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Research Article

# VIRTUAL REALITY ENHANCES STUDENT'S ACHIEVEMENT IN BIOLOGY: A COMPARATIVE STUDY WITH INTERACTIVE WHITEBOARDS AND TRADITIONAL METHODS

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**Abstract**
Studies of immersive technologies as transformative tools for the teaching of science are on the rise but very few empirical studies have been done to compare immersive to semi-immersive and traditional methods. The purpose of the current study was to analyse the effects of three different levels of immersion-virtual reality (VR), interactive whiteboards (IWB) and traditional teaching-on tenth-grade students' biology achievement in the topic of cell division. A quasi-experimental design of teaching that had three groups (VR group, n = 72; IWB group, n = 58; control group, n = 64) was used. The same qualified biology teacher taught all three groups, using semi-immersive, fully immersive, and traditional teaching through nine teaching sessions. An achievement test (validated for content reliability) was given as a pretest and a post-test. The pretest established the groups equivalently; and the post-test measured student learning gains since the three teaching methods could count for their test scores. ANCOVA results revealed that there were statistically significant differences in the groups' achievements. The VR group scores were the highest and the IWB group, the second highest-while the control group received the lowest post-test scores. The results suggest that more immersive teaching effects positively aided learning comprehension of abstract biological processes like cell division. The significance of the study was its direct comparison of fully immersive, semi-immersive and traditional teaching of the topic, providing practical implications for integrating VR into science classrooms to enhance students' comprehension of abstract biological processes.

Keywords: Achievement, Active Learning, Engagement, Immersion, Interactive Methods



## INTRODUCTION

According to The Cognitive-Affective Theory of Learning with Media (CATLM), cognitive engagement is based on motivational factors; metacognitive factors affect cognitive and affective processes; and individual differences in prior knowledge affect the efficiency of learning with media (Moreno & Mayer, 2007). In a world that is fully immersed in information and communication technology

(ICT), similar immersion in the educational field emerged as a reaction, represent ed in employing suitable technologies in the classroom that enable students to immerse in educational contents and improve their attitudes towards learning (Rojas-Sánchez et al., 2023; Asmaningrum et al., 2025).

Most recent studies concluded that technology-enhanced classrooms lead to better engagement of students and therefore, to better achievement. (Low et al., 2022; Ozkan Bekiroglu et al., 2022; Sırakaya & Alsancak Sırakaya, 2022; Alneyadi et al., 2023; Richardson, 2023; Islami et al., 2025). While there are many studies on technology enhanced classrooms, not as many have systematically compared differences in immersion such as fully immersive VR, semi-immersive such as interactive whiteboards, and face to face instruction in the same curriculum. This indicates a clear gap in research both in theory and in practice.

This highlights CATLM as a framework of the various ways through which teachers understand how best to affect students' achievement by enhancing cognition with affective aspects of learning (Moreno & Mayer, 2007; Park et al., 2014; Tanti et al., 2021). However, despite the value given to balance cognitive engagement with affective engagement theoretically, the empirical basis to support this suggestion is bit scattered, there are only a few potential direct comparison studies of immersive and semi-immersive approaches in biology education.

Educators have been seeking interactive classroom strategies since the beginning of the centur (Buehl, 2023; Jackson & Alfaki, 2025; Tanti et al., 2025). In an era of a technological revolution, technological educational tools can be easily integrated and applied into the teaching learning environment, enhancing a student-centered classroom that is mainly characterized by students' greater indulgence and interaction and therefore, affecting achievement (Swan et al., 2010; Behmanesh et al., 2022; Haleem et al., 2022; Hmoud et al., 2023; Le & Aye, 2025; Tanti et al., 2025). The focus has been on technologies like interactive whiteboards (or Smart screens) and extended reality (XR) in the form of virtual reality (VR), augmented reality (AR) and mixed reality (MR) to provide with excellent experiences and enable creativity and innovation by increasing interaction (Bucea-Manea-Țoniş et al., 2020; R. Yang et al., 2021). Nonetheless, the absence of comparative evidence constrains school decisions to move forward with engaging and cheaper innovations. It is critical to address this gap as pressures arise for schools to offer advanced and emerging technologies without knowing how they equate in their overall impact on student learning.

Most educators believe that technology-enhanced teaching and learning leads to a better engagement for students which is highly correlated with achievement (Tanti et al., 2021; Ozkan Bekiroglu et al., 2022; Saqr et al., 2023; Linh et al., 2025). Engagement can integrate behavioral, emotional and cognitive elements that can affect students' achievement through enhancing active learning attitudes, relatedness to learning and learning performances (Hmoud et al., 2023). Many studies about the relationship between engagement and achievement resulted in a high correlation between the two concepts. Engagement in STEM learning plays a critical role in achievement (Guzey & Li, 2022). A higher level of overall, behavioral, emotional, and cognitive engagement is associated with higher academic achievement (Lei et al., 2018; Rahajo & Kumyat, 2025). Yet, what remains unresolved is whether higher levels of technological immersion directly enhance both engagement and achievement compared with more traditional approaches. This still unclear question underpins the current research.

Thus, this study aimed to determine the effects of three levels of immersion: virtual reality (VR), interactive whiteboards (IWB), and traditional teaching on tenth grade students' achievement in biology, using the conceptually abstract concept of cell division as an example. Based on the principles of CATLM, this study focuses on different levels of immersive and interactive educational technologies. In order to understand how each level of immersion affects students' engagement and achievement, the following section reviews the theoretical and empirical foundations of VR and IWBS.

## LITERATURE REVIEW

### *Interactive Whiteboard (Screens)*

A kind of multimedia projector that allows the display of educational material on an external or internal (built-in) computer. It enables users to control applications by touching with their fingers or digital non-ink pens (Swan et al., 2010; Kilic et al., 2015; Kuhl & Wohninsland, 2022; Divya, V., 2023). It can increase interaction by enriching the classroom environment and allows for more eye-contact between the teacher and the students from one side and enhances social interaction between students which makes learning more effective (Kilic et al., 2015). Compared to other teaching methods, like lecture-based approaches, IWBs stand out as a relatively new but widely adopted instructional tool.

Research has demonstrated that interactive whiteboard (IWB)-based instruction can effectively enhance student learning outcomes and contribute to improved teaching productivity (Shi et al., 2021).

Richardson (2023), states that any interactive content is always superior to static one in terms of retention, cognition, and increased levels of engagement. Interactive methods of instructions had a significant difference on primary school students' attitudes and achievement, compared with traditional methods of instruction (Bui, 2023). Shared screens in arithmetic classes enhance memory by functioning as a shared memory device by keeping the records of all students' posts. Such results encouraged employing digital tools in order to increase student-student interaction (Shaikh et al., 2023). Swan et al., (2010) however, highlight the idea that significant differences in students' achievement in Reading/Language arts and Mathematics based on teachers' usage of Whiteboards is based on the way teachers employ the tool. IWBs also can be motivational and supportive to learning English as a Foreign Language (EFL), if used properly (Kuhl & Wohninsland, 2022). Teachers highlighted the potential of IWBs for teaching language skills and stressed the need for ongoing training, curriculum flexibility, and institutional support for effective integration (Dashtestani, 2019).

Schut (2007) studied Student Perceptions of IWB in a Biology Classroom and concluded that it is a valuable tool for Biology lessons for engaging students, increasing interaction, and improving visuals. IWBs offer a variety of stimuli that increase attention for easily distracted students. They also add enjoyment and interest, and an increased understanding of the content. Yang and Wang (2012) also discussed the benefits of using IWBs in Biology classes. They stated a number of topics in Biology that are difficult to explain to junior-high students in the traditional lecture method such as "cell division, photosynthesis, cell respiration, food chain, food web and evolution". A potential solution is in IWBs as they are flexible and versatile and can improve teaching efficiency through multimedia presentations.

Biological concepts are best taught through simulation, virtual examinations, and virtual activities. IWBs can enhance the educational process of biological concepts dramatically. Experience with employing IWBs for learning biological concepts proved to be effective and influential for the learning process. They have led to greater engagement, comprehension and memorization of biological ideas Divya, (2023). However, Chang et al. (2011) state that although IWBs have many benefits related to interaction with the content and learning activities and result in increasing students' motivation, a single screen is not enough in terms of space for interaction in the classroom.

### *Virtual Reality (VR)*

VR "is a computer-generated virtual environment of a three-dimensional image that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors." (Freina & Ott, 2015; Shen et al., 2019; Lampropoulos et al., 2022; Hmoud et al., 2023; Marougkas et al., 2023). The concept of education has been lacking much of its meaning due to its inability to provide students with experiences that facilitate the acquisition of knowledge, skills, and positive values under dangerous circumstances or in cases where experiments are not accessible enough to enable students actively interact with the targeted concepts due to classroom limitations such as space, time, or cost (Lege and Bonner, 2020; Rojas-Sánchez et al, 2023). Compared with traditional education, using VR provides a safer and more efficient method for the transmission of knowledge and application of experiments within an unlimited interactive virtual environment (Lege & Bonner, 2020; Rojas-Sánchez et al., 2023).

Implementing VR in education provides a more immersive and engaging learning experience (Neiroukh & Ayyoub, 2025). Villena-Taranilla et al. (2022) classify immersion into three levels based on devises: Non-immersive mood obtained by devices like computers and laptops; semi-immersive mood, by multiscreen devices and glasses, and immersion devices represented by VR headsets. VR takes the learners to difficult-to-access places, such as historical monuments, outer space or even within the human body. Students are able to better understand the subject and engage with the learning material (Sarıoğlu & Girgin, 2020; Marougkas et al., 2023).

Ragan et al. (2010) suggested that the effects of higher levels of immersion would benefit tasks that involve abstract mental activities. Their study concluded that increasing the level of immersion even to moderate levels, can improve performance significantly compared to lower levels of immersion. Uriarte-Portillo et al. (2022) examined the relationship between student immersion and learning outcomes in marker-based augmented related settings. The study aimed to assess the learning effectiveness of an augmented reality experiential activity for practicing the basic principles of chemistry and the level of immersion achieved by the middle school students who participated in the intervention. Their study empirically proved the positive relationships between immersion through augmented reality (semi-immersive) and learning outcomes. Most importantly, the study concluded that students with higher immersive learning profiles achieve better learning outcomes than those who achieve lower immersive profiles.

On the other hand, Huang et al. (2021) examined the effects of different levels of immersion on motivation, engagement and performance. The study concluded that higher immersion through VR was associated with higher motivation and engagement, but not with performance. Rojas-Sánchez et al. (2023) believe that learning sciences cannot always be fully implemented in classrooms due to safety aspects, costs, and other classroom limitations. VR technology can easily overcome those challenges seamlessly and with great engagement to the level of "immersion". The concept of "immersion" is very much connected to virtual reality. Implementation of VR technology results in a state of unawareness of real time and space with great concentration on the content being displayed in the virtual reality (Freina & Ott, 2015; Lampropoulos et al., 2022; Hmoud et al., 2023). This fact about VR encouraged teachers to adopt VR as a tool for teaching not only when experiments are not accessible but also when full immersion is required.

As a result of ICT, teachers nowadays can integrate a combination of media in their classrooms to increase students' interaction (Chang et al., 2011), and therefore, an increased engagement or immersion, leading to a better achievement (Swan et al., 2010; Behmanesh et al., 2022; Haleem et al., 2022; Hmoud et al., 2023). Employing VR in teaching science in elementary schools has a positive effect on students' attitudes and achievement. Using VR in teaching about 'The Cell' has a significant effect on students' achievement and attitudes towards science (Sarıoğlu & Girgin, 2020). A meta-analytical and meta-thematic Turkish study tried to investigate the effects of VR environments on students' achievement. The study concluded that VR enhanced environments have many advantages that lead to a better achievement. The meta-analysis part of the study found that immersive learning environments had positive impacts on students' thinking skills, emotional engagement, and physical abilities by creating a realistic sense of presence. These environments facilitated learning, boosted motivation, provided a safe and interactive space for students, and offered many other benefits for the learning process (Akgün & Atici, 2022).

The effects of virtual reality-based classrooms on students' learning performance in science lessons attracted the attention of many educators. (Liu et al., 2020), state that assessing VR in different subjects rendered positive results through empirical evidence. There are many potential advantages related to motivation and engagement through active participation and reduction of distraction. The researchers conducted a quasi-experimental study about the effect of VR-enhanced science classes on students' performance, engagement, and technology acceptance. Findings proved that the VR-enhanced science group had significantly higher achievement and engagement than the traditional one. Furthermore, all four subdimensions of engagement: cognitive, behavioral, emotional, and social subdimensions of the experimental group were significantly higher than those of the control group. VR environments can also affect students' satisfactory attitudes towards collaborative learning. In a study about collaborative learning through VR, Kim (2021) concluded that VR positively impacted students' learning after the 3rd day sessions and that participants in the collaborative group scored higher than their counterparts in the individual group. Moreover, collaborative learners through VR showed better acceptance and appreciation of collaborative learning, higher levels of engagement and enjoyment.

A teaching method has a great effect on learning outcomes (Behmanesh et al., 2022; Chebotib, et al., 2022; Nurhayat et al., 2023). Those methods are usually either teacher-centered where teaching and learning is mainly controlled and directed by teachers like lectures, or student-centered where students are actively engaged in the teaching-learning process. Although in teacher-centered classes a large amount of information can be transferred for a big number of students, students usually lose concentration after ten minutes. However, student-centered classes require more time but enhance students' learning, problem solving and communication skills (Behmanesh et al., 2022). Achievement at the personal level (cognitive abilities and self-discipline) is associated with clarity and understandability (Chebotib, et al., 2022). Nurhayat, et al. (2023) believe that improving students' achievement is based on raising their motivation which is influenced by the teaching model.

In an era of rapid digital transformation, immersive technologies like VR and IWBs became of great importance in the educational field in a way that they affected every aspect of the teaching learning process as tools used to enhance learning motivation and student outcomes (Cevikbas et al., 2023). Therefore, it became critically important for educators to understand their impact on group dynamics and cognitive performance in professional settings (Macchi & De Pisapia, 2024). This awareness will enable curriculum designers, school principals and educators to effectively plan for the best strategies to be applied for a smooth and successful achievement of the goals wished for.

Previous studies have focused on comparing the impact of one level of immersion with traditional teaching such as comparing VR with the tradional method (Kim & Kim, 2023), or IWBs (Sarıoğlu & Girgin, 2020). However, none examined all three modalties in one study (full, Semi, or non-immersive methods). This poses a gap in understanding the relative impact of different immersion levels on students' engagement and achievement. Traditional instruction provides content efficiently but often lacks interaction, whereas IWBs offer visual and tactile engagement, and VR allows for full immersion in simulated environments (Divya, V., 2023; Rojas-Sánchez et al., 2023). This study focuses on these three instructional methods to identify which best supports students' understanding of abstract biological concepts such as mitosis. While traditional methods provide content efficiently, they lack interaction. VRI and IWBs on the other hand, allow for greater interaction and construction of knowledge in a dynamic, Student-centered classroom environment (Swan et al., 2010; Divya, 2023; Rojas-Sánchez et al., 2023).

## RESEARCH METHOD

This was a quantitative research study is a quasi-experimental design using a pretest-posttest non-equivalent groups design. Pre-existing classes were assigned to each of three instructional conditions (VR, IWB, traditional), thus lending itself to a quasi-experimental design given the limitations of working within a school schedule and possibility of collective random assignment not being feasible. The design compares posttest achievement across groups, while using a covariate pretest to control for any differences in baseline measurements.

The participants were tenth grade students attending Shu'fat Comprehensive School. Using a multistage process (purposive selection of the school because of readiness in terms of the infrastructure and teachers, followed by random section selection), we were able to obtain N = 194 students and allocated them as follows: VR (n = 72); IWB (n = 58); and traditional control (n = 64). This design helps balance ecological validity (the use of intact classes) and internal validity (random section selection that occurred within one school). The study was sufficiently powered to detect medium to large effects, with achieved power estimates of .95 (medium effect, f = .25) and > .99 (large effect, f = .40). Thus, nonsignificant results should not be attributed to inadequate sample size (Cohen, 1988). All groups studied the Cell Division unit as part of the second-semester curriculum for tenth-grade students. The choice of the topic 'Cell Division' was based on factors like difficulty to explain or to access in a traditional teaching setting (Marougkas et al., 2023; Sarıoğlu & Girgin, 2020; Yang & Wang, 2012). Biology is one of four subjects (Math, Physics, Chemistry and Biology) on which decision about tenth graders' future stream (Scientific or Literary) will be made at the end of year.

A thorough analysis of the content of the unit 'Cell Division' was conducted with three biology teachers at school, and a total of nine sessions were agreed upon to cover the major six sub-topics of the unit. Behavioral Objectives of the unit, counted 37 were classified under four levels of the revised Bloom's Taxonomy (BT) (Krathwohl, 2002): Knowledge, Comprehension, Application and Higher Order Thinking Skills (HOTS): Synthesis, Analysis and Creation.

The Cell Division achievement instrument consisted of 30 items, which were scored, based on the unit model: 5 Multiple Choice Questions (MCQs), and 25 constructed-response items (short answers, comparisons, drawings and diagram-labeling). Each item was scored 0/1 with analytic rubrics; total was 0–30. The content validity was established by experts. Internal consistency for the pretest (N = 194) was very good (KR-20 = .91), (KR-20 is equivalent to Cronbach's α for 0/1 items), calculated across 80 dichotomously scored scoring elements derived from the 30 blueprint items. All items were keyed so that higher values indicate greater achievement. The same instrument was used for the pretest and posttest, and ANCOVA models with pretest as a covariate in comparing posttest achievement among VR, IWB, and control groups. ANCOVA was selected because it controls baseline differences and improves precision relative to ANOVA on posttest or gain scores when pretest reliability is high and assumptions (linearity; homogeneity of regression slopes) hold. Table 1 summarizes the unit subtopics, the sessions assigned to each, and the number and percentage of objectives at each Bloom level.

Table 1. Specification table for Cell Division Unit

| | Total | Total number of objectives and percentage | | | | Total | Total | Total | Test Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 7 | 10 | 19 | 5 | 41 | 100% | 100% | 30 | | | |
| | | 17% | 24% | 46% | 12% | | | | 6 | 8 | 14 | 3 |
| Units/Lessons | # of sessions | Knowledge | Comprehension | Application | HOTS | Unit Objectives | percent of unit weight | Percent of goals weight | Knowledge | Comprehension | Application | HOTS |
| Cycle of the Cell | 1 | 3 | 1 | 4 | 0 | 8 | 11 | 20 | 1 | 1 | 2 | 0 |
| Cell Division | 2 | 1 | 2 | 6 | 0 | 9 | 22 | 22 | 1 | 2 | 3 | 1 |
| Tumers | 1 | 1 | 2 | 1 | 1 | 5 | 11 | 12 | 1 | 1 | 2 | 0 |
| Metosis: Levels of Metosis | 2 | 2 | 1 | 3 | 2 | 8 | 22 | 20 | 1 | 2 | 3 | 1 |
| Phenomenon of Crossing | 1 | 0 | 2 | 2 | 1 | 5 | 11 | 12 | 0 | 1 | 2 | 0 |
| Gametogenesis | 2 | 0 | 2 | 3 | 1 | 6 | 22 | 15 | 1 | 1 | 3 | 1 |

In Table 1, the blueprint outlines the structuring of objectives across the six subtopics and Bloom levels to ensure average total content representation and cognitive demand relevant to Cell Division. The relative weighting of application and higher order skills reflects the abstract, process-oriented aspects of mitosis/meiosis and associated events. This blueprint also influenced the (a) the assembly of a 30-item test (MCQs and constructed responses, with 80 scoring elements that were dichotomous nested within the 30 items), (b) the nine-session lesson plan, so that instructional time and assessment emphasis were matched. By holding to the same sequencing and coverage of objectives across the VR, IWB, and control groups, the study elements are fair and any differences in posttest scores can be attributed to instructional modality and not the content.

Research Hypotheses: H1: VR and IWB students will have significantly higher achievement than students in the traditional group; H2: VR students will have significantly higher achievement than students in the traditional group; H3: IWB students will have significantly higher achievements than students in the traditional group; H4: Students in the VR group will have significantly higher achievement than students in the IWB group.

To increase transparency of measurement and procedure, Table 2 summarizes the instrument and its data-collection method; and presents the administration timeline.

Table 2. Instrument and data-collection grid (with administration timeline)

| Category | Description |
|---|---|
| Instrument (Language) | Achievement test "Cell Division" Arabic |
| Measured construct | Biology achievement on the Cell Division unit |
| Item # and Type | 30 items: 5 MCQs plus 25 constructed responses; 80 dichotomous scoring elements within 30 items |
| Scale and scoring | 0/1 per item; total 0-30; analytic rubrics for constructed responses |
| Reliability | KR-20 = .91 (pretest, N = 194; equivalent to Cronbach's α for 0/1 items). |
| Validity evidence | Expert review; blueprint alignment to revised Bloom's taxonomy |
| Data collection Methods | In-class, paper-based test; teacher read standardized instructions; proctored; 45-60 min; answer sheets collected at end of session |
| Administration (who/where) | Biology teacher; classroom setting, Shu'fat Comprehensive School |
| Timing | Pretest (Week 0) and Post-test (Week 4) |

A pretest was prepared according to the specification table and was conducted on the intended three 10th grade groups (10th A (VR method), 10th B (IWB method) and 10th C (traditional lecture method) as the control group) before intervention. One competent biology teacher was chosen to teach all three classes using a different method with each class. An Arabic version of 'Cell Division' from Mozaik3d educational application was downloaded on Meta-quest 3 headsets for the first experimental group (Class A). The same content was downloaded on a large IWB and I-Pads for the second experimental group (Class B). The experiment started at the beginning of the second semester (Feb. 2024) in accordance with the arrangement of the coursebook and lasted for one month.

Experimental Group A were taken nine 45-minute sessions to the school lab and explored cell division sub-titles using VR headsets under the instruction of the teacher. Teaching and learning were based on pre-questions and activities assigned by the teacher followed by watching relevant short 3D scenes that would help students find answers. Some questions needed more detailed answers and were left for the students' own exploration and manipulation in the last ten minutes of each session, where students were given the freedom to explore cell division scenes on their own to enhance their motivation about learning within the scope of CATLM.

Experimental Group B were exposed to the different sub-titles of cell division on a large portable interactive whiteboard in their class and were allowed at the end of sessions to interact with the content through I-pads to find more pre-assigned detailed answers as part of CATLM. Control Group C were exposed to the content in the traditional method in their class. The teacher followed the traditional lecture method and used the traditional board to elaborate and explain about the content of the topic. At the end of the experiment, a posttest was conducted by the participating students and was corrected by the same teacher based on strict criteria.

Data was analyzed using Analysis of Covariance (ANCOVA) to determine the effectiveness of the three instructional methods on students' achievement in the biology topic 'Cell Division'. ANCOVA allows for the comparison of posttest scores among the three groups while statistically controlling for pretest scores. This method increases accuracy and validity of the comparison by adjusting for covariante influence. Descriptive statistics were also used to summarize the central tendency and variability of scores. All analyses were conducted using SPSS, with statistical significance set at $p < .05$. Effect sizes were calculated using partial eta squared to determine the strength of the observed differences between groups.

## RESULTS AND DISCUSSION

The results section presents the findings of the study in alignment with the research questions. First, descriptive statistics to provide an overview of the difference in students' scores before and after interventions. Then, inferential analyses using ANCOVA to examine differences in post-test achievement while controlling for the pre-test scores. Planned contrasts were conducted to identify specific pairwise differences between the three groups. Results are presented with relevant effect size to help interpret the practical significance of the findings in Table 3.

Table 3. Descriptive statistics

| Group # | Group | After | | | Before | |
|---|---|---|---|---|---|---|
| | | N | M | SD | M | SD |
| 1 | Virtual reality (VR) | 72 | 25.36 | 2.79 | 7.31 | 2.71 |
| 2 | Interaction white board (IWB) | 58 | 21.45 | 3.76 | 7.97 | 2.91 |
| 3 | Traditional (T) | 64 | 17.52 | 6.29 | 6.41 | 2.58 |

The pre-test mean of the students' biology achievement was close, with the largest difference between them equal to (1.56) and even the standard deviations being close, as the table makes clear. In the post-test, the means differed, with the largest difference, equal to (7.64), between the group that learned via Virtual reality (VR) method and the traditional. There are different effects for each method of teaching (VR method, IWBs and the traditional method) on students' achievement (Groups: A, B and C) in the post test. Group A ranked highest in post-test means, followed by Group B, and Group C ranking lowest.

Table 4. ANCOVA test to compare groups achievements

| Cases | SS | df | MS | F | p | η² |
|---|---|---|---|---|---|---|
| Group | 836.87 | 2 | 418.44 | 49.39 | < .001 | 0.30 |
| Before | 338.66 | 1 | 338.66 | 39.96 | < .001 | 0.12 |
| Residuals | 1610.14 | 17.50 | | | | |

Results of ANCOVA revealed a statistically significant effect of teaching method on student achievement after controlling for pre-test scores. There is a significant difference in achievement mean between the groups [F (2,92) = 23.91, p < .001], with a partial Eta Squared value 0.3. This indicates that at least two groups' means significantly differ from one another, and as table 4 shows, planed contrasts were utilized to determine where to find the differences.

Table 5. Planned Contrasts between groups

| Comparison | VR | IWB | T | Contrast | Estimate | df | t | p | Cohen's d |
|---|---|---|---|---|---|---|---|---|---|
| H1 | 1 | 1 | -2 | VR+IWB vs T | 9.91 | 92 | 5.35 | < .001 | 2.37 |
| H2 | 1 | 0 | -1 | VR vs T | 7.05 | 92 | 6.84 | < .001 | 1.69 |
| H3 | 0 | 1 | -1 | IWB vs T | 2.86 | 92 | 2.60 | 0.011 | 0.68 |
| H4 | 1 | -1 | 0 | VR vs IWB | 4.20 | 91 | 3.97 | < .001 | 1.00 |

The achievement means [t (92) = 5.35, p <.001] varies significantly between the two experimental groups VR & IWB together and the traditional group T in favour of VR & IWB groups. The means by which students achieve differ significantly. The VR group is preferred over the traditional group [t (92) = 6.84, p <.001]. The methods that students use for achievement differ significantly [t (92) = 2.60, p <.05]. The IWB group is favored over the traditional group. The means by which students achieve differ significantly. The VR group is preferred over the IWB group [t (92) = 3.97, p <.001]. Cohen's d for H3 was medium because it fell between 0.5 and 0.8, whereas effect sizes were large for H1, H2, and H4 because their values were 2.37, 1.69, and 1, respectively, which are greater than 0.8 (Sullivan & Feinn, 2012). Hence, all four hypotheses of the study (H1, H2, H3 and H4) are accepted.

Results of the experiment proved that different methods of teaching have different effects on students' achievement (Behmanesh et al., 2022; Chebotib, et al., 2022; Nurhayat et al., 2023).These differences are attributed to cognitive engagement highlighted by CATLM through motivational and metacognitive factors that affect the cognitive and affective processes of the learner (Moreno & Mayer, 2007).

Comparing the results of the experimental group A's achievement which was based on the VR method of teaching and learning, with the other experimental group B's achievement whose teaching and learning was based on IWBs method, it was clear that group A significantly surpassed group B. This aligns with classification of immersion into three major levels and having VR on top of immersing tools. It also supports the connection between levels of immersion and levels of concentration as evidenced by (Ragan et al., 2010). It also echoes the empircal evidence arrived at by (Uriarte-Portillo et al., 2022) about how students with higher immersive learning profiles achieve better learning outcomes than those who achieve lower immersive profiles.

Both experimental groups A and B satisfactorily achieved higher than the control group C who were taught the topic 'Cell Division' traditionally. This corroborates with many recent studies which concluded that technology-enhanced classrooms lead to better engagement of students and therefore, to better achievement." (Alneyadi et al., 2023; Buehl, 2023; Freina & Ott, 2015; Low et al., 2022; Ozkan Bekiroglu et al., 2022; Richardson, 2023; Sırakaya & Alsancak Sırakaya, 2022). Experimental groups A and B compared with the lowest achievement of the control group C can be generally attributed to the interference of the technological tools in the teaching and learning methods of the experimental groups compared with the non-use of any technology in the case of the control group (Ozkan Bekiroglu et al., 2022; Saqr et al., 2023). According to Hmoud et al. (2023), active learning attitudes can be enhanced through technology use by increasing engagement which in turn integrates behavioral, emotional, and cognitive elements that enhance achievement.

It wasthat the use of VR technology and IWBs in the teaching of "Cell Division" increased students' engagement which enhanced achievement. According to Lei et al. (2018), the higher engagement, the better achievement, especially in STEM learning where higher levels of behavioral, emotional, and cognitive engagement is highly correlated with higher achievements (Guzey & Li, 2022).

Dunn and Kennedy (2019) found that intrinsic motivations can predict engagement which can, in turn, predict better achievement. They concluded that interactive Technology Enhanced Learning can significantly predict grades, whereas using passive Technology Enhanced Learning environments in which learners can only learn through, but not from, technology is a misleading predictor of achievement. In other words, the level of interaction between learners and technology is critical in determining the ability to predict students' achievement and engagement which aligns with Niederhauser (2013). In the case of our experimental groups, VR and IWBs are interactive Technology tools with different levels of interaction, and therefore can be considered as good predictors of students' higher achievement. Students' learning in the two experimental groups was based on interaction and exploration of the concepts presented in the topic "Cell Division" with different levels of cognitive competency. They had more freedom to explore areas with specific details about the different facts, concepts, principals, and procedures of the topic, with more engagement, less distractors and less teacher's guidance. Group C students' learning, however, was solely based on the teacher's explanation and guidance, with very limited engagement based on traditional, classroom tools.

On the other hand, differences in achievement between groups A and B can be attributed to factors related to the level of immersion of each group according to Villena-Taranilla et al. (2022) . More immersion renders more behavioral, emotional, and cognitive indulgence and interaction (Behmanesh et al., 2022; Haleem et al., 2022; Hmoud et al., 2023; Swan . et al., 2010), and therefore, achievement. During the experiment, group A students were learning more from the virtual reality than from their biology teacher which is consistent with CATLM in how learners' cognitive engagement is influenced by their motivational states, while metacognitive factors shape both cognitive processing and emotional responses during learning (Moreno & Mayer, 2007). Students were exploring areas of knowledge of their interests which helped them discover the facts, concepts, principals, and procedures of the related subtitles of the "Cell Division" topic, under a minimal guidance of their teacher. Group B students also had the same experience but with less engagement and relatively more dependence on the teacher's guidance.

VR technology provides more engaging learning experiences (Villena-Taranilla et al., 2022) than IWBs do. The VR technology enabled to provide group A students with virtual active and interactive experiences that helped to acquire knowledge about "Cell Division" which would not have been allowed in a traditional classroom environment (Lege & Bonner, 2020; Rojas-Sánchez et al., 2023), due to class limitations related to space, cost and/or time. On the other hand, group B students had a similar experience, but with a relatively less engagement. According to Villena-Taranilla et al. (2022), VR technology is classified as a fully immersive device that can take learners to difficult-to-access places, such as historical monuments, outer space or even within the human body, like the case of this experiment where the students were taken into the human cells which allowed students to better understand the topic and its subtitles through engagement with the learning material. On the other hand, semi-immersive mood devices such as, multiscreen devices and glasses which provides with a great deal of engagement and interaction with the topic, but the learner is still aware of his natural surroundings. This supports Marougkas et al. (2023) and Sarıoğlu and Girgin (2020) of how VR takes the learners to difficult-to-access places, such as historical monuments, outer space or even within the human body. VR took students inside human cells and made cell devision more concrete.

Group B students working on their tablets and interacting with the interactive white board screen, were able to control "Cell Division" applications by the touch of their fingers but were still aware of the learning process and their surroundings. However, social interaction was highly enhanced between students themselves, from one side, and between students and their teacher, from another side, and made learning more effective (Kilic et al., 2015). This explains the lower difference in achievement when compared to the fully immersed group A students and the higher difference in achievement with the non-immersed group C. This supports Villena-Taranilla et al. (2022) idea of Semi-immersive mood devices such as multiscreen devices and glasses which provide a great deal of engagement and interaction with the topic, but the learner is still aware of his natural surroundings.

## CONCLUSION

Different levels of immersion in the learning environment can relatively affect students' engagement with the topic and greatly affect their achievement. An environment that provides learners with full-immersing technological devices ensures higher levels of engagement throughout many engagement-derivative factors such as, interest, enjoyment, independency of learning, active indulgence with the content, and freedom of exploration and discovery of the content of the topic. A semi-immersive device can still generate interest and engagement and can increase achievement, but less than a full-immersive learning environment. Depending on the nature of the topic targeted, teachers must try hard to increase the level of immersion of the students as deep as possible by employing the best device that suits the content and nature of the topic and the learning environment. The results of this study proved that VR technology is a competent device that increases students' achievement in the topic "Cell Division" more than IWBs which improved students' achievement less clthan VR but still more than in a traditional classroom environment. Differences of achievement can be attributed to the different levels of immersing devices. The more immersive the device is, the more engagement and therefor, the better achievement. This highlights CATLM as a framework of the various ways through which teachers understand how best to affect students' achievement by enhancing cognition with affective aspects of learning (Park et al., 2014).

Based on this, the study suggests a new way to think about learning: more immersion leads to more engagement and higher achievements. Hence, Teachers should consider using immersive tools like VR, especially when teaching difficult science topics. Future studies can test this idea in different subjects or with other student groups. However, practical implementation must consider the varying contexts of school environments. Resource constraints might limit the full adoption of the VR tool especially with under-funded schools. Our recommendations should be seen as flexible and adaptable. Under-funded schools can start with more affordable alternatives such as computer simulations, mobile-based VR, or even cheaper sets of VR tools. Such schools can find creative ways to introduce the tool based on their context.

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## AUTHOR CONTRIBUTIONS

"Conceptualization, Nader Neiroukh & Nardin Hamad; Software, Nader Neiroukh, Nardin Hamad & Abdul karim Ayyoub. Validation, Nader Neiroukh, Nardin Hamad & Abdul karim Ayyoub. Formal Analysis, Nader Neiroukh & Nardin Hamad & Abdul karim Ayyoub; Investigation, Nader Neiroukh & Nardin Hamad; Resources, Nader Neiroukh & Nardin Hamad; Data Curation, Nader Neiroukh; Nardin Hamad & Abdul karim Ayyoub; Writing – Original Draft Preparation, Nader Neiroukh & Nardin Hamad; Writing – Review & Editing, Nader Neiroukh & Nardin Hamad; Visualization, Nader Neiroukh & Nardin Hamad; Supervision, Nader Neiroukh; Project Administration, Nader Neiroukh."

## CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

## USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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