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ASSESSING THE EFFECT OF LIGHTBOARD TECHNOLOGY ON STUDENTS' COGNITIVE PERFORMANCE IN ELEMENTARY SCHOOL

Eftychia Aslanidou[1,2],
Georgios P. Heliades[1i]
[1]Ionian University,
Department of Digital Media and Communication,
Antonis Tritsis Ave, 28100, Argostoli,
Greece
[2]The Hellenic American MKO,
Zakynthos, 29092,
Greece

Abstract:
Recent advancements in technology have increasingly facilitated the adoption of different instructional methodologies in education. The Lightboard (LB), an innovative pedagogical tool, comprises a specially illuminated glass surface upon which instructors articulate written content during lessons. This allows for sustained visual engagement with both the instructor and the instructional material. While empirical investigations into face-to-face classroom application of the LB have predominantly emerged from the United States, these studies, focusing on specific dimensions of the learning process, suggest that the LB fosters cognitive development and sustains engagement among typically developing learners. This study presents the inaugural findings from the Greek educational context, assessing the efficacy of the LB in face-to-face instruction relative to the traditional Whiteboard. The research, conducted with 30 elementary school students enrolled in a non-profit educational program, examines learning experiences within the domain of mathematics. Employing a mixed-methods research design, the study utilized two data collection instruments: (a) cognitive assessments (pre-test, main test, and post-test) tailored to the developmental stage of the participants, and (b) systematic teacher observations to document extra-linguistic phenomena. The results underscore the significant potential of the LB as a modern instructional tool, particularly given its ability to achieve cognitive outcomes comparable to those of the traditional Whiteboard, which has been a cornerstone of classroom teaching for centuries. This alignment with such a well-established method highlights the LB's promise, while also encouraging further exploration through larger-scale studies to fully understand and expand its educational

[i] Correspondence: email easlanidou@ionio.gr, heliades@ionio.gr

impact. Moreover, the research explores students' perceptions of the teacher and the LB, as juxtaposed with other educational technologies employed during instruction.

Keywords: lightboard, cognitive performance, technology-enhanced pedagogy, students' learning outcomes, elementary education, educational technology

1. Introduction

The post-pandemic era has emphasized the pivotal role of Information Technology (IT) in contemporary education, establishing its integration into teaching practices as a keystone of effective instruction (Negi *et al.*, 2011). The COVID-19 pandemic accelerated the transition toward digital and blended educational frameworks, amplifying the demand for creative strategies that actively engage learners and foster meaningful learning experiences. While traditional instructional tools such as the Whiteboard (see Fig. 1 & 2) remain widely utilized due to their straightforward application for explaining fundamental concepts, their effectiveness diminishes in large educational contexts like auditoriums, where physical limitations compromise visibility and hinder interaction (Skibinski *et al.*, 2015; Beatty, 2019).

Figure 1 & 2: Learning with the Whiteboard

To address these challenges, progressive education increasingly leverages technology-enhanced methods to cater to diverse educational needs. Blended learning, which merges in-person teaching with online components, has become an essential approach for promoting both instructional adaptability and learner engagement (Hall & Villareal, 2015). As educational environments evolve, instructors are turning to innovative tools that not only capture students' attention but also facilitate active content interaction. The Lightboard (LB), an illuminated glass panel that allows instructors to write while maintaining eye contact with learners (see Fig. 3 & 4), exemplifies such technological advancements, enabling dynamic, interactive, and visually engaging lessons (Aslanidou & Heliades, 2024).

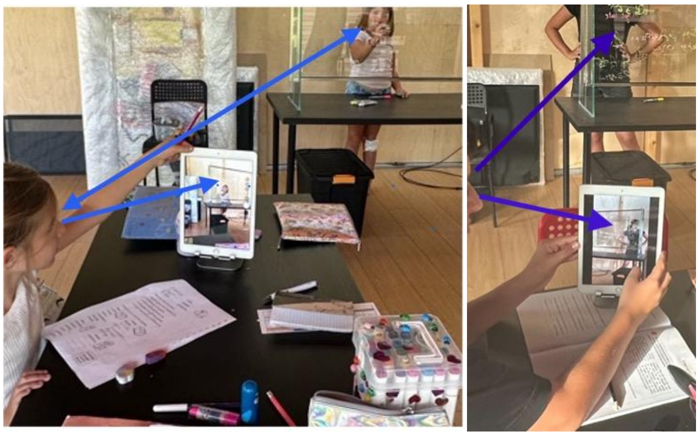

Figure 3 & 4: Learning with the LB

In addition to its technical advantages, the LB aligns closely with the pedagogical priorities of 21st-century education, particularly the cultivation of critical thinking, communication, collaboration, and creativity—the "4Cs." Achieving these competencies requires an active and participatory approach to learning, supported by educators who foster metacognitive, social, and communicative skills (Saavedra & Opfer, 2012). Research indicates that visual aids enhance comprehension and analytical thinking by helping students connect concepts (Paivio, 1990).

By enabling instructors to write and draw directly on a transparent surface while maintaining eye contact with the audience, means that the LB could improve verbal and non-verbal communication. The LB's flexibility in using drawings, and color-coding allows educators and students to express ideas creatively. For example, instructors in art classes can demonstrate techniques live, inspiring students to experiment and innovate. This interactive approach can make lessons more engaging and ensure effective material delivery. Also, other research has shown that tools that combine visual and verbal interaction improve information retention and communication skills (Clark & Mayer, 2016).

Furthermore, LB can foster collaboration by allowing students to present their ideas visually to peers during group discussions. This setup encourages peer-to-peer learning and teamwork. Specifically, students can collaborate to solve problems or create joint presentations, aligning with findings by Johnson & Johnson (2009), who demonstrated that collaborative learning tools promote teamwork and deeper understanding.

Given the context, the unique challenges posed by the pandemic have amplified the necessity for teaching methods that nurture adaptability and innovation in students. By incorporating advanced tools like the LB into their instructional repertoire, educators not only enrich their teaching practices but they can also model an ethos of continuous learning and adaptability, qualities that students are encouraged to adopt (Fullan & Langworthy, 2014).

In Greece, where the education system emphasizes preparing students for global citizenship, the LB holds significant potential as a tool to create engaging and impactful learning environments. Through the application of effective pedagogies and advanced instructional technologies, Greek educators can help students acquire the skills needed to thrive in an interconnected and rapidly evolving world (Papanastasiou *et al.*, 2020). Despite its adoption in various international contexts, particularly in the United States, the use of the LB in Greek classrooms remains limited. This study investigates the potential of this innovative teaching tool to enhance student participation and improve learning outcomes in the Greek educational setting.

2. Literature Review

2.1 Framing Lightboard

The LB is a technology first conceptualized by Professor Michael Peshkin at Northwestern University (Birdwell & Peshkin, 2015). Independently, professor Matt Anderson at San Diego State University developed a similar device, naming it the 'Learning Glass', which was specifically designed to enhance in-person teaching by allowing educators to maintain eye contact with students while writing on a transparent, illuminated panel (Firouzian *et al.*, 2016). This tool features a glass surface with LED illumination along its edges, enabling instructors to write using specialized markers. A strategically positioned camera captures the instructor's work, with the video mirrored to present a correctly oriented image to viewers. This configuration ensures that students can simultaneously observe the educator and the instructional content, overcoming many physical barriers associated with traditional Whiteboards. Beyond live classroom use, the LB has also been employed in creating educational videos, offering a more interactive and flexible learning modality (Skibinski *et al.*, 2015).

From a pedagogical perspective, the LB can offer distinct advantages, particularly its ability to sustain uninterrupted communication and a sense of immediacy with learners. Unlike conventional boards, which require instructors to turn away from their audience, the LB ensures that educators remain visible, fostering a stronger sense of connection and engagement throughout the lesson (Firouzian *et al.*, 2016). The uninterrupted visual contact could support the use of diverse communication strategies and visual aids that facilitate the understanding of abstract or complex topics. Additionally, the tool has demonstrated a capacity to sustain student focus, mitigating distractions often present in traditional classroom setups.

While some researchers have posited that the LB could potentially replace traditional AI-driven PowerPoint presentations, particularly those that exceed students' attention spans (Fung, 2017), this assertion remains speculative. Lubrick *et al.* (2019) highlight the LB's capacity to enhance engagement but emphasize the need for longitudinal research to validate its efficacy across varied educational settings. Misirlis and Munawar (2022) argue that the integration of hybrid learning tools has become a necessity in contemporary education. As educators are increasingly required to incorporate innovative methodologies into their practices, the LB emerges as a transformative tool capable of transitioning passive classroom environments into more interactive and participatory learning spaces, thereby strengthening student-instructor communication (Tosheva & Abdullaeva, 2022).

2.2 Prior Research on the cognitive benefits of the LB

Empirical research on the cognitive benefits of the LB reveals encouraging results, particularly in terms of learning outcomes and student perceptions. A study conducted by Firouzian *et al.* (2016) at San Diego State University (SDSU) involving 542 students compared two instructional groups: one utilizing the LB and the other employing a traditional projector. Both groups achieved similar academic outcomes, but students taught with the LB reported significantly higher levels of engagement and a stronger sense of instructor immediacy. These findings indicate that the LB can replicate the interactive experience of face-to-face instruction even within online or hybrid learning contexts without compromising the quality of education.

Moreover, at Western Michigan University (WMU), researchers observed that the LB enhanced students' comprehension of complex material by enabling real-time visualization and clarification (Talanda-Fisher, 2020). Similarly, Georgia Southern University integrated the LB into a flipped classroom model, comparing the performance of students who used LB-supported lessons with those who relied on traditional methods. The experimental group not only demonstrated improved academic performance but also expressed strong support for LB videos on a Likert scale, citing greater engagement, satisfaction, and understanding of the material (Rogers & Botnaru, 2019). Enhanced cognitive retention among LB users further underscores its value in supporting long-term learning outcomes.

Further evidence reinforces these findings. At Northwestern University, students reported positive experiences using the LB for final presentations, highlighting its ability to create dynamic and engaging presentations (Birdwell & Peshkin, 2015). Similarly, at Bond University, the incorporation of the LB into small-group learning environments yielded notable academic benefits. A study involving 60 participants divided into groups of six demonstrated a 17.87% improvement in academic performance among students using the LB compared to those employing traditional methods (Schweiker & Levonis, 2020). It merits mentioning that students reported a stronger sense of connection with instructors and increased participation, further validating the LB's potential to foster active learning environments.

In conclusion, the LB represents a compelling innovation for addressing the limitations of both traditional and digital teaching approaches by facilitating real-time interaction, enhancing student engagement, and supporting cognitive retention. LB technology could align with the demands of 21st-century pedagogy. Thus, further investigation is necessary to explore its applicability across various disciplines and educational settings, particularly in hybrid and distance learning scenarios.

3. Research Aims

Unlike university-level students, who have more developed cognitive and self-regulatory abilities, primary school students are still in the process of developing essential skills such as attention, problem-solving, and logical reasoning. The decision to focus on elementary school education stems from the critical role that this stage plays in shaping foundational skills and attitudes toward learning. Research indicates that early high-quality education is crucial for cognitive development, as it establishes the groundwork for future academic success and lifelong learning (Goswami & Bryant, 2007). As such, instructional innovations like the LB could have a profound impact by fostering engagement, enhancing comprehension, and addressing diverse learning needs during this formative stage. Moreover, since younger learners often require more interactive and visually engaging methods to sustain attention and interest (Matthews & Zimmerman, 2020), tools like the LB hold unique potential in primary education.

Additionally, primary education plays a crucial role in laying the foundation for lifelong learning (UNESCO, 2014), particularly in core subjects such as mathematics, which fosters critical thinking, problem-solving, and logical reasoning. Mathematics education at this stage is pivotal, as it equips young learners with essential skills required for both academic success and everyday life (Aslanidou, 2019). However, teaching mathematics effectively to primary school students often requires creative and engaging approaches to overcome challenges such as limited attention spans or varying levels of comprehension.

Furthermore, studying the use of the LB in Greece is particularly significant because of the distinct educational and cultural context. While much of the existing research on the LB has been conducted in the United States, Greece presents an opportunity to explore its efficacy in a different educational framework, characterized by Greek primary education emphasizes traditional methods and rigid curricula, making it an ideal context to assess the transformative potential of innovative tools like the LB. Also, the Greek educational system often face challenges in adopting and integrating new technologies due to resource limitations, making it essential to evaluate whether cost-effective solutions like the LB can address these barriers (Neofotistos & Karavakou, 2018). The way students engage with teachers and technology in Greece may differ from the U.S. due to cultural attitudes toward education, teacher-centered approaches, and classroom dynamics. These differences warrant localized studies to determine the LB's adaptability and effectiveness in such contexts.

Lastly, non-formal teaching environments, which operate outside the traditional classroom, offer flexible and innovative spaces for learning (Aslanidou, 2019). These environments are especially valuable for experimenting with novel instructional methods and technologies, as they provide a less structured yet impactful platform for addressing diverse learner needs (Yang *et al.*, 2021). By combining the LB with non-formal teaching settings, there is an opportunity to reimagine mathematics education and explore how technology can enrich learning experiences for young students.

All things considered, this study seeks to assess the impact of LB technology on the learning outcomes of primary education students in mathematics within a non-formal teaching environment, as compared to a Whiteboard instruction. Specifically, it seeks to determine whether the use of LB as a teaching tool results in improved, comparable, or diminished learning outcomes when compared to traditional Whiteboard instruction. Thus, the hypothesis is that the use of LB technology enhances the cognitive performance of elementary school students in mathematics compared to Whiteboards.

4. Methods

4.1 Participants-Procedures

One key aspect of this research is that it represents one of the first studies focused on the implementation of LB technology within the Greek educational context. The primary aim is to develop an initial understanding of the educational environment and the effects of the LB in this setting. The current study specifically targets primary school students, marking the first phase in a series of investigations that will explore the applicability of similar technologies across various educational levels. This strategic choice provides valuable insights into how younger learners engage with innovative teaching tools, laying the groundwork for future studies on LB integration in secondary and higher education.

A mixed sampling approach was employed to select the sample. On the one hand, convenience sampling allowed for ease of access to primary school students, particularly through educational institutions affiliated with The Hellenic American MKO. However, to ensure the sample was robust and aligned with the study's objectives, a structured design was applied to the final selection. This included considering key parameters representative of the wider population, such as homogeneity in terms of cognitive development, particularly in mathematics. The selected sample consisted of primary school students of typical cognitive development without identified learning difficulties in mathematics. These students also shared the common characteristic of attending supplemental evening courses based on American educational standards. All participants were from the island of Zakynthos and exhibited similar socio-economic backgrounds, which helped ensure a more controlled analysis of results.

In terms of sample size, a number of researchers recommend that a minimum of 30 participants is often sufficient for statistical analysis in educational research (Cohen *et al.*, 2000; Creswell, 2014). For this study, a total of 30 students were selected, comprising 12 boys and 18 girls. To further strengthen the research design, matching procedures were used during the sample selection process to ensure comparable groups, and students were randomly assigned to either the experimental or control group. This ensured that any differences in learning outcomes could be more confidently attributed to the use of the LB, thus allowing the use of both quantitative and qualitative methods for a more comprehensive analysis (Cohen *et al.*, 2000; Teddlie & Tashakkori, 2009). This methodological approach, combining both quantitative and qualitative data, enables a more nuanced understanding of how LB technology impacts student learning outcomes. It also facilitates the use of both analytical and inferential statistics, providing deeper insights into specific participant groups and ensuring that the research results are both valid and reliable.

4.2 Measure

This study's methodology was designed using established research protocols, tailored to align with the participants' learning environment and objectives. (Michael *et al.*, 2024). A mixed-methods approach was utilized, combining quantitative and qualitative data to provide a comprehensive analysis of the research question. Quantitative data were analyzed using statistical methods, including t-tests, to assess differences between experimental and control groups, while qualitative data were collected through structured observations to capture student perceptions (Tankersley *et al.*, 2008).

Student perceptions were gathered through paper-and-pencil questionnaires and interviews administered during classes by researchers to schools in the spring of 2024. Participants had the option to decline participation or discontinue the survey. Anonymity and data confidentiality were maintained following the guidelines of the General Data Protection Regulation (EU 2016/679 GDPR). Also, the confidentiality and protection of the children's personal data was ensured, having obtained the approval of the Research Ethics and Ethics Committee of the Ionian University and their guardians.

4.3 Data Collection

4.3.1 Tests

In order to address the research questions, it was necessary to establish a baseline of the students' prior knowledge concerning the mathematical concepts that would be explored. Identical surveys were administered both before and after the intervention to assess how the introduction of the LB tool impacted students' conceptual understanding of mathematics, as well as how they perceived the two instructional media used (Whiteboard and LB). To answer the research question, each student received an overall score based on their correct responses, and the scores obtained before the intervention, immediately after the intervention, and fifteen days later were compared. Throughout the research process, from the beginning to the post-test period, students did not engage with the instructional content outside of the research context, ensuring that their exposure was limited to the tools used.

To assess the students' cognitive level, we consulted the PISA 2009 framework, and performance tests were utilized to measure achievement in the units taught. Consequently, the data collection followed a similar methodology to that employed by other researchers who measured the cognitive performance of children, with some incorporating digital educational games during mathematics instruction (Fokidis & Pachidis, 2017; PISA, 2010). Furthermore, the diagnostic tests for sixth-grade students were designed in accordance with the recommendations of the Institute of Educational Policy (IEP) regarding national diagnostic exams. Specifically: (a) the pre-test was used to assess students' prior knowledge and confirm a shared cognitive starting point; (b) evaluation sheets were administered immediately following each session to capture the immediate learning outcomes; and (c) a delayed post-test was administered approximately fifteen days after the intervention to assess knowledge retention. The aforementioned diagnostic tests, standardized for each age group, primarily consisted of closed-type questions (true/false, multiple choice, fill-in-the-blank, table completion, and problem-solving). The questions/exercises were similar and inspired by those found in the school textbook.

4.3.2 Observation

By observing, the researchers gathered extra insights into students' comprehension of the new material, and paid attention to students' body language during the research process and later when the video recordings were transcribed. This served as a valuable supplementary data collection tool, which, alongside pre-tests, main tests, and delayed tests, helped uncover significant information about the topic under investigation and for future studies on the topic (Cohen *et al.*, 2000).

4.3.3 Internal Consistency & Reliability-Cronbach's Alpha

According to DeVellis (2016), Cronbach's Alpha helps to ensure that items in a test consistently reflect the same underlying cognitive construct. Therefore, a crucial step in test validation is to check whether the items or subtests have internal consistency and coherence (Gliem & Gliem, 2003). Using PSPP, after entering the scores given by the research subjects for each cognitive task, this consistency was measured. The thirty children who took part in the research completed cognitive tests designed to measure how they perceive and solve problems using two different tools during their class. The analysis of the cognitive test showed a high correlation between the test items and strong internal consistency, with a Cronbach's Alpha value of 0.81, which is considered acceptable for psychological and cognitive assessments (Nunnally & Bernstein, 1994). Therefore, the cognitive test demonstrated sufficient internal coherence, allowing the use of aggregated scores for further analysis.

4.4 Data Analysis

4.4.1 Statistical analysis

4.4.1.1 Baseline Equivalence

A pre-test was administered to establish the comparability of participants' baseline mathematics abilities prior to intervention. Analysis of the results revealed a high degree of uniformity:

- Mode and Frequency: Both groups exhibited a mode of 10 with a frequency of 9.
- Median: Both groups achieved a median score of 10.
- Mean Scores: LB group: M=9.72, Whiteboard group: M=9.71

These findings confirmed the homogeneity of the two groups at baseline, thereby enhancing the validity of subsequent comparative analyses. The study design, incorporating randomization and pre-test evaluations, ensured that observed outcomes could be attributed to the instructional methods rather than pre-existing differences.

4.4.1.2 Immediate Post-Instruction Performance

Following the instructional intervention, participants completed a standardized cognitive assessment to evaluate the effectiveness of the two teaching methods. The results demonstrated minimal variation between groups:

- Mean Scores: LB group: M=9.70, Whiteboard group: M=9.69
- Mode and Median: Both groups maintained a mode of 10 and a median of 10.

To determine the statistical significance of the difference in mean scores, a t-test was conducted:

- t-value: 0.042 (df = 28),
- Critical t-value (one-tailed): 1.70,
- p-value: 0.48.

The computed t-value fell substantially below the critical threshold, and the p-value exceeded the conventional significance level of 0.05. These results indicate that the observed differences in cognitive performance between the two instructional methods are not statistically significant.

4.4.1.3 Retention Analysis

The post-tests' findings indicated consistent performance across both groups:

- Mean Scores: LB group: M=9.58, Whiteboard group: M=9.57
- Mode: LB group: 10 (frequency = 7), Whiteboard group: 10 (frequency = 6)
- Median: LB group: 9.60, Whiteboard group: 9.50

As with the main-test analysis, a t-test was performed to evaluate the significance of these differences:

- t-value: 0.084 (df = 28)
- Critical t-value (one-tailed): 1.70
- p-value: 0.46

These results indicate that the minor observed differences in retention are not statistically significant. The similarity in mean scores and other metrics suggests that both instructional methods are equally effective in supporting the long-term retention of mathematical concepts.

4.4.2 Qualitative Feedback

In addition to quantitative measures, qualitative data were gathered through and classroom observations, providing insight into participants' experiences with each teaching method. Feedback from the LB group highlighted enhanced engagement, with students frequently citing the interactive and dynamic nature of the tool as a key benefit. It is noteworthy that consistent eye contact with the instructor was identified as a factor contributing to a sense of connection and focus. In contrast, feedback from the Whiteboard group emphasized the clarity of the method for understanding the material, though some students expressed a desire for greater visual enhancement, such as the use of color.

More precisely, students reported that using the LB during problem-solving activities maintained their attention and encouraged collaborative engagement with peers, creating a conducive learning environment. Students in the Whiteboard groups noted that the instructor frequently turned away to write, which limited direct interaction and occasionally disrupted their engagement with the lesson.

These qualitative insights align with prior literature suggesting that interactive and visual tools can significantly influence student engagement and motivation (Wang & Antonenko, 2017). While the quantitative analysis demonstrated no significant performance differences, the qualitative feedback suggests potential areas for enhancement, particularly in the domain of engagement.

4.4.3 Validity & Reliability

The study's validity is supported by Cronbach's Alpha analysis, ensuring internal consistency, while the novelty of concepts for participants bolstered internal validity by eliminating prior cognitive biases. Reliability is affirmed through the instruments' prior use in similar studies, validating their effectiveness in measuring intended constructs (Cohen *et al.*, 2000). External validity, reflecting the generalizability of results, was addressed through robust sampling and comprehensive coverage of examined variables. Specifically, content validity was achieved by defining and measuring attitudes toward the teacher across immediacy, perception, and intimacy dimensions, with instructions provided in participants' native language to ensure clarity (Hughes, 2003).

Despite these strengths, limitations such as a small, homogenous sample restrict generalizability. Self-reported measures also introduce potential biases. Future research should address these by including diverse, larger samples and employing longitudinal designs to explore the sustained impacts of instructional methods. Prior research (Firouzian *et al.*, 2016) aligns with these outcomes, further substantiating reliability. The study's methodology, standardized protocols, and consistent results across comparable environments ensure replicability, supporting its reliability and adherence to experimental standards (Cohen *et al.*, 2000).

5. Results and Discussion

This study tested the hypothesis that LB technology enhances cognitive performance compared to the traditional Whiteboard. The results revealed no statistically significant difference in cognitive performance and retention of mathematical concepts between the LB and Whiteboard groups. These findings support that both tools are equally effective in facilitating cognitive outcomes. While the LB group appeared to show slightly higher engagement and marginally improved post-test medians, these differences were not substantial enough to suggest a definitive advantage, indicating that the two tools may offer similar levels of effectiveness.

Our findings that the LB slightly outperforms the Whiteboard in engagement align with Skibinski *et al.*'s (2015) research, which demonstrated the effectiveness of dynamic tools in fostering student focus. Similarly, Beatty (2019) emphasized the role of visual aids in promoting participation. By extending these insights, the current study highlights the LB's capacity to enhance engagement beyond cognitive outcomes, suggesting its potential to support diverse learning objectives. Both tools effectively supported comprehension and engagement through structured, real-time demonstrations and clear visual presentation. Minimal variance in test scores further underscores their comparable efficacy. The use of consistent curricula and teaching methods across groups minimized external influences, ensuring a fair assessment of the tools' impacts on learning. This consistency aligns with prior research emphasizing the importance of reliability in instructional design (Firouzian *et al.*, 2016).

Qualitative feedback provides additional insights. Students described the LB as engaging and highlighted its ability to maintain teacher-student eye contact, a factor known to enhance motivation and concentration (Wang & Antonenko, 2017). The LB's digital and transparent features fostered a sense of immersion, with students likening the experience to "*being in the iPad but in front of us*." Conversely, the Whiteboard's familiarity remained a strength, though some students noted disengagement when the teacher turned away while writing. Both tools received suggestions for improvement, such as incorporating more colors, and highlighting the universal importance of visually enriched materials (Mayer, 2004).

The slight engagement advantage observed with the LB suggests its potential as an effective tool in classrooms, prioritizing interaction and teacher-student connection. This aligns with Wilson and Korn's (2007) findings that tools facilitating eye contact contribute to a supportive learning environment. However, the results also affirm the Whiteboard's continued relevance as a reliable, effective teaching tool.

In conclusion, while both the LB and Whiteboard support cognitive performance and retention effectively, the LB's interactive features present promising opportunities for enhancing engagement (McCorkle & Whitener, 2020). Further investigation into their long-term impacts and use in varied educational contexts could inform more comprehensive instructional strategies.

6. Recommendations

Future research should investigate the LB's role in complementing other instructional technologies to maximize its potential benefits. Longitudinal studies and diverse sample populations will further elucidate the LB's long-term impact and adaptability, ensuring its effective integration into evolving pedagogical frameworks.

A key limitation of this study is the relatively small and homogenous sample, which restricts generalizability. Additionally, the 15-day interval between the main test and post-test may not fully capture long-term retention (Bell & Kozlowski, 2008). Future research with different age groups, across different subjects, different educational contexts and extended follow-up periods could provide deeper insights into the tools' broader applicability and sustained impacts. It is also recommended that future evaluations of the LB not only highlight its advantages, but also examine potential challenges associated with its use. This includes addressing technical issues that may arise during operation, the costs of maintenance and equipment, and the learning curve for educators who may lack prior training. Considering these barriers would provide a more comprehensive understanding of the LB's feasibility and its practical implications for broader implementation.

Lastly, further research should examine students' attitudes toward instructors utilizing the LB and their perceptions of the tool itself. Exploring these attitudes in greater depth and across varied contexts will provide critical insights into the dynamics of teacher-student interactions and the extent to which the LB influences students' engagement, motivation, and overall learning experience. Replicating such studies with diverse populations and longitudinal designs could validate and enrich our understanding of these attitudinal factors.

7. Conclusion

This study demonstrates the LB as an effective instructional tool, achieving cognitive outcomes comparable to the widely used Whiteboard. This equivalence is particularly significant given the Whiteboard's longstanding reputation as a reliable educational aid. The LB not only matches the cognitive support provided by the Whiteboard but also offers unique advantages, such as fostering engagement and maintaining consistent teacher-student eye contact, which may enhance classroom dynamics and student motivation. Although differences in cognitive outcomes between the two methods were statistically insignificant, the LB's slight edge in engagement suggests its potential value in interactive and high-participation learning environments. This conclusion aligns with previous research, such as that of Firouzian *et al.* (2016) and Skibinski *et al.* (2015).

All things considered, both tools demonstrated their efficacy in delivering structured, visually clear instruction and facilitating comprehension and retention of mathematical concepts. The LB, however, represents an innovative option for modern classrooms, blending traditional reliability with engaging design elements. By integrating the LB into a broader ecosystem of educational tools, such as interactive Whiteboards, virtual platforms, and augmented reality (AR), educators could also create a multimodal approach that supports diverse aspects of the learning process, including visual engagement, collaboration, and individualized learning.

Conflict of Interest Statement

The authors declare no conflicts of interest.

About the Authors

Eftychia Aslanidou is a PhD Candidate at the Ionian University, Department of Digital Media & Communication and the Head of Studies at The Hellenic American MKO. She began her academic journey at the School of Primary Education, University of Crete (Valedictorian, Class of '12). She was recognized by the State Scholarship Foundation for her exemplary character and outstanding academic performance, earning the distinction of "top graduate student in Greece" for each academic year between 2008 and 2012. Additionally, she was awarded the "Triantafyllia Kriezi" scholarship as the highest-ranking Macedonian student. Driven by a commitment to expanding her knowledge and contributing to the education of children in Greece, Eftychia pursued advanced studies in bilingualism in New York, attending the City University of New York, Long Island University, and Westchester College. During this period, she also taught at the Greek-American school Plato. Upon returning to Greece, she furthered her academic pursuits in Inclusive Education at the European University of Cyprus and Preschool Education at Aristotle University. Eftychia has actively disseminated her research on inclusive education through national conferences and academic journals. She served as a public school educator in Zakynthos before co-founding The Hellenic American MKO, a non-profit organization, alongside Steve Krause. Through this initiative, she designed a model learning center aimed at delivering high-quality, individualized education to meet the diverse needs of children in Zakynthos.

Georgios P. Heliades is an Associate Professor in the Department of Digital Media and Communication at the Ionian University at Kefalonia. He holds a Degree in Computing and has completed postgraduate and doctoral studies in Human-Computer Interaction in UK universities. He spent an eight-year period at Loughborough University, UK, researching and teaching, alongside pioneering names in the convergence of science and art. After years of presence in the European IT and Telecommunications market as a business executive, he returned to academia. Since 2004, he has been teaching at the Ionian Islands Institute of Technology, Department of Sound Technology and Musical Instruments and at the Ionian University since 2018. He has served as the Head of these two departments for a total of eight years through which he has organized a good number of conferences and workshops. His research record holds a fair number of journal and conference publications in the research areas of user experience, digital media in education and audiovisual production.

References

Aslanidou, E., & Heliades, G. P. (2024). *The students' attitude towards the teacher who uses the Lightboard technology while teaching.* Research presented in 2024 First International & Pedagogical Conference of DIPE, Pieria, Greece.

Aslanidou, E. (2019). Home Learning Activities and Children's Learning Outcomes: A Review of Recent Evidence. *European Journal of Education Studies, 6 (1*), 100-159. http://dx.doi.org/10.46827/ejes.v0i0.2375.

Beatty, B. J. (2019). Hybrid-Flexible Course Design: Implementing student-directed hybrid classes. https://doi.org/10.59668/33

Bell, B. S., & Kozlowski, S. W. J. (2008). Active Learning: Effects of Core Training Design Elements on Self-Regulatory Processes, Learning, and Adaptability. *Journal of Applied Psychology, 93*, 296-316. https://doi.org/10.1037/0021-9010.93.2.296

Birdwell, J. A., & Peshkin, M. (2015). Capturing technical lectures on Lightboard. In *2015 ASEE Annual Conference & Exposition* (pp. 26-325). https://doi.org/10.18260/p.23664

Clark, R. C., & Mayer, R. E. (2016). *E-learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning*. Wiley. Doi:10.1002/9781119239086

Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education* (S. Kyranakis, M. Mavraki, Ch. Mitsopoulou, P. Bithara, & M. Filopoulou, Trans.) (5th ed.). Metaixmio. (Original work published 2000). Retrieved from https://www.akademika.no/studieteknikk/metode/research-methods-education/9781138209886

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (4th ed.). Thousand Oaks, CA: Sage. Retrieved from https://www.ucg.ac.me/skladiste/blog_609332/objava_105202/fajlovi/Creswell.pdf

DeVellis, R. F. (2016). *Scale Development: Theory and Applications* (4th ed.). SAGE Publications. Retrieved from https://books.google.com.pe/books?id=48ACCwAAQBAJ&printsec=frontcover#v=onepage&q&f=false

Firouzian, S., Rasmussen, C., & Anderson, M. (2016). Adaptations of learning glass solutions in undergraduate STEM education. *The XIX Annual Conference on Research on Undergraduate Mathematics Education*, 25-27. Retrieved from https://www.researchgate.net/publication/299395180_Adaptations_of_learning_glass_solutions_in_undergraduate_STEM_education

Fokidis, E., & Pachidis, G. (2017). Digital educational games, mathematics, and primary school students. Results of a pilot project. *Open Education: The Journal for Open and Distance Education and Educational Technology, 13 (2),* 77-96. https://doi.org/10.12681/jode.14061

Fullan, M. & Langworthy, M. (2014). *A Rich Seam: How New Pedagogies Find Deep Learning*. London: Pearson. Retrieved from https://www.michaelfullan.ca/wp-content/uploads/2014/01/3897.Rich_Seam_web.pdf

Fung, F. M. (2017). Adopting Lightboard for a Chemistry flipped classroom to improve technology-enhanced videos for better learner engagement. *Journal of Chemical*

Education, 94(7), 956-959. Doi: 10.1021/acs.jchemed.7b00004. Retrieved from https://pubs.acs.org/doi/10.1021/acs.jchemed.7b00004

General Data Protection Regulation (GDPR). (2016). Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). *Official Journal of the European Union, L119*, 1-88. Retrieved from http://data.europa.eu/eli/reg/2016/679/oj

Gliem, J. A., & Gliem, R. R. (2003). Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. *Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education.* Retrieved from https://scholarworks.iupui.edu/bitstream/handle/1805/344/Gliem%20%26%20Gliem.pdf?sequence=1&isAllowed=y, last accessed 2024/11/12.

Goswami, U., & Bryant, P. (2007). *Children's cognitive development and learning. Cambridge Primary Review Research Survey 2/1a*. University of Cambridge Faculty of Education. Retrieved from https://cprtrust.org.uk/wp-content/uploads/2015/02/COMPLETE-REPORT-Goswami-Childrens-Cognitive-Development-and-Learning.pdf, last accessed 2024/12/10.

Hall, S., & Villareal, D. (2015). The hybrid advantage: Graduate student perspectives of hybrid education courses. *International Journal of Teaching and Learning in Higher Education, 27*(1), 69-80. Retrieved from https://www.isetl.org/ijtlhe/pdf/IJTLHE1897.pdf

Hughes, A. (2003). *Testing for language teachers.* Cambridge University Press. https://doi.org/10.1017/CBO9780511732980

Johnson, D. W, & Johnson, R. T. (2015). *Cooperation and Competition.* International Encyclopedia of the Social & Behavioral Sciences (Second Edition). Elsevier. Doi: https://doi.org/10.1016/B978-0-08-097086-8.24051-8.

Lubrick, M., Zhou, G., & Zhang, J. (2019). Is the future bright? The potential of lightboard videos for student achievement and engagement in learning. *EURASIA Journal of Mathematics, Science and Technology Education, 15*(8). https://doi.org/10.29333/ejmste/108437

Matthews, M., & Zimmerman, W. (2020). The impact of visual displays on learning across the disciplines: A systematic review. *Educational Psychology Review*, 32(3), 697–736. https://doi.org/10.1007/s10648-020-09523-3

Mayer, R. E. (2004). Should There Be a Three-Strikes Rule Against Pure Discovery Learning? The Case for Guided Methods of Instruction. *American Psychologist, 59*, 14-19. https://doi.org/10.1037/0003-066x.59.1.14

McCorkle, S., & Whitener, P. (2020). The Lightboard: Expectations and experiences. *International Journal of Designs for Learning, 11*(1), 75–84. https://doi.org/10.14434/ijdl.v11i1.24642

Michael, D., Tsigilis, N., Michaelidou, V., Gregoriadis, A., Charalambous, V., & Vrasidas, C. (2024). Evaluating the classroom environment: Multilevel validation and measurement invariance of classroom behavioral climate. *Journal of Psychoeducational Assessment*, *0*(0). https://doi.org/10.1177/07342829241242350

Misirlis, N., & Munawar, H. B. (2022). An analysis of the technology acceptance model in understanding university students' behavioral intention to use metaverse technologies. In *12th International Conference: The Future of Education*(pp. 159-163). https://doi.org/10.48550/arxiv.2302.02176

Negi, P. S., Negi, V., & Pandey, A. C. (2011). Impact of information technology on learning, teaching, and human resource management in the educational sector. *International Journal of Computer Science and Telecommunications*, *2*(4), 66-72. https://doi.org/10.26483/ijarcs.v2i4.598

Neofotistos, V., & Karavakou, V. (2018). Factors Influencing the Use of ICT in Greek Primary Education. *Open Journal for Educational Research (OJER), 2 (2),* 73-88. http://dx.doi.org/10.32591/coas.ojer.0202.02073n

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric Theory* (3rd ed.). McGraw-Hill. Retrieved from https://books.google.no/books/about/Psychometric_Theory.html?id=r0fuAAAAMAAJ&redir_esc=y

Paivio, A. (1990). Dual Coding Theory. In Mental Representations: A Dual Coding Approach (pp. 583-605). Oxford: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195066661.003.0004

Papaioannou, A., Milosis, D., Kosmidou, E., & Tsigilis, N. (2002). Multidimensional structure of goal orientations: The importance of adopting a personal development goal in physical education. *Psychologia, 9*, 494-513. https://doi.org/10.12681/psy_hps.24075

PISA (2010). PISA 2009 Results: *What Students Know and Can Do: Student Performance in Reading, Mathematics and Science*. Italy: OECD. Retrieved from https://www.oecd-ilibrary.org/education/pisa-2009-results-what-students-know-and-can-do_9789264091450-en

Rogers, P. D., & Botnaru, D. T. (2019). Shedding light on student learning through the use of Lightboard videos. *International Journal for the Scholarship of Teaching and Learning, 13*(3), 6. http://dx.doi.org/10.20429/ijsotl.2019.130306

Saavedra, A., & Opfer, V. (2012). *Teaching and Learning 21st Century Skills: Lessons from the Learning Sciences. A Global Cities Education Network Report*, New York: Asia Society. Retrieved from http://asiasociety.org/files/rand-0512report.pdf

Schweiker, S. S., & Levonis, S. M. (2020). A quick guide to producing a virtual chemistry course for online education. *Future Medicinal Chemistry, 12*(14), 1289-1291. https://doi.org/10.4155/fmc-2020-0103

Skibinski, E. S., DeBenedetti, J. I., Ortoll-Bloch, A. G., & Hines, M. A. (2015). A blackboard for the 21st century: An inexpensive Lightboard projection system for classroom use. *Journal of Chemical Education, 92*(10), 1754-1756. Retrieved from https://pubs.acs.org/doi/10.1021/acs.jchemed.5b00155

Talanda-Fisher, M. (2020). Through the learning glass. *STEM Instructional Graduate Teaching Assistant Posters, 18*. Retrieved from https://scholarworks.wmich.edu/stem-gta-posters/18

Tankersley, M., Harjusola-Webb, S., & Landrum, T. J. (2008). Using single-subject research to establish the evidence base of special education. *Intervention in School & Clinic, 44*(2), 83-90. https://doi.org/10.1177/1053451208321600

Teddlie, C. and Tashakkori, A. (2009) Foundations of Mixed Methods Research: Integrating Quantitative and Qualitative Approaches in the Social and Behavioral Sciences. Sage, London. Retrieved from https://www.academia.edu/15527309/C_Teddlie_and_A_Tashakkori_Foundations_of_Mixed_Methods_Research_Integrating_Quantitative_and_Qualitative_Approaches_in_the_Social_and_Behavioural_Sciences_Sage_Publications_Los_Angeles_2008_RRP_AUD_81_00_ISBN_9780761930129, *last accessed 2024/11/30.*

Tosheva, N., & Abdullaeva, G. (2022). The concept of innovation and types of innovative technologies. *Scientific Progress, 3*(3), 586-589. Retrieved from https://cyberleninka.ru/article/n/the-concept-of-innovation-and-types-of-innovative-technologies

UNESCO. (2014). *Teaching and learning: Achieving quality for all*. Education for All Global Monitoring Report 2013/4. United Nations Educational, Scientific and Cultural Organization. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000225660

Wang, J., & Antonenko, P. D. (2017). Instructor presence in instructional video: Effects on visual attention, recall, and perceived learning. *Computers in Human Behavior, 71*, 79–89. https://doi.org/10.1016/j.chb.2017.01.049

Wilson, K., & Korn, J. H. (2007). Attention During Lectures: Beyond Ten Minutes. Teaching of Psychology, 34, 84-89. Retrieved from https://www.scirp.org/reference/referencespapers?referenceid=2625419.

Yang, S., Carter, R. A., Zhang, L., & Hunt, T. (2021). Emanant themes of blended learning in K 12 educational environments: Lessons from the Every Student Succeeds Act. *Computers & Education, 163*. https://doi.org/10.1016/j.compedu.2020.104116