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Embracing Digital Technology: The Use of Interactive Flat Panels (IFPs) in Science Education

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Abstract

Digital technology is increasingly integrated into education and is encouraging the use of interactive devices in classrooms. One of the widely used devices is the interactive flat panels (IFPs), which has the potential to improve learning effectiveness. This case study aims to explore the impact of IFP use on student learning outcomes and identify student perceptions of its implementation in the classroom. This study employed an explanatory sequential mixed methods design, beginning with a quantitative analysis of students' learning outcomes and perceptions using paired-sample t-tests and effect size calculations. Subsequently, semi-structured interviews were conducted to further explore and explain the quantitative findings. The results indicate that the use of IFPs in science learning significantly improves students' learning outcomes ($t = -16.540$, $p < .05$), with a large effect size (Cohen's $d = 2.7$). In addition, students demonstrate positive perceptions of IFP use, particularly in terms of supporting their understanding of vibration and wave concepts as well as its ease of use. Nevertheless, several students reported experiencing discomfort when viewing the IFP screen for extended periods. These findings provide implications for optimizing the use of IFP to ensure more effective implementation while maintaining students' comfort during the learning process.

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Kata Kunci

Panel Datar Interaktif;
Hasil Belajar;
Persepsi Murid;
Pembelajaran IPA;
Teknologi Digital.

Abstrak

Teknologi digital semakin terintegrasi dalam pendidikan dan mendorong pemanfaatan perangkat interaktif di ruang kelas. Salah satu perangkat yang banyak digunakan adalah interactive flat panel (IFP) yang berpotensi meningkatkan efektivitas pembelajaran. Penelitian studi kasus ini bertujuan untuk mengeksplorasi pengaruh penggunaan IFP terhadap hasil belajar murid serta mengidentifikasi persepsi murid terhadap implementasinya di kelas. Penelitian ini menggunakan desain explanatory sequential mixed methods, yang diawali dengan analisis kuantitatif terhadap data hasil belajar dan persepsi murid menggunakan uji t berpasangan dan perhitungan effect size. Tahap selanjutnya dilakukan wawancara semi-terstruktur untuk memperdalam dan menjelaskan temuan kuantitatif. Hasil penelitian menunjukkan bahwa penggunaan IFP dalam pembelajaran IPA secara signifikan meningkatkan hasil belajar murid ($t = -16.540$, $p < .05$) dengan hasil effect size yang besar (Cohen's $d = 2.7$). Selain itu, murid menunjukkan persepsi positif terhadap penggunaan IFP, terutama dalam aspek dukungan pemahaman konsep getaran dan gelombang serta aspek kemudahan penggunaan. Meskipun demikian, beberapa murid melaporkan ketidaknyamanan saat menatap layar IFP dalam durasi yang cukup lama. Temuan ini memberikan implikasi bagi optimalisasi pemanfaatan IFP agar lebih efektif dan ramah bagi kenyamanan murid dalam proses pembelajaran.

A. Introduction

Over the past two decades, digital technology has played an increasingly significant role in education. Learning experiences during the COVID-19 pandemic clearly demonstrated that digital technologies can facilitate teachers in conducting learning activities that were previously difficult to implement through conventional approaches. This condition has been supported by the rapid development of digital technological devices in terms of both features and performance, as well as the increasingly widespread accessibility of these technologies (Clark-Wilson et al., 2020). Currently, learning activities in many educational institutions have become more diverse with the emergence of various digital technology products. Moreover, the role of the teacher has also undergone a transformation, from initially functioning as the main provider of material to being a facilitator whose job is to design the learning processes, provide direction, and constantly evaluate students' development and learning outcomes (Kozma, 2003).

The use of digital technology in the learning process requires teachers to possess an adequate set of professional competencies. These competencies encompass not only technical mastery of digital devices but also pedagogical skills to effectively integrate technology into teaching activities. Therefore, in many countries, teacher professional development programs focused on the use of digital technology have been widely implemented (Gabriel et al., 2022; Musarokah et al., 2026). These training programs are designed to help teachers understand the potential of technology to support learning objectives, select and use appropriate devices, and design innovative, student-centered learning strategies (Khoir, 2025). Through such training, teachers become more confident and motivated in using digital technology into their teaching practices.

In line with various initiatives undertaken in several countries, the Indonesian government has also taken strategic steps to improve teachers' ICT competencies. These efforts have been realized through various professional development programs, such as Technology and Communication Based Learning (PembaTIK) and Micro-Credential Scholarship program. In addition to improving teacher capacity, attention is also directed to equitable distribution of digital education services. One of the initiatives launched was "*Digitalisasi Pembelajaran untuk Indonesia Cerdas*" program on 17 November 2025 (BPMI Setpres, 2025). This program aims to support the improvement of learning quality through the provision of interactive flat panels (IFPs) devices for more than 280,000 schools across Indonesia (Jatnika, 2025).

IPFs are known by various terms, such as interactive whiteboards (IWBs), smart boards, and digital whiteboards. An interactive whiteboard is a large touchscreen display that allows users to write, draw, and operate various applications (Campbell et al., 2019). This device can function either as a standalone touchscreen computer or be connected to another computer (Bourbour, 2023). With their diverse features, interactive whiteboards can provide numerous benefits for students (Yang et al., 2012).

In many countries, IFPs have long been utilized in educational settings, particularly in Europe and the United States (Tsai, 2019). As these devices has become increasingly widely used in educational settings, various studies have been conducted to assess its effectiveness in improving the quality of learning. An experimental study conducted by Aktas & Aydin (2016) showed that students who participated in learning using smart boards achieved higher academic test scores compared to students who participated in learning without using these devices. The ability of IFPs to display various media, such as images, videos, and simulations, is an important factor in improving student understanding (Tsayang et al., 2020; Budiarto, 2024). In addition, through mixed method study, Chowdhury (2024) found that interactive whiteboards can significantly enhance student engagement in the learning process. This technology allows the integration of various digital media sources and interactive activities that can encourage active student participation in learning activities.

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From students' perspectives, the use of interactive whiteboards is perceived as helping them understand the subject matter while providing an opportunity for them to be more actively involved in the learning process (Tsayang et al., 2020). Learning materials become more engaging and easier to understand because they are presented with various multimedia (Kırbaş, 2018). Various studies have shown that students generally have a positive perception of the use of interactive whiteboards, primarily because this technology can create a fun learning experience and support more effective conceptual understanding (Aytaç, 2013; Kırbaş, 2018; Tsayang et al., 2020).

However, studies investigating the use of IFPs in teaching and learning, particularly at the primary education level, remain limited in Indonesia. This limitation is partly related to the unequal availability of IFP facilities in schools in the previous years. Furthermore, in the context of science education, studies examining the impact of interactive whiteboard use on student skills and learning outcomes are also relatively few, requiring further research attention (Ormanci et al., 2015). Along with the implementation of *"Digitalisasi Pembelajaran untuk Indonesia Cerdas"* program, an increasing number of schools are starting to be equipped with IFP devices. This development opens up opportunities and demonstrates the need to explore how the initial implementation of IFPs can affect the learning process and outcomes in the classroom. Therefore, this study was conducted to examine the impact of the initial implementation of IFPs on students' cognitive learning outcomes and to determine students' perceptions of the use of this technology in learning.

This research is expected to contribute to the development of studies on the use of IFPs, in the context of primary education. Theoretically, the results of this study can enrich the literature discussing the relationship between the use of interactive whiteboard technology with cognitive learning outcomes and student engagement in science learning, while also providing an empirical picture of how the initial implementation of digital technology in the classroom affects students' learning experiences. Practically, the findings of this study are expected to provide input for teachers in utilizing IFP devices more effectively to support interactive and meaningful learning, as well as serve as a reference for schools in optimizing the use of available technological facilities. Furthermore, from an education policy perspective, the results of this study are also expected to provide empirical information for policymakers in evaluating and developing learning digitalization programs, particularly those related to the provision and utilization of IFP devices in schools.

B. Method

This study employed a case study approach focusing on science teaching practices using an interactive flat panel (IFP) at a public junior secondary school in Tanjung Jabung Barat Regency, Jambi Province. This case study adopted an explanatory sequential mixed methods design within a case study framework. Creswell & Clark (2018) explain that the explanatory sequential mixed methods design begins with quantitative data collection and analysis, followed by qualitative data collection and analysis to provide a more in-depth explanation of the quantitative findings.

The participants in this study consisted of 24 eighth-grade students (11 males and 13 females) aged between 14 and 16 years. The participants were selected using convenience sampling based on the researcher's accessibility to the class where the implementation took place. None of the participants had prior experience using an IFP. During lessons on vibrations and waves, the IFP supported direct student interaction through the touchscreen during exploration and observation activities. As a result, the instruction was not limited to expository teaching but also involved active student engagement throughout the lesson. The interactive media used included PhET simulations, YouTube videos, and Wayground.

The research instruments included a learning achievement test, a student perception questionnaire, and a semi-structured interview guide. The learning achievement test was used to measure students' learning outcomes on the topic of vibrations and waves through a pretest–posttest design consisting of 20 items. The quality of the test instrument was evaluated using Rasch modelling to obtain evidence of validity based on the fit of the data to the model, as well as to estimate measurement reliability. The analysis results indicate adequate measurement consistency at the respondent level, as reflected by the person reliability values (Real = .75; Model = .77) and the score reliability coefficient (KR-20/Cronbach's Alpha = .77). The separation indices (Real = 1.72; Model = 1.85) indicate that the instrument was able to distinguish students' abilities into more than one stratum. Model–data fit was also supported by the mean INFIT MNSQ value, which was close to 1.00, and the mean OUTFIT MNSQ value, which fell within the acceptable range (≈ .86). Furthermore, the very high correlation between person raw scores and Rasch measures (≈ .99) reinforces the consistency between the observed scores and the Rasch logit estimates. Overall, the test instrument demonstrates acceptable measurement quality and is appropriate for use in evaluating learning outcomes within the context of this study.

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The student perception questionnaire was used to examine students' responses to the implementation of the IFP. It consisted of 15 closed-ended items rated on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The instrument was designed to assess five aspects: ease of use, support for conceptual understanding of vibrations and waves, student engagement, clarity of content presentation and management of cognitive load, and the perceived usefulness and acceptance of IFP use.

The interview instrument used in this study was a semi-structured interview guide designed to explore students' experiences and perspectives regarding the use of IFPs in science learning on the topic of vibrations and waves. The interview guide included a number of open-ended questions that served as the primary guideline, while still providing flexibility for researchers to ask follow-up questions based on the participants' responses. The questions in the interview guide were designed to explore several key aspects, including learning experiences using IFPs, perceptions of the device's ease of use, its impact on conceptual understanding, and the level of student engagement during the learning process.

Data were collected through a pretest administered prior to the implementation of IFP-assisted instruction, followed by science instruction on the topic of vibrations and waves supported by the IFP over four instructional sessions. At the end of the instructional period, a posttest was administered and students completed the perception questionnaire. Learning outcome data were analyzed using statistical analyses. Differences between pretest and posttest scores were examined using a paired-samples *t*-test after confirming the normality of the score differences, and effect size was reported using Cohen's *d*. Subsequently, semi-structured interviews were conducted to provide deeper insights into the quantitative findings, particularly regarding improvements in learning outcomes and students' responses to the use of the IFP in the learning process.

C. Results and Discussion

The section presents the finding of the study obtained through the pretest and posttest on cognitive learning outcome, filling out the perception questionnaire, and interviews. In the discussion, the findings are analysed by linking them to relevant theories and previous research to answer the research questions.

1. Results

1.1 Demographics

The study involved 24 participants with a relatively balanced gender distribution. As shown in Table 1, most participants were 14 years old. All participants had the same level of prior experience with the IFP, as none had previously used the device.

Table 1. Partisipans' Demographic Profile

	n	%
Age		
14	20	83.3
15	3	12.5
16	1	4.2
Gender		
Male	11	45.8
Female	13	54.2
Learning Experiences Using the Interactive Flat Panels (IFPs)		
Did not have experience	24	100

1.2 Quantitative Findings

a. Learning Outcome Improvement

A pretest was administered at the beginning of the study and a posttest at the end. Descriptive analysis showed differences in students' learning outcomes before and after science instruction using the IFP. The mean posttest score was higher than the mean pretest score, indicating improved conceptual understanding of vibrations and waves (Table 2).

Table 2. Descriptive Statistics of Students' Learning Outcomes

	N	Minimum	Maximum	Mean	Std. Deviation
Pretest	24	5	35	17.50	8.85
Posttest	24	20	95	57.92	19.22

The Shapiro–Wilk test indicated that the difference between pretest and posttest scores was normally distributed ($p = .29$). Therefore, a paired-samples t-test was conducted to examine differences in learning outcomes before and after instruction. The results showed a significant difference between the mean pretest and posttest scores ($t = -16.540$, $p < .05$). The analysis was further extended by calculating the effect size to determine the magnitude of the difference. The calculation was performed using an

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effect size calculator (Lenhard & Lenhard, 2022), which yielded a Cohen's *d* value of 2.7, indicating a very large effect size. This result suggests that science instruction supported by the IFPs had a strong impact on students' learning outcomes.

b. Students' Perceptions of the Interactive Flat Panels

Descriptive analysis indicates that students report highly positive perceptions of the use of the IFP in science instruction, with all aspects yielding mean scores above 3.41, reflecting perceptions ranging from positive to highly positive (Table 3).

Table 3. Descriptive Statistics of Students' Perceptions of Interactive Flat Panels

Aspect	Mean	Std. Deviation
Ease of use	4.40	.39
support for conceptual understanding	4.52	.32
Student engagement	3.97	.45
Clarity of content presentation and management of cognitive load	4.11	.34
Perceived usefulness and acceptance	4.33	.29

The aspect with the highest average score was support for understanding the concepts of vibration and waves (M = 4.53, SD = .32). This finding suggests that the visualizations and simulations presented through IFP help students understand abstract concepts. Additionally, the aspects of ease of use (M = 4.40, SD = .39) and perceived usefulness and acceptance (M = 4.33, SD = .29) were also rated as highly positive, suggesting that students found the technology easy to use and beneficial for learning.

The aspect of clarity of presentation and cognitive load management obtained a mean score of 4.11 (SD = .34), indicating that the use of the IFPs provided clear instruction without imposing excessive cognitive load on most students. Meanwhile, the aspect with the lowest score was student engagement (M = 3.97, SD = .45), although it still fell within the positive category. This suggests that, while the IFPs support understanding, not all students demonstrate the same level of improvement in learning engagement.

1.3 Qualitative Findings

Based on these quantitative findings, the analysis continued by selecting interview subjects to deepen our understanding of students' learning experiences using an IFP. Subject selection was conducted purposively, taking into account variations in learning outcome scores and perception scores across the five analysed aspects. This strategy aimed to obtain a more comprehensive picture of the relationship between student perceptions and improved learning outcomes. Eight students who obtained the lowest and highest scores on the posttest were selected as interview participants. This approach enabled an in-depth exploration of factors that support or hinder improvements in learning outcomes, as well as how perceptions of visualization support, ease of use, learning engagement, and cognitive load management contribute to students' achievement.

Table 4 presents the themes and sample responses from the interview participants. Most participants reported that the use of simulations on the IFPs facilitated their understanding of vibration and wave concepts. One participant stated, "*Saya lebih mudah paham materinya kalau melihat simulasi di IFP.*" (I understand the material more easily when I see simulations on the IFP.) Another added, "*Simulasinya membuat saya mudah membayangkan gerakan bandul dan gelombang*." (The simulations help me visualize the motion of a pendulum and waves.) These findings suggest that dynamic visual representations support students in understanding concepts that are otherwise difficult to visualize. By seeing directly how a pendulum moves or how waves are formed, students can more easily connect the teacher's explanation with the examples shown on the screen.

Although some students showed improved understanding after using IFP, students with low posttest scores still experienced difficulties in the mathematical calculations. These difficulties emerged in various types of problems involving mathematical operations and identified from several student statements. One student stated, "*Saya masih kesulitan menghitung panjang gelombang*." (I still have difficulty calculating wavelengths.) Furthermore, other students also expressed similar difficulties in the calculation process, such as "*Saya bingung saat menggunakan rumus*." (I am confused when using formulas.) These statements indicate that calculation difficulties are a pattern that appears in the group of students with low learning outcomes, not limited to one particular type of concept.

Table 4. Themes and Sample Responses from Semi-Structured Interviews

Themes	Sample Responses
Understanding	"*Kalau pakai IFP, saya bisa langsung melihat simulasinya, jadi lebih mudah memahami materi dibandingkan hanya mendengarkan penjelasan guru.*" (When using the IFP, I

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Themes	Sample Responses
	could directly see the simulation, making it easier to understand the material than just listening to the teacher's explanation.) "*Karena ada video dan simulasi, saya jadi paham seperti apa satu getaran atau satu gelombang*." (Because there were videos and simulations, I was able to understand what a vibration or a wave looked like.)
Interactivity	"*Pembelajarannya jadi lebih seru karena bisa digerak-gerakkan langsung di layar*." (The lesson became more engaging because the content could be directly manipulated on the screen.) "*Ketika diberi kesempatan untuk maju dan menggunakan IFP, saya menjadi lebih fokus dan lebih cepat memahami materi*." (When I was given the opportunity to come forward and use the IFP, I became more focused and understood the material more quickly.)
Content presentation	"*Materinya jadi lebih menarik karena ada simulasi yang bisa langsung dilihat gerakannya*." (The material was more interesting because the simulations allowed me to directly see the motion.) "*Menurut saya, pembelajaran jadi tidak membosankan karena ada berbagai tampilan, seperti gambar dan video*." (I think the lesson was not boring because it used different formats, like images and videos.)
Challenge	"*Jika terlalu lama melihat layar IFP, mata saya terasa sakit dan kadang pusing*." (If I looked at the IFP screen for too long, my eyes started to hurt and I sometimes felt dizzy.) "*Cahaya layar yang terlalu terang membuat saya merasa silau, terutama ketika duduk di bagian depan*."(The screen was too bright, causing glare, especially when I sat at the front.)

Interactivity emerged as a key advantage of the IFPs highlighted by the interview participants. Phrases such as "could be moved", "could practice directly", and "could touch the screen" frequently appeared in student responses when describing their learning experiences. Participants stated that through the IFPs, they were able to try controlling the simulation themselves, which made them understand better and more engaged. The activity of coming forward to try the simulation directly was considered fun and helped strengthen understanding, as students not only listened but also actively engaged in the learning process. This indicates that the interactive aspect of the IFPs not only enhances visual appeal but also encourages cognitive engagement and active participation of students in building an understanding of the concepts of vibrations and waves.

The ability of the IFPs to present instructional content through multiple media formats was also highlighted by the interview participants. Students noted that, through the IFPs, teachers could go beyond text-based explanations by incorporating interactive simulations, instructional videos (e.g., from YouTube), illustrative images, and quizzes that support conceptual understanding. The variety of presentation formats makes vibration and wave content more concrete and less monotonous, as students can directly observe examples and relate the teacher's explanations to the visual representations displayed on the screen. For example, one interview participant stated, "*Saya suka pembelajaran dengan IFP karena bentuk materinya bisa bermacam-macam, seperti gambar dan video.*" (I like learning with IFPs because the materials can be presented in various formats, such as images and videos.) This statement indicates that media variety is a key attraction in using IFP. Similarly, another participant stated that when IFPs are simply used as regular whiteboards without simulations or videos, learning feels ordinary and not significantly different from a traditional classroom board. This finding indicates that the effectiveness of IFPs depends on the utilization of its multimodal features, not just the device itself.

Despite its many advantages, the use of IFPs also presented a number of challenges experienced by participants. Several students revealed that the high screen brightness caused glare, especially during long lessons or when they were asked to come to the front to write on the screen. This situation caused some students to experience discomfort, such as sore eyes or dizziness. One interview participant said, "*Kalau melihat IFP terlalu lama, mata saya terkadang terasa sakit.*" (If I looked at the IFP for too long, my eyes sometimes hurt.). Another participant echoed this sentiment, adding, "*Saya sekali-kali melihat ke arah lain agar mata saya tidak merasa silau.*" (I occasionally looked away to avoid the glare.). Even though the IFP screen brightness was set to the lowest level, some participants still felt uncomfortable staring at the screen for extended periods. These findings indicate that while IFPs have great potential to support learning, optimizing its use still requires technical management to prevent it from hindering students' learning.

2. Discussion

2.1 The Effect of Interactive Flat Panels on Learning Outcomes

The results of this study indicate that the use of interactive flat panels (IFPs) has an impact on improving student learning outcomes in the topic of vibrations and waves. This

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finding indicates that the integration of IFPs in science learning is an effective strategy to help students understand abstract concepts through the presentation of dynamic visualizations and multimedia integration. This finding is consistent with various previous empirical studies that reported that the use of interactive whiteboards contributes positively to students' academic achievement (Aktas & Aydin, 2016; Andleeb, 2022; Hasibuan et al., 2026; Hendawi & Nosair, 2020; Odoh, 2024; Onder & Aydin, 2016). Furthermore, a meta-analysis conducted by Shi et al. (2020) of 23 studies on the use of interactive whiteboards showed that these devices had a significant positive impact on students' cognitive learning outcomes with a medium effect size.

The large effect size observed in this study can be explained by several factors. First, students' prior understanding of vibration and wave concepts was limited, allowing visually rich and interactive instruction to produce substantial learning gains. Second, the IFP was not used merely as a substitute for a conventional board but was employed to deliver interactive simulations, quizzes, and instructional videos aligned with the targeted concepts. As suggested by Ormanci et al. (2015), content presented through the IFP should incorporate interactive visual elements, such as animations, videos, and simulations. In addition, varied presentation formats enable instruction to accommodate diverse learning styles among students (Shi et al., 2020). Third, technology integration was implemented in a planned manner and aligned with instructional objectives through activities designed to promote students' cognitive engagement. Therefore, the observed improvement in learning outcomes cannot be attributed solely to the use of the IFPs, but also to the pedagogical strategies and systematically designed learning activities. This finding is consistent with the view of Chowdhury (2024) who emphasize that the effectiveness of technology in education is strongly influenced by the quality of the accompanying instructional design.

Vibration and wave topics involve abstract concepts that are difficult to understand when presented only through verbal explanations or static images. Therefore, instructional media that can represent these concepts in a visual and dynamic manner—such as simulations and instructional videos—are needed to support students in developing deeper conceptual understanding. One widely used simulation tool in science education is PhET simulations (Ngandoh, 2022; Ringo & Mulvia, 2022). PhET simulations are designed as interactive and exploratory environments that emphasize the connection between everyday phenomena and scientific concepts, and visualize conceptual models of physics that cannot be directly observed (Perkins et al., 2006; Wieman et al., 2010). The direct interaction between student actions and visual responses to the PhET simulation also helps clarify causal relationships and supports the development of deeper conceptual understanding (Wieman et al., 2008). In addition to simulations, instructional videos are also effective in supporting science learning (Kustadiyono, 2023). Instructional videos present the concepts of vibrations and waves in a more concrete way through the integration of visuals, audio, and structured explanations. Through videos, students can directly observe real-world phenomena, such as air waves and object vibrations, which facilitates the connection between abstract concepts and everyday experiences, ultimately enhancing conceptual understanding.

The use of PhET simulations on the IFP further facilitates students' interaction with the media. Students can adjust variables and operate simulation tools directly by touching the IFP screen. The screen-splitting feature of the IFPs allows teachers to display two simulations simultaneously, enabling more students to actively engage with the simulations and increasing opportunities for collaborative exploration of concepts. This feature is particularly beneficial in supporting instruction, especially in schools with limited access to computers or laptops.

However, the impact of the IFP use on improving learning outcomes has not been fully felt by some students, particularly those with low numeracy skills. Although the IFP use helps students understand the concepts of vibrations and waves, they still experience difficulties when having to use formulas to determine the magnitude of a quantity. This finding aligns with Chen et al. (2020), who stated that students with higher numeracy skills tend to demonstrate better achievement in science learning. Based on these findings, the use of the IFPs in learning needs to be integrated with strategies oriented towards strengthening students' numeracy skills.

2.1 Students' Perceptions of the Interactive Flat Panels

Students' perceptions of the use of interactive flat panels (IFPs) in science learning are an important indicator hin assessing the success of integrating learning technology in the classroom. Positive perceptions not only reflect students' acceptance of the technology but also indicate how the technology influences engagement, motivation, and conceptual understanding during the learning process. The results of this study, which show a tendency for positive student perceptions of IFP, align with various previous research findings regarding the use of the IFPs in education (Aytaç, 2013; Kırbaş, 2018; Tsayang et al., 2020).

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Regarding ease of use, students expressed highly positive perceptions. This perception is crucial because ease of use is a prerequisite for technology acceptance in learning. When students do not encounter technical barriers, their cognitive attention can be fully focused on the material. This finding aligns with previous research (Önal, 2017; Tsayang et al., 2020). IFPs were perceived as easy to operate, both in terms of touchscreen usage, feature navigation, and the clarity of the instructions displayed. The practicality of running simulations and displaying various media also made the learning process feel more efficient than using conventional media. Meanwhile, in research Önal (2017), participants highlighted the convenience of interactive whiteboards, which eliminate the need for writing tools like markers that require ink.

In the context of understanding science concepts, students tend to perceive that IFPs help them understand the material more easily and clearly. The characteristics of IFPs, which can display animations, images, videos, and simulations, make abstract science concepts more concrete and easier to understand. This finding is consistent with research conducted by Onder & Aydin (2016) in biology class, in which students stated that they understood the material more easily when it was presented using a smart board rather than through verbal explanation alone. Thus, students' perception that IFPs facilitate understanding of the material indicates a match between the characteristics of the technology and the needs of science learning that emphasizes the visualization of scientific concepts.

From the student engagement perspective, the use of IFP is perceived as enhancing students' active participation during science learning. The touchscreen features, interactive visualizations, and multimedia integration enable students to become more than just recipients of information, but also directly involved in the learning process. This finding is consistent with that of Yang et al. (2012), who reported that students actively participate in learning and take responsibility for their own learning. This suggests that students' positive perceptions of IFPs are inseparable from changes in the learning experience, which has become more active and student-centered.

In terms of presentation clarity, students perceived the presentation of material through IFPs as well-organized, focused, and helpful in focusing attention on important information. One of the advantages of interactive whiteboards is their ability to present material through various media (Saltan, 2019). This systematic multimedia presentation supports the flow of learning activities, making it easier for students to follow the material explanations. From the perspective of cognitive load theory, structured information presentation can help reduce extrinsic cognitive load and optimize the processing of relevant information. This suggests that IFPs not only enhance visual appeal but also facilitates information management and makes it easier to follow.

In terms of usefulness and acceptance, students perceived the use of the IFPs as effective in supporting learning about vibrations and waves and expressed a desire to use the device in other science materials. This perception reflects a high level of technology acceptance. From a technology acceptance perspective, perceived usefulness is a key determinant of reuse intention. When students perceive that the IFP truly facilitates understanding and makes learning more effective, their tendency to accept and support its future use is stronger. However, these findings also indicate that the usefulness of the IFPs is highly dependent on the quality of its interactive features. If the IFP is used solely as a digital whiteboard without simulations or multimedia, its added value is limited. Thus, the effectiveness of the IFPs is not inherent to the device, but rather to its pedagogical integration strategy (Murcia & Sheffield, 2010).

On the other hand, interview findings in this study indicate that some students also have negative perceptions regarding the use of IFPs, particularly regarding visual comfort. Three of the eight students interviewed stated that the IFP screen lighting was quite distracting during learning. These findings align with previous studies (Aytaç, 2013; Şad & Özhan, 2012; Wall et al., 2005) that indicated student concerns about the health impacts of interactive whiteboard use, including headaches, sore eyes, and the risk of epileptic seizures. Aytaç (2013) reported that nearly 80% of 202 elementary and middle school students experienced eye pain after staring at an IFP screen for extended periods. Furthermore, Şad & Özhan (2012) found that prolonged use of interactive whiteboards can cause watery eyes and irritation. This condition can be influenced by several factors, such as large screen size, high brightness (luminance), and long screen exposure duration (Sproul et al., 2017).

These findings indicate that while students' perceptions of IFPs are generally positive, health and visual comfort still require attention in their classroom implementation. This indicates that prolonged use of IFPs without proper lighting can cause eye fatigue and reduce student learning comfort. Therefore, teachers need to regulate screen usage duration, brightness levels, and the variety of learning activities to ensure that IFP use supports the learning process without negatively impacting student health.

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D. Conclusion

This case study examined the effect of using interactive flat panels (IFPs) in science learning on the cognitive and perceptual learning outcomes of junior high school students. Based on quantitative findings, the implementation of IFPs on vibrations and waves demonstrated a statistically significant improvement in learning outcomes with a very large effect size. These findings indicate that pedagogically designed IFP integration can have a substantial impact on students' conceptual understanding, particularly on abstract materials requiring dynamic visualization.

Qualitative findings corroborate the quantitative results by showing that students have highly positive perceptions of the use of IFPs. Students felt that visualizations through simulations, videos, and interactive media helped them understand concepts more concretely, increased learning engagement, and created a more engaging and varied learning environment. However, this study also identified challenges in the form of visual discomfort due to prolonged screen exposure. This suggests that the effectiveness of IFPs is determined not only by its technological sophistication but also by appropriate technical and pedagogical management.

The findings of this study provide several important implications. First, the use of IFPs should not be limited to replacing digital whiteboards, but should be optimized through the use of interactive features such as simulations, multimedia, and exploratory activities that encourage student cognitive engagement. Second, teachers need to design lessons that combine the use of IFPs with discussions, experiments, and other methods to maintain a balanced learning environment and avoid over-reliance on screens. Third, ergonomic aspects such as screen brightness settings, usage duration, and student seating positions need to be considered to minimize negative impacts on visual comfort. Furthermore, the results of this study can be used as a consideration by schools and policymakers in optimizing learning digitalization programs, particularly in ensuring that the provision of technological devices is accompanied by adequate pedagogical training for teachers.

This study has some limitations that should be acknowledged. It was conducted in the context of a single class in a single school with a limited number of participants, so the generalization of the findings requires caution. The focus of the research was restricted to cognitive learning outcomes and student perceptions. In addition, the study design did not include a control group, so direct comparisons with other learning models could not be conducted experimentally. Therefore, future research is recommended to involve a larger sample size, use an experimental or quasi-experimental design, and explore the long-term impact of IFP use on various dimensions of learning outcomes. Studies across subjects and educational levels are also needed to gain a more comprehensive understanding of the effectiveness of IFP integration in the Indonesian education system.

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