.126	5.894	0.001
Intercept	663.262	1	663.262	35.498	0.000
Pre	293.687	1	293.687	15.718	0.000
Genre	2.321	1	2.321	0.124	0.725
Genre * Pre	0.008	1	0.008	0.000	0.983
Error	1420.010	76	18.684		
Total	20447.000	80			
Corrected Total	1750.388	79			

Note: a. R Squared = .189 (Adjusted R Squared = .157)
a. R Squared = .724 (Adjusted R Squared = .709).

The results reveal a non-significant main effect of gender, $F(1, 76) = 0.124$, *p* = .725, suggesting no performance differences between girls and boys, even after controlling for pretest scores. The overall model was significant, $F(3, 76) = 5.89$, *p* = .001, with a coefficient of determination ($R^2 = 0.189$), indicating that 18.9% of the variance in posttest scores was explained by the model.

These findings indicate that the improvement in students' performance on the Newtonian Gravity Concept Inventory (NGCI) was not influenced by the learners' gender, with male and female students showing similar results in their conceptual understanding of Newton's gravity. This outcome aligns with other studies [87] which suggest that gender does not impact student engagement in physics learning. Learning in an environment using interactive digital media does not require tailoring specific methods for male and female students.

4.3.5. Correlation Between NGCI Performance and Learning Motivation in an Interactive Multimedia Learning Environment

To investigate the effects of Interactive Multimedia Learning Environments (IMLE) on students' motivation at different stages of the learning process, and to determine whether a significant linear relationship exists between students' motivation and their conceptual performance on the NGCI achievement test, a correlation analysis was conducted. This analysis aimed to examine the extent to which students' motivation—measured across five sub-dimensions: intrinsic motivation, extrinsic motivation, self-efficacy, career motivation, and grade motivation—influences their understanding of the concept of gravity in physics within an IMLE. Motivation scores obtained through the adapted Motivated Strategies for Learning Questionnaire (MSQ-II) were correlated with posttest performance on the NGCI. The normality of the NGCI and MSQ-II posttest score distributions was assessed using the Shapiro-Wilk test, as shown in Table 9. No significant deviation from normality was detected ($p > 0.05$) for any of the variables, allowing the use of the parametric Pearson correlation test.

Table 9.
Normality test of student learning motivation in the experimental group.

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Intrinsic motivation	0.156	40	0.016	0.917	40	0.006
Extrinsic motivation	0.143	40	0.039	0.953	40	0.093
Career motivation	0.106	40	.200*	0.974	40	0.488
Grade Motivation	0.180	40	0.002	0.956	40	0.124
Sel-Efficacity	0.091	40	.200*	0.969	40	0.328

Note: *. This is a lower bound of the true significance.
a. Lilliefors Significance Correction.

After confirming data normality, we calculated the Pearson correlation between students' performance on the NGCI conceptual gravity test and their motivation as detailed in Table 10.

Table 10.
Pearson correlation between motivation and results of the students' NGCI posttest scores.

		N	NGCI test score	Intrinsic motivation	Extrinsic motivation	Career motivation	Grade Motivation	Sel-Efficacity
NGCI Posttest Score	Pearson Correlation	40	1	0.629**	0.679**	0.476**	0.886**	0.857**
	Sig. (2-tailed)			0.000	0.000	0.002	0.000	0.000
Intrinsic motivation	Pearson Correlation	40	0.629**	1	0.305	0.233	0.461**	0.529**
	Sig. (2-tailed)		0.000		0.055	0.147	0.003	0.000
Extrinsic motivation	Pearson Correlation	40	0.679**	0.305	1	0.439**	0.669**	0.647**
	Sig. (2-tailed)		0.000	0.055		0.005	0.000	0.000
Career motivation	Pearson Correlation	40	0.476**	0.233	0.439**	1	0.596**	0.516**
	Sig. (2-tailed)		0.002	0.147	0.005		0.000	0.001
Grade Motivation	Pearson Correlation	40	0.886**	0.461**	0.669**	0.596**	1	0.831**
	Sig. (2-tailed)		0.000	0.003	0.000	0.000		0.000
Sel-Efficacity	Pearson Correlation	40	0.857**	0.529**	0.647**	0.516**	0.831**	1
	Sig. (2-tailed)		0.000	0.000	0.000	0.001	0.000	

Note: **. Correlation is significant at the 0.01 level (2-tailed).

The findings highlight a significant connection between students' motivation and their conceptual understanding of Newton's gravitational force in the group that used an IMLE. Strong correlations were observed between the NGCI conceptual test scores and both grade motivation ($r = 0.886$, $p = 0.000$) and self-efficacy ($r = 0.857$, $p = 0.000$). These high correlation coefficients suggest that students who performed best in understanding the concept of Newtonian gravity were generally those who placed a high value on academic achievement and possessed strong confidence in their learning abilities. A moderate to strong correlation was also found with extrinsic motivation ($r = 0.679$, $p = 0.000$) and intrinsic motivation ($r=0.629$, $p=0.000$), indicating that students motivated by external rewards such as grades also performed well, and that personal interest in science plays an important role in the conceptual understanding of gravitational concepts.

Finally, career motivation showed a positive but weaker correlation ($r = 0.476$, $p = 0.002$), suggesting that while it has a positive influence on performance, its impact is less pronounced compared to the other motivational dimensions.

5. Discussion

The study examined the importance of integrating interactive content, such as interactive videos, simulations, and quizzes, within a single interactive multimedia learning environment for the assimilation of abstract physics concepts. To assess the effectiveness of learning within the IMLE, students' performances were measured before and after the intervention using the Newtonian Gravity Conceptual Inventory (NGCI) test. The results revealed that students in the experimental group, who used the IMLE as part of their learning process, achieved an average improvement of 12.050 points. In contrast, the control group demonstrated a more modest gain of 5.900 points, resulting in a difference of 6.150 points in favor of the experimental group.

The variability in individual improvements was greater in the experimental group (standard deviation = 3.289) compared to the control group (standard deviation = 2.629), which may indicate a more diverse range of responses to the intervention among students in the experimental group. This finding is supported by previous research indicating that teaching physics through an interactive multimedia learning environment motivates students and enhances their conceptual understanding of complex physics topics [88]. Students' grasp of fundamental physics concepts is most effectively reinforced through active engagement in interactive learning activities. Therefore, it is essential for physics educators to adopt instructional strategies that incorporate exploration, discovery, demonstration, simulations, practical exercises, laboratory-based experiences, and other forms of hands-on learning [50].

Consistent with earlier studies Mrani, et al. [89] the IMLE plays a key role in determining the effectiveness of computer simulations in student learning. Our findings similarly show that participation in IMLE-based learning activities improves several important outcomes: students' interest in physics, their aspirations toward technology, and their confidence in solving physics and science-related problems.

However, the significant difference observed between the two groups at pretest constitutes an important methodological limitation, as it indicates an initial inequality among participants. The use of ANCOVA allowed for a statistical correction of this difference, revealing that the use of IMLE had a significant and positive effect on students' conceptual understanding of Newtonian gravity in the experimental group compared to those who received traditional instruction, even after controlling for initial differences in pretest performance. Nevertheless, stricter randomization or prior matching of groups could enhance internal validity in future studies.

The analysis of gender effects on conceptual understanding of Newtonian gravity, conducted using ANCOVA, revealed no significant differences between girls and boys on the posttest once pretest scores were controlled. The absence of a significant gender effect ($F(1, 76) = 0.124$, $p = 0.725$) suggests that, within the context of this study, students' gender did not influence their final conceptual performance after adjusting for initial ability levels. These findings align with previous research asserting that gender does not have a significant impact on such outcomes [87]. Furthermore, these results are consistent with recent studies in science education, which show that gender differences in conceptual performance tend to diminish when pedagogical contexts are equitable and interactive [90, 91]. It is possible that the characteristics of the interactive multimedia learning environment facilitated equal access to conceptual resources, thereby reducing the gender-related disparities traditionally observed in science instruction.

The final objective of this study was to examine how the Interactive Multimedia Learning Environment (IMLE) influences students' motivation to actively participate in the teaching-learning process. To assess the impact of IMLE on motivational factors, data were collected using the SMQ II questionnaire, focusing on students' level of engagement, self-efficacy, and involvement throughout the learning experience, and their academic trajectory. Pearson correlation analyses revealed a positive and statistically significant relationship between the NGCI conceptual test scores and all dimensions of motivation among students who learned through an Interactive Multimedia Learning Environment (IMLE). Specifically, a strong correlation was observed between grade-related motivation ($r = 0.886$, $p < 0.001$) and perceived personal effectiveness ($r = 0.857$, $p < 0.001$) with performance in Newtonian gravity concepts. This highlights the importance of motivation in science learning, as it directly affects students' engagement and academic performance. Moreover, the strongest associations were found with dimensions related to self-esteem and academic goals, suggesting that enhancing self-confidence and reinforcing academic objectives could significantly improve students' performance in physical sciences. These findings align with those of other studies demonstrating that the use of technology in the learning process enhances both motivation and academic achievement.

In this study, students who used IMLE expressed greater interest in pursuing a career in the scientific field, which was correlated with their performance on the conceptual test. It has been shown that IMLE increases student motivation through interactive and entertaining elements, making learning more engaging. Furthermore, students indicated that IMLE helped them better understand complex concepts and encouraged more active learning. This effect is consistent with the theory of

digital resource-based learning, which posits that learning becomes more effective and enjoyable when it occurs within an engaging and interactive environment [88].
Additionally, our results broadly validated the hypotheses presented in this study.

6. Conclusion

This study examined how interactive digital resources, integrated into a web-based learning environment, influence students' conceptual understanding of gravity. This interactive environment aimed to foster autonomy, engagement, and deeper comprehension of the abstract concept of gravity through an innovative approach combining interactive videos, simulations, and self-assessment quizzes, while supporting cognitive development and motivation throughout the learning process.

The results reveal that while an IMLE can support the conceptual development of Newtonian gravity, its effectiveness lies in its capacity to promote meaningful student engagement by enhancing conceptual understanding through the integration of interactive resources. Students in the experimental group demonstrated significantly greater improvements in their understanding of gravity, measured using the Newtonian Gravity Concept Inventory than those in the control group. Moreover, no significant differences were found based on gender, indicating that the learning environment was equally effective for both male and female students.

Statistical analysis using Pearson correlation confirmed that motivation plays a crucial role in the effect of IMLE on students' conceptual performance on the NGCI posttest, highlighting its central importance in the effective acquisition of abstract concepts supported by interactive resources. Indeed, students who were more motivated by academic achievement and those with higher levels of self-efficacy achieved better results. These findings underscore the key role of motivation as a pedagogical lever in the integration of educational technologies.

From a theoretical perspective, this study enriches our understanding of immersive learning environments by reframing conceptual development and motivation not merely as technological byproducts, but as fundamental mechanisms enabling the emergence of complex competencies, such as mastery of physics concepts. At the practical level, these findings inform teaching practices by proposing strategies for integrating an IMLE into science instruction, particularly for concepts that pose major didactic challenges. They emphasize that the effectiveness of such tools lies not only in their novelty but in carefully designed pedagogical engineering that fosters sustained cognitive engagement and active knowledge construction.

Future research should expand its scope along three main axes: including more diverse learner populations, systematically exploring complementary educational technologies (e.g., virtual labs, serious games) alongside an IMLE, and investigating additional abstract physics concepts to better support teachers in classroom practice and researchers in designing experimental frameworks.

7. Limitations of the Study

The study had several limitations that may have impacted the generalizability of its findings. One key limitation was that the research focused exclusively on a single grade level within secondary school. To determine whether similar outcomes can be observed across different academic levels, further research is necessary. Additionally, the sample size of the study was limited, affecting the generalizability of the results. The variability observed between the two participating classes represents a methodological limitation that restricts the generalizability of the findings, thereby warranting a cautious interpretation of the study's results. Another limitation of this study was the lack of exploration into the platform's more advanced multimedia components, such as virtual reality scenarios and gamified elements. Future research should consider integrating these features to better understand their potential impact on student engagement and knowledge retention.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Copyright:

References

[1] R. C. Rodrigues and P. M. C. Dias, "The laws of planetary motion (A Teaching Method Inspired by the History of Physics)," *Physics Teacher*, vol. 60, no. 8, pp. 684-685, 2022. https://doi.org/10.1119/5.0058067

[2] D. S. Wahab *et al.*, "Experimental study of gravity measurement with a video-based laboratory pendulum with tracker software: Comparison of weighted and unweighted tests," *Journal of Novel Engineering Science and Technology*, vol. 4, no. 01, pp. 1-11, 2025.

[3] W. Qian, "The essence of gravity is the expansion tendency of the universe after the Big Bang," *Journal of Modern Physics*, vol. 15, no. 6, pp. 804-849, 2024.

[4] M. Slavov, "Newton's law of universal gravitation and Hume's conception of causality," *Philosophia Naturalis*, vol. 50, no. 2, pp. 277-305, 2013.

[5] S. Frappart and V. Frède, "Conceptual change about outer space: How does informal training combined with formal teaching affect seventh graders' understanding of gravitation?," *European Journal of Psychology of Education*, vol. 31, no. 4, pp. 515-535, 2016. https://doi.org/10.1007/s10212-015-0275-4

[6] G. Tura, "Is an apple act gravitational force on earth? Constructivist approach to understanding gravity and universal law of gravitation," *Energy Education Science and Technology Part B: Social and Educational Studies*, vol. 4, no. 2, pp. 773-784, 2012.

[7] J. Ablanque, F. Revuelta, J. C. Losada, and R. M. Benito, "Persistence of conceptual errors in first-year university physics course and its possible relationship with learning styles," *Education Sciences*, vol. 14, no. 4, p. 401, 2024. https://doi.org/10.3390/educsci14040401

[8] M. Ohnesorge, "The problem of the earth's figure: Measurement, theory, and evidence in physical geodesy," Doctoral Dissertation, 2024.

[9] C. M. Wheatley, "An exploration of misconceptions in introductory physics," Doctoral Dissertation, West Virginia University, 2024.

[10] C. I. Sneider and M. M. Ohadi, "Unraveling students' misconceptions about the earth's shape and gravity," *Science Education*, vol. 82, no. 2, pp. 265-284, 1998.

[11] E. Pardiyanto and W. Winarti, "Generative learning strategy assisted by flash animation to remediate students' misconceptions on Newton's law of gravity," *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, vol. 9, no. 2, pp. 201-216, 2021.

[12] J. A. Jelinek, "Concept of the Earth's shape in 10–15 years old students," *Review of Science, Mathematics and ICT Education*, vol. 18, no. 1, pp. 53-75, 2024.

[13] K. Kotsis, "Common misconceptions regarding physics concepts in the fairy tales written by the Grimm Brothers," *EIKI Journal of Effective Teaching Methods*, vol. 2, no. 1, 2024. https://doi.org/10.59652/jetm.v2i1.89

[14] N. Shofiyah, N. Suprapto, B. K. Prahani, B. Jatmiko, D. M. Anggraeni, and K. Nisa', "Exploring undergraduate students' scientific reasoning in the force and motion concept," *Cogent Education*, vol. 11, no. 1, p. 2365579, 2024. https://doi.org/10.1080/2331186X.2024.2365579

[15] D. Panagou, C. Kostara, G. Stylos, and K. T. Kotsis, "Unraveling force and weight misconceptions: A study among medicine enrolled honors high school graduates," *European Journal of Physics Education*, vol. 15, no. 1, pp. 25-46, 2024.

[16] C. Huang, "Changing learning with new interactive and media-rich instruction environments: Virtual labs case study report," *Computerized Medical Imaging and Graphics*, vol. 27, no. 2-3, pp. 157-164, 2003. https://doi.org/10.1016/S0895-6111(02)00089-7

[17] S. Schweder and D. Raufelder, "Does changing learning environments affect student motivation?," *Learning and Instruction*, vol. 89, p. 101829, 2024.

[18] L. David and N. Weinstein, "Using technology to make learning fun: Technology use is best made fun and challenging to optimize intrinsic motivation and engagement," *European Journal of Psychology of Education*, vol. 39, no. 2, pp. 1441-1463, 2024. https://doi.org/10.1007/s10212-023-00734-0

[19] A. Métioui and L. Trudel, "Children and preservice teachers' misconceptions and scientifically acceptable conceptions about movement, force, and gravity," *Modern Perspectives in Language, Literature and Education*, vol. 5, pp. 26-42, 2021.

[20] I. Galili, V. Bar, and Y. Brosh, "Teaching weight-gravity and gravitation in middle school: Testing a new instructional approach," *Science and Education*, Article vol. 25, no. 9-10, pp. 977-1010, 2016. https://doi.org/10.1007/s11191-016-9865-z
[21] O. Dardary, Z. Azar, M. Tridane, and S. Belaaouad, "Place of experimentation, simulation and computer-assisted experimentation in physics teaching," *International Journal on Technical and Physical Problems of Engineering*, vol. 16, no. 2, pp. 37-43, 2024.
[22] R. Chakour, A. Alami, S. Selmaoui, A. Eddif, M. Zaki, and Y. Boughanmi, "Earth sciences teaching difficulties in secondary school: A teacher's point of view," *Education Sciences*, Article vol. 9, no. 3, 2019, Art no. 219. 10.3390/educsci9030242
[23] T. Bouzid, F. Kaddari, and H. Darhmaoui, "Force and motion misconceptions' pliability, the case of Moroccan high school students," *The Journal of Educational Research*, vol. 115, no. 2, pp. 122-132, 2022. https://doi.org/10.1080/00220671.2022.2064802
[24] A. Hachmi, A. Ouariach, R. Essaadaoui, M. El Hadi, and A. El Moussaouy, "Impact of the place of lightwave in secondary school curricula on conceptual understanding of their basic concepts: A moroccan case study," *Physics Education*, vol. 59, no. 4, p. 045014, 2024. https://doi.org/10.1088/1361-6552/ad424e
[25] J. T. Norbutaevich, "Use of digital learning technologies in education on the example of smart education," *Journal La Edusci*, vol. 1, no. 3, pp. 33-37, 2020.
[26] H. G. Van de Werfhorst, "Changing societies and four tasks of schooling: Challenges for strongly differentiated educational systems," *International Review of Education*, vol. 60, pp. 123-144, 2014.
[27] J. Andrews and H. Higson, "Graduate employability, 'soft skills' versus 'hard' business knowledge: A European study," *Higher Education in Europe*, vol. 33, no. 4, pp. 411-422, 2008. https://doi.org/10.1080/03797720802522627
[28] A. Haleem, M. Javaid, M. A. Qadri, and R. Suman, "Understanding the role of digital technologies in education: A review," *Sustainable Operations and Computers*, vol. 3, pp. 275-285, 2022.
[29] K. F. Geisinger, "21st century skills: What are they and how do we assess them?," *Applied Measurement in Education*, vol. 29, no. 4, pp. 245-249, 2016.
[30] N. A. Jalaludin, M. H. M. Salim, M. S. Rasul, A. F. M. Amin, and M. A. Saari, "The impact of virtual collaboration tools on 21st-century skills, scientific process skills and scientific creativity in STEM," *International Journal of Advanced Computer Science and Applications*, vol. 15, no. 8, 2024. https://doi.org/10.14569/IJACSA.2024.01508130
[31] B. S. V. Baskar and R. Kesavan, "Assessments of student's adaptability using convoluted geyser bidirectional long short-term memory in online education," *International Journal of Computational Intelligence Systems*, vol. 18, no. 1, 2025. https://doi.org/10.1007/s44196-024-00724-0
[32] C. D. Craig and R. Kay, "Online student peer-assessment in higher education: A systematic review of the literature," *Journal of University Teaching and Learning Practice*, vol. 22, no. 2, 2025. https://doi.org/10.53761/7jj6at39
[33] S. Yulianci, N. Nurjumiati, and A. A. Adiansha, "The effect of interactive multimedia and learning styles on students' physics creative thinking skills," *Jurnal Penelitian Pendidikan IPA*, vol. 7, no. 1, pp. 87-91, 2021.
[34] E. England and A. Finney, "Interactive media-what's that? Who's involved," *ATSF White Paper-Interactive Media UK*, vol. 12, 2011.
[35] S. Timotheou *et al.*, "Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review," *Education and Information Technologies*, vol. 28, no. 6, pp. 6695-6726, 2023.
[36] R. A. Kutbiddinova, A. Eromasova, and M. A. Romanova, "The use of interactive methods in the educational process of the higher education institution," *International Journal of Environmental and Science Education*, vol. 11, no. 14, pp. 6557-6572, 2016.
[37] W. L. Johnson, J. W. Rickel, and J. C. Lester, "Animated pedagogical agents: Face-to-face interaction in interactive learning environments," *International Journal of Artificial Intelligence in Education*, vol. 11, no. 1, pp. 47-78, 2000.
[38] D. Zhang, L. Zhou, R. O. Briggs, and J. F. Nunamaker Jr, "Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness," *Information & Management*, vol. 43, no. 1, pp. 15-27, 2006. https://doi.org/10.1016/j.im.2005.01.004
[39] K. Kustyarini, S. Utami, and E. Koesmijati, "The importance of interactive learning media in a new civilization era," *European Journal of Open Education and E-Learning Studies*, vol. 5, no. 2, pp. 48–60, 2020. https://doi.org/10.46827/ejoe.v5i2.3298
[40] S. P. Han and B. Kumwenda, "Bridging the digital divide: Promoting equal access to online learning for health professions in an unequal world," *Medical Education*, vol. 59, no. 1, pp. 56-64, 2025. https://doi.org/10.1111/medu.15455
[41] C. Moore-Hayes, "Technology integration preparedness and its influence on teacher-efficacy," *Canadian Journal of Learning and Technology/La revue canadienne de l'apprentissage et de la technologie*, vol. 37, no. 3, pp. 1–15, 2011. https://doi.org/10.21432/T2B597
[42] B. Shambare and T. Jita, "A new era of learning: Exploring science teachers' perceptions of virtual lab in rural schools," *Education and Information Technologies*, pp. 1-21, 2025.

DOI: 10.55214/2576-8484.v9i9.9769

[43] I. V. S. Mullis, M. von Davier, P. Foy, B. Fishbein, K. A. Reynolds, and E. Wry, *PIRLS 2021 international results in reading*. Amsterdam, The Netherlands: International Association for the Evaluation of Educational Achievement (IEA); TIMSS & PIRLS International Study Center, Boston College, 2023.

[44] M. AlSalouli, M. AlGhamdi, F. AlShaya, A. AlMufti, B. Aldarwani, and S. Pagliarani, "The impact of science teaching strategies in the Arabic-speaking countries: A multilevel analysis of TIMSS 2019 data," *Heliyon*, vol. 10, no. 5, 2024.

[45] A.-M. Nortvig, A. K. Petersen, and S. H. Balle, "A literature review of the factors influencing e-learning and blended learning in relation to learning outcome, student satisfaction and engagement," *Electronic Journal of E-learning*, vol. 16, no. 1, pp. pp46-55-pp46-55, 2018.

[46] M. L. Cheok and S. L. Wong, "Predictors of e-learning satisfaction in teaching and learning for school teachers: A literature review," *International Journal of Instruction*, vol. 8, no. 1, pp. 75-90, 2015.

[47] M. Mustafa and L. Trubel, "The impact of cognitive tools on the development of the inquiry skills of high school students in physics," *International Journal of Advanced Computer Science and Applications*, vol. 4, no. 9, pp. 1-8, 2013.

[48] M. E. Ng and K. H. Chua, "The effect of using PhET in changing Malaysian students' attitude to learning physics in a full virtual environment," *Pertanika Journal of Social Sciences & Humanities*, vol. 31, no. 2, pp. 1335–1350, 2023.

[49] A. Rosadi, "PhET simulation media part time using a problem based learning model improves student learning outcomes," *Jurnal Pendidikan Profesi Guru*, vol. 1, no. 1, pp. 43-53, 2023.

[50] S. Alabidi, K. Alarabi, H. Tairab, S. Alamassi, and N. R. Alsalhi, "The effect of computer simulations on students' conceptual and procedural understanding of Newton's second law of motion," *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 19, no. 5, p. em2259, 2023. https://doi.org/10.29333/ejmste/13140

[51] E. Agyei and D. Agyei, "Enhancing students' learning of physics concepts with simulation as an instructional ICT tool," *European Journal of Interactive Multimedia and Education*, vol. 2, no. 2, p. e02111, 2021. https://doi.org/10.30935/ejimed/11259

[52] O. Dardary, Z. Azar, M. Tridane, and S. Belaaouad, "Place of experimentation, simulation and computer-assisted experimentation in physics teaching," 2024.

[53] A. Hamamous and N. Benjelloun, "Impact of using computer-assisted experimentation on learning physical sciences in secondary schools in Morocco," *Knowledge Management & E-Learning*, vol. 15, no. 4, pp. 554-574, 2023. https://doi.org/10.34105/j.kmel.2023.15.032

[54] Y. Menchafou, M. Aaboud, and M. Chekour, "Effectiveness of real and computer-assisted experimental activities in Moroccan secondary school physics education," *International Journal of Interactive Mobile Technologies*, vol. 17, no. 16, pp. 16–29, 2023. https://doi.org/10.3991/ijim.v17i16.39267

[55] A. Hamamous and N. Benjelloun, "Influences of the effective use of a computer simulation on learning in physical science," *International Journal of Evaluation and Research in Education*, vol. 12, no. 3, pp. 1591-1598, 2023.

[56] M. Ben Ouahi, D. Lamri, T. Hassouni, A. Ibrahmi, and E. Mehdi, "Science teachers' views on the use and effectiveness of interactive simulations in science teaching and learning," *International Journal of Instruction*, vol. 15, no. 1, pp. 277-292, 2022.

[57] T. Katanosaka, M. Khan, and K. Sakamura, "PhyGame: An interactive and gamified learning support system for secondary physics education," *International Journal of Advanced Computer Science & Applications*, vol. 15, no. 6, p. 84, 2024. https://doi.org/10.14569/ijacsa.2024.0150611

[58] L. T. Escalada and D. A. Zollman, "An investigation on the effects of using interactive digital video in a physics classroom on student learning and attitudes," *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, vol. 34, no. 5, pp. 467-489, 1997.

[59] E. Barut Tugtekin and O. O. Dursun, "Effect of animated and interactive video variations on learners' motivation in distance Education," *Education and Information Technologies*, vol. 27, no. 3, pp. 3247-3276, 2022.

[60] J. Engelman, "How college students' conceptions of newton's second and third laws change through watching interactive video vignettes: A mixed methods study," Doctoral Dissertation, University of Cincinnati, 2016.

[61] F. Haroky, S. Nikmah, I. Wilujeng, and H. Kuswanto, "Android-assisted physics comic learning to train students' conceptual understanding of Newton's gravity," in *Journal of Physics: Conference Series, vol. 1233, no. 1, p. 012045. IOP Publishing*, 2019.

[62] P. Hämäläinen, J. Marshall, R. Kajastila, R. Byrne, and F. F. Mueller, "Utilizing gravity in movement-based games and play," in *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play*, 2015, pp. 67-77.

[63] J. Sweller, "Cognitive load during problem solving: Effects on learning," *Cognitive Science*, vol. 12, no. 2, pp. 257-285, 1988. https://doi.org/10.1207/s15516709cog1202_4

[64] E. Von Glasersfeld, "Piaget and the radical constructivist epistemology," *Costruttivismi*, vol. 1, no. 2, pp. 94-107, 2014.

[65] N. Veraksa and A. Veraksa, *Developing the ability of children to use and construct visual models. In Springer International Handbooks of Education*. Cham, Switzerland: Springer, 2018.

[66] D. Hestenes and I. Halloun, "Interpreting the force concept inventory," *The Physics Teacher*, vol. 33, no. 8, pp. 504-506, 1995.

[67] E. M. Nussbaum, G. M. Sinatra, and A. Poliquin, "Role of epistemic beliefs and scientific argumentation in science learning," *International Journal of Science Education*, vol. 30, no. 15, pp. 1977-1999, 2008.

[68] V. Khandagale and R. Chavan, "Identification of misconceptions for gravity, motion and inertia among secondary school students," *Online Submission*, vol. 4, no. 11, pp. 197-205, 2017.

[69] K. Gafoor and Akhilesh, "Misconception in physics among secondary school students," *Journal of Indian Education*, vol. 34, pp. 77-90, 2008.

[70] T. Neidorf *et al.*, *An introduction to student misconceptions and errors in physics and mathematics. In Student Misconceptions and Errors in Physics and Mathematics: Exploring Data from TIMSS and TIMSS Advanced*. Cham: Springer International Publishing, 2020.

[71] D. Hestenes, M. Wells, and G. Swackhamer, "Force concept inventory," *The Physics Teacher*, vol. 30, no. 3, pp. 141-158, 1992. https://doi.org/10.1119/1.2343497

[72] A. Asghar and J. C. Libarkin, "Gravity, magnetism, and," *Science Educator*, vol. 19, no. 1, pp. 42-55, 2010.

[73] H. Bani-Salameh, "Detecting gravity-related misconceptions of first year medical students using the Newtonian gravity concept inventory," *Physics Education Research Journal*, vol. 5, no. 2, pp. 55-60, 2023.

[74] K. Williamson, E. E. Prather, and S. Willoughby, "Applicability of the Newtonian gravity concept inventory to introductory college physics classes," *American Journal of Physics*, vol. 84, no. 6, pp. 458-466, 2016. https://doi.org/10.1119/1.4945347

[75] H. N. Bani-Salameh, "How persistent are the misconceptions about force and motion held by college students?," *Physics Education*, vol. 52, no. 1, p. 014003, 2017. https://doi.org/10.1088/1361-6552/52/1/014003

[76] M. Droui, A. E. Hajjami, A. B. Amjoud, and K. Ahaji, "Exploration des conceptions naïves à propos de la force et du mouvement chez des lycéens marocains," 2015.

[77] N. Nasser, M. EL KHOUZAI, and M. Taoufik, "Difficulties in learning physical sciences among secondary qualifying schools' students in Morocco," *American Journal of Innovative Research & Applied Sciences*, vol. 5, no. 2, pp. 199-125, 2017.

[78] R. E. Mayer, *Multimedia learning. In R. R. Detweiler & R. Glaser (Eds.), Psychology of learning and motivation*. San Diego, CA: Elsevier, 2002.

[79] R. E. Mayer, *Multimedia learning*. Cambridge, UK: Cambridge University Press, 2001.

[80] H. N. Bani-Salameh, "How persistent are the misconceptions about force and motion held by college students?," *Physics Education*, vol. 52, no. 1, p. 014003, 2017. https://doi.org/10.1088/1361-6552/52/1/014003

[81] K. E. Williamson, S. D. Willoughby, and E. E. Prather, "Development of the Newtonian gravity concept inventory," *Astronomy Education Review*, vol. 12, no. 1, pp. 010108-1–010108-20, 2013.

[82] K. S. Taber, "The use of Cronbach's alpha when developing and reporting research instruments in science education," *Research in Science Education*, vol. 48, pp. 1273-1296, 2018.

[83] S. M. Glynn, P. Brickman, N. Armstrong, and G. Taasoobshirazi, "Science motivation questionnaire II: Validation with science majors and nonscience majors," *Journal of Research in Science Teaching*, vol. 48, no. 10, pp. 1159-1176, 2011. https://doi.org/10.1002/tea.20442

[84] O. R. Holsti, *Content analysis for the social sciences and humanities*. Reading, MA: Addison-Wesley, 1969.

[85] D. A. Kolb, *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall, 1984.

[86] D. Kolb, "Towards an applied theory of experiential learning," *Theories of Group Process*, pp. 33-56, 1975.

[87] L.-J. Chanlin, "The effects of gender and presentation format in computer-based learning," *Educational Media International*, vol. 38, no. 1, pp. 61-65, 2001.

[88] X. Wu, Y. Li, T. Zu, J. Hutson, L. C. Loschky, and N. S. Rebello, "Using multimedia hints to facilitate conceptual problem solving in physics: Investigating the effects of multiple modalities," *Frontiers in Education*, vol. 10, 2025, Art no. 1568406. https://doi.org/10.3389/feduc.2025.1568406

[89] C. A. Mrani, A. El Hajjami, and K. El Khattabi, "Effects of the integration of PhET simulations in the teaching and learning of the physical sciences of common core (Morocco)," *Universal Journal of Educational Research*, vol. 8, no. 7, pp. 3014-3025, 2020. https://doi.org/10.13189/ujer.2020.080730

[90] A. Liccardo, A. Gargano, and A. Pastena, "The gender of science: A scientific analytically-based project to enhance secondary school students' awareness of gender stereotypes in STEM," *Education Sciences*, vol. 15, no. 3, p. 270, 2025, Art no. 270. https://doi.org/10.3390/educsci15030270

[91] Y. Safsouf, K. Mansouri, and F. Poirier, "An analysis to understand the online learners' success in public higher education in Morocco," *Journal of Information Technology Education: Research*, vol. 19, pp. 113-130, 2020. https://doi.org/10.28945/4526