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The Influence of Interactive Flat Panels on Students' Digitalization Skills and Engagement in Mathematics Learning

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Abstract

Background: The integration of digital technology into elementary mathematics learning remains a challenge, particularly in developing students' digital literacy and active engagement. Conventional learning practices may provide limited opportunities for students to interact directly with digital tools and participate actively in the learning process. Interactive Flat Panels (IFPs) offer an interactive learning environment that may support both technological competence and meaningful classroom participation. **Methods:** This study examined the effect of Interactive Flat Panels on students' digital literacy and engagement in elementary mathematics learning. A quantitative approach was employed using a quasi-experimental static group pretest-posttest design. The participants were 46 fourth-grade students, consisting of 23 students in the experimental group and 23 students in the control group. Data were collected using a digital literacy assessment and a student engagement questionnaire. The data were analyzed using independent-samples t-tests and MANOVA at a significance level of 0.05. **Results:** The findings indicated that students who learned with IFPs achieved higher digital literacy scores than those in the control group, with mean scores of 31.57 and 21.83, respectively. The difference was statistically significant ($p = 0.000$). Student engagement was also higher in the experimental group, with mean scores of 31.74 compared with 21.74 in the control group ($p = 0.000$). Furthermore, MANOVA confirmed a significant simultaneous effect of IFP use on digital literacy and student engagement ($p = 0.000$). **Conclusion:** The use of Interactive Flat Panels significantly improves students' digital literacy and engagement in elementary mathematics learning. Beyond functioning as a medium for presenting instructional content, IFPs provide students with opportunities to interact with digital technology, solve learning tasks, and participate more actively in classroom activities. Therefore, IFPs can be considered a relevant instructional innovation for developing digital competencies and strengthening student engagement in elementary mathematics education.

INTRODUCTION

Digital transformation has brought about fundamental changes in the provision of education, including teaching and learning practices at the elementary school level. The demands of twenty-first-century education are no longer limited to the mastery of knowledge but also encompass students' abilities to utilize technology, think critically, communicate, collaborate, and adapt to digital developments. In this context, the integration of technology into learning has become a strategic necessity for creating more interactive, contextualized, and student-centered learning experiences. The use of digital technology is also relevant to the implementation of the Merdeka Curriculum, which emphasizes active and innovative learning as an essential component of student competency development. Nevertheless, mathematics instruction in elementary schools still faces challenges associated with the use of conventional methods, teacher-centered lectures, reliance on whiteboards, and relatively monotonous practice exercises (Duatepe Paksu & Akkuş, 2007; Jupri et al., 2015; Sembiring et al., 2008). Such conditions may reduce students' active involvement and create difficulties when they encounter abstract mathematical concepts.

These challenges are not limited to students' learning engagement but also concern their readiness to utilize technology as an integral part of the learning process. Digital literacy among students does not merely refer to the ability to operate technological devices but encompasses the capacity to understand, access, utilize, and manage technology and digital information effectively (Spante et al., 2018; Sparks et al., 2016).The limited use of technology-based learning media may restrict students' opportunities to develop these competencies. Therefore, learning media are needed that not only function as tools for delivering instructional content but also provide students with opportunities to interact directly with learning materials and use technology productively.

One technological alternative with these characteristics is the Interactive Flat Panel (IFP). An IFP is an interactive digital medium that enables instructional content to be presented through text, images, videos, animations, applications, and touch-based activities. These characteristics facilitate interaction between students and learning materials, teachers and students, as well as among students through activities such as discussions, problem-solving, simulations, presentations, and interactive exercises. In elementary mathematics instruction, the characteristics of IFPs are particularly relevant because various mathematical concepts require visualization to be understood more concretely. Interactive learning media can make mathematical ideas such as arithmetic operations, fractions, measurement, geometry, and three-dimensional forms easier for students to explore by combining visual explanations with direct learning activities. This approach can make abstract concepts feel more concrete and encourage students to participate more actively throughout the learning process.

Previous research has shown that the integration of Interactive Flat Panels (IFPs) in classroom instruction can contribute positively to the quality and effectiveness of the learning process. Nabila Hidayah et al. (2026), through a case study of mathematics instruction, found that the integration of IFPs could shift learning from conventional patterns toward more interactive and student-centered practices while facilitating the visualization of abstract mathematical concepts. Sjarif et al. (2016) similarly demonstrated through a quasi-experimental design that the use of IFPs resulted in significantly greater

learning gains than those observed in the control group and contributed to increased student motivation and participation. Hasanah & Gunawan (2026) further reported that the integration of IFPs with Project-Based Learning enhanced students' motivation and active participation in IPAS instruction.

Similar findings were reported by Kusuma & Suratno (2025), who found improvements in learning outcomes following the implementation of IFPs in IPAS instruction. Their study also indicated increases in students' motivation, engagement, and conceptual understanding. Meanwhile, Lundstrom et al. (2011) found that IFPs could enhance learning motivation and collaboration through engaging visual presentations, touch-screen interaction, group activities, and multi-touch features. Hartanto & Wahyuningsih (2026) further demonstrated that IFPs could facilitate teacher–student, student–content, and student–student interactions through digital activities and contribute to improvements in motivation, conceptual understanding, collaborative skills, concentration, and student participation. Arsyad et al. (2024) also reported that the use of IFPs/Smartboards could increase active participation, facilitate the understanding of complex concepts, and promote student motivation and collaboration.

Although these studies demonstrate the benefits of IFPs, previous research has predominantly focused on motivation, learning outcomes, conceptual understanding, collaboration, and student engagement, while digital literacy as a competency directly related to the use of technology in learning has received comparatively limited attention. Furthermore, studies that simultaneously examine the effects of IFPs on digital literacy and student engagement, particularly in elementary mathematics instruction, remain limited. The present study shares similarities with previous research in its use of IFPs as the principal instructional medium or independent variable; however, its dependent variables, namely digital literacy and student engagement, represent a distinct focus from those examined in most previous studies.

Based on this research gap, the scientific novelty of this study lies in its empirical examination of the effect of Interactive Flat Panels on two interrelated aspects, namely students' digital literacy and engagement, both individually and simultaneously in elementary mathematics instruction. Rather than positioning the IFP merely as a medium for improving learning outcomes or motivation, this study conceptualizes it as a digital learning environment that provides students with direct experience in using technology while simultaneously encouraging active participation throughout the learning process. Accordingly, this study extends the existing literature on IFP effectiveness from an emphasis on academic and motivational outcomes toward the development of students' digital competencies and learning engagement.

The urgency of this study is further supported by empirical conditions in fourth-grade mathematics instruction at UPTD SDN Bilaporah 3, Socah District, Bangkalan Regency. Preliminary observations indicated that learning was still dominated by traditional approaches, resulting in relatively passive and less enthusiastic student behavior. The utilization of modern instructional technologies, including IFPs, had also not been optimized. This condition was reflected in the achievement of 46 students, of whom 31 obtained scores below the minimum mastery criterion (KKM), while only 15 students met the criterion. These circumstances indicate the need for instructional innovation that can not only improve the mathematics learning process but also provide students with opportunities to develop digital literacy and increase their active engagement during learning.

Based on these conditions, the research problems are formulated into three main questions: whether the use of Interactive Flat Panels affects students' digital literacy, whether the use of Interactive Flat Panels affects the improvement of students' engagement, and whether the use of Interactive Flat Panels simultaneously affects students' digital literacy and engagement in elementary mathematics instruction. Consistent with these research problems, the hypotheses propose that the use of Interactive Flat Panels has an effect on students' digital literacy, has an effect on the improvement of students' engagement, and has a simultaneous effect on students' digital literacy and engagement in elementary mathematics instruction. Accordingly, this study aims to analyze the effect of Interactive Flat Panels on students' digital literacy, analyze the effect of Interactive Flat Panels on the improvement of students' engagement, and examine the simultaneous effect of Interactive Flat Panels on students' digital literacy and the improvement of their engagement in elementary mathematics instruction.

METHODS

This study adopted a quantitative approach within an experimental research framework. The quantitative approach was selected because the research followed a structured process that included identifying the research problem, reviewing relevant theories, developing the research instruments, collecting and analyzing data, and formulating conclusions. An experimental method was employed to determine the effect of a particular instructional treatment on the variables being studied. Casler (2015) describes experimental research as an approach used to examine the influence of a specific treatment on other variables under controlled conditions. In the present study, the treatment consisted of integrating an Interactive Flat Panel (IFP) into mathematics instruction to investigate its potential influence on students' digital literacy and engagement.

A quasi-experimental design was applied using a static group pretest-posttest model. Two existing Grade IV classes were included in the study and designated as the experimental and control groups based on the existing classroom arrangement. The grouping was determined in consultation with the school to maintain the regular class structure and learning schedule, without reallocating individual students between classes. The experimental group received mathematics instruction supported by an IFP, whereas the control group received the same mathematics instruction without IFP support. Before the instructional treatment, students in both groups completed a pretest to establish their initial condition. The learning activities were then conducted according to the assigned instructional approach, followed by a posttest administered to both groups after the learning activities were completed. The overall research procedure is summarized in Table 1.

Table 1. Static Group Pretest-Posttest Research Design

Research Group	Pretest	Treatment	Posttest
Experimental group	O_1	X	O_2
Control group	O_3	–	O_4

Note: O_1–O_3 = pretest; O_2–O_4 = posttest;
X = treatment involving the use of the Interactive Flat Panel (IFP).

The study included 46 Grade IV students from UPTD SDN Bilaporah 3, Socah District, Bangkalan Regency. The participants were drawn from two existing Grade IV classes, with 23 students in Grade IV-A and 23 students in Grade IV-B. The two classes were selected in consultation with the school and retained their existing classroom composition throughout the study. Grade IV-A was designated as the experimental group and received mathematics instruction supported by an IFP, while Grade IV-B was designated as the control group and received the same instruction without IFP support. Thus, the study involved 46 participants in total, with 23 students in each group.

The research instruments consisted of a digital literacy assessment sheet and a student engagement questionnaire. The digital literacy instrument was adapted from the four indicators proposed by Techataweewan & Prasertsin (2018) accessing, evaluating, managing, and creating digital information. These indicators were operationalised into eight assessment aspects to align the instrument with students' digital learning activities, including operating digital devices, accessing and selecting digital features, using appropriate features for learning tasks, solving learning problems digitally, producing digital solutions, and presenting the results. This adaptation provided more specific and observable criteria for assessing students' digital literacy in the learning context. The results for each assessment aspect were analysed as ordinal data and presented in the Results section.

Digital literacy was assessed using a five-point ordinal scale, ranging from 1 (very poor) to 5 (very good). Student engagement was measured using a questionnaire adapted from Lam et al. (2012), comprising four indicators: enthusiasm in participating in learning activities, willingness to ask questions, willingness to answer the teacher's questions, and willingness to present understanding in front of the class. The ordinal scores for each engagement indicator were presented and discussed in the Results section. Data on digital literacy were collected through an assignment involving the tools available on the IFP. Students were instructed to measure five angles using the device, after which their performance was assessed using a 1–5 scale and recorded for analysis. Meanwhile, data on student engagement were collected through a questionnaire using a 1–5 Likert scale: 1 = never, 2 = rarely, 3 = sometimes, 4 = often, and 5 = always. The instruments were pilot-tested with 10 Grade V students at UPTD SDN Bilaporah 3, Socah. The pilot-test data were analyzed using SPSS 21 to determine the validity and reliability of the instruments. The instruments were considered valid and reliable when the obtained coefficient was ≥0.632 at the 5% significance level, whereas a coefficient <0.632 indicated that the instrument was invalid or unreliable (Alfiyah et al., 2025).

Before hypothesis testing, a sample homogeneity test was conducted. The samples were considered homogeneous when the significance value was >0.05 and non-homogeneous when the significance value was ≤0.05 (O'Neill & Mathews, 2002). Subsequently, the first hypothesis concerning the effect of IFP use on students' digital literacy and the second hypothesis concerning its effect on student engagement were analyzed using an independent-samples t-test. The third hypothesis concerning the simultaneous effect of IFP use on students' digital literacy and engagement was analyzed using MANOVA. The hypotheses were accepted when the significance value (Sig. or Sig. 2-tailed) was ≤0.05 and rejected when the significance value was >0.05.

RESULT AND DISCUSSION

The purpose of this study was to analyze the effect of the Interactive Flat Panel (IFP) on students' digital literacy and engagement in elementary school mathematics instruction. The study involved 46 fourth-grade students divided into control and experimental groups, with 23 students in each group. Data were collected using a digital literacy assessment sheet and a student engagement questionnaire. The results indicated that the use of IFP produced significant differences in both variables and had a simultaneous effect on students' digital literacy and engagement. These findings reinforce previous research demonstrating that IFP can serve as an instructional medium that promotes student engagement and the productive use of technology during the learning process (Gregorcic & Haglund, 2021; Torff & Tirotta, 2010).

Students' digital literacy was assessed across eight aspects: operating digital devices, accessing digital features, selecting available features, determining appropriate features for learning activities, operating digital features appropriately, using digital features to solve learning problems, producing digital solutions, and presenting problem-solving results digitally. As shown in Table 2, the control group ((n=23)) obtained a mean score of 21.83 ((SD=2.31)), with scores ranging from 17 to 24. In contrast, the experimental group ((n=23)) achieved a higher mean score of 31.57 ((SD=3.69)), with scores ranging from 26 to 39. The 9.74-point difference in mean scores indicates that the experimental group demonstrated higher overall digital literacy scores than the control group. However, comparisons of percentages for individual indicators could not be conducted because indicator-level data were unavailable.

Table 2. Descriptive Statistics of Students' Digital Literacy

Group	n	Minimum Score	Maximum Score	Mean	SD
Control	23	17	24	21.83	2.31
Experimental	23	26	39	31.57	3.69

The individual digital literacy results indicate a clear difference in performance between the two groups. Students in the experimental group generally obtained higher scores, with several students reaching scores between 36 and 39. In contrast, most students in the control group obtained scores within the 18–24 range. This difference indicates that students who participated in mathematics instruction supported by IFPs demonstrated stronger digital literacy performance than those who received instruction without IFP support. The change was reflected in students' ability to operate digital devices, access and select appropriate digital features, use these features to support problem solving, and present their results digitally. These findings suggest that the use of IFPs provided students with more opportunities to interact directly with digital tools as part of the mathematics learning process. The independent-samples t-test provided statistical confirmation of this difference, producing a significance value of 0.000, which was below the 0.05 criterion. The analysis also yielded a mean difference of 9.73913, with a significance value of 0.000. Based on these results, the first hypothesis was supported, demonstrating that the use of IFPs had a statistically significant effect on students' digital literacy in elementary mathematics learning.

Table 3. Independent-Samples t-Test of Students' Digital Literacy

Variable	Mean Difference	Sig. (2-tailed)	Decision
Digital literacy	9.73913	0	Hypothesis accepted

The scientific interpretation of these findings indicates that IFP functions not only as a device for displaying instructional materials but also as a learning environment that enables students to interact directly with digital technology. In this study, digital literacy encompasses the skills of accessing, evaluating, managing, and creating digital information (Sparks et al., 2016). When students directly use the device to complete mathematics tasks, the learning process extends beyond the passive reception of information and develops into an experiential process in which students use digital devices and features to solve problems.

Pedagogically, this difference may be related to the learning experiences provided in each group. In the experimental group, the use of IFP gave students opportunities to operate digital features, select appropriate tools, solve problems, and present their work using digital media. In contrast, the control group received mathematics instruction using the regular classroom approach without IFP support. Students in the control group were taught the same mathematical content and completed learning activities related to measuring angles, but their activities did not require direct interaction with IFP tools or the digital features used by the experimental group. In this study, digital literacy was assessed through an activity requiring students to use IFP tools to measure five angles. Thus, the assessment was closely aligned with the learning activities in the experimental group, where students repeatedly practiced using digital tools during mathematics instruction. The control group, although engaged in the same mathematical learning objectives, had fewer opportunities to practice these specific digital operations. This difference in instructional experience provides a possible explanation for the higher digital literacy scores observed in the experimental group.

These findings are consistent with Saputri et al., (2026), who reported that integrating Interactive Flat Panels (IFPs) into mathematics instruction supports interactive, student-centered learning and the visualization of abstract mathematical concepts. In the present study, the experimental group achieved a mean digital literacy score of 31.57, compared with 21.83 in the control group. This difference indicates higher overall digital literacy scores among students in the IFP-supported group. However, the students' digital literacy levels (low, medium, or high) cannot be determined without predefined classification criteria for the assessment scores. Therefore, the findings support a comparison of overall scores rather than a definitive classification of students' digital literacy proficiency. The analysis revealed a notable difference in student engagement across the two groups. In the control group, engagement scores ranged from 16 to 24, with an average of 21.74. In contrast, students in the experimental group recorded scores between 25 and 39, achieving a higher mean of 31.74. The resulting 10.00-point difference in the group means indicates greater student engagement among those who participated in mathematics learning supported by IFPs.

Table 4. Descriptive Statistics of Student Engagement

Group	n	Min Score	Max Score	Mean	SD
Control	23	16	24	21.74	2.43
Experimental	23	25	39	31.74	3.26

The individual data indicate that student engagement scores in the experimental group were generally higher. Most students in the experimental group obtained scores above 30, with some students achieving scores of 36 and 39. In contrast, the scores of students in the control group were predominantly within the range of 18–24. The observed difference was reinforced by the independent-samples t-test, which produced a significance value of 0.000, well below the established threshold of 0.05. The analysis also showed a mean difference of 10.00000 between the two groups. These results support the second hypothesis, indicating that the use of IFPs significantly contributed to higher student engagement in elementary mathematics learning.

Table 5. Independent-Samples t-Test of Student Engagement

Variable	Mean Difference	Sig. (2-tailed)	Decision
Student engagement	10	0	Hypothesis accepted

The scientific findings demonstrate that IFP can create a more participatory learning environment, rather than merely increasing engagement scores numerically. In this study, student engagement encompassed enthusiasm for participating in learning activities, willingness to ask questions, willingness to answer questions, and willingness to present understanding in front of the class. These indicators were based on. This improvement can be understood in terms of the characteristics of IFP, which enables students to interact directly with instructional materials through touch-screen activities, problem-solving tasks, discussions, and presentations. Through this learning pattern, students have more opportunities to provide responses and participate actively during instruction than in learning environments that rely primarily on conventional whiteboards. The research data also indicate that IFP features can make learning more engaging and provide students with greater opportunities to participate actively.

These results are in line with the findings of Baharsyah et al. (2026), who reported that incorporating Interactive Flat Panels (IFPs) into classroom instruction can foster students' motivation and encourage more active participation throughout the learning process. The findings are also consistent with Nurfadillah et al., (2026), who found that interaction through IFP can shift learning from a teacher-centered to a student-centered approach because students are provided with opportunities to process, explore, and present learning materials more actively. Furthermore, support these findings by demonstrating that IFP/Smartboards provide opportunities for students to engage in collaborative activities, access digital learning resources, and participate directly in the learning process. A simultaneous analysis was conducted using MANOVA to determine the effect of IFP on students' digital literacy and engagement jointly. The results of the Tests of Between-Subjects Effects showed a significance value of 0.000 for student engagement and 0.000 for digital literacy. Both values were lower than 0.05, indicating that the model and class variable produced significant differences in both dependent variables.

Table 6. MANOVA Results for Digital Literacy and Student Engagement

Source	Dependent Variable	Sig.	Observed Power
Corrected Model	Student engagement	0	1
Corrected Model	Digital literacy	0	1
Class	Student engagement	0	1
Class	Digital literacy	0	1

These findings provide support for the third hypothesis, indicating that the implementation of Interactive Flat Panels IFPs had a significant combined influence on students' digital literacy and engagement during elementary mathematics learning. The results suggest that IFP use can simultaneously support the development of students' digital competencies while encouraging more active involvement in classroom activities. The most important scientific finding from the simultaneous analysis is that the use of IFP contributes to two interrelated dimensions of learning: technological competency and student engagement in the learning process. The combined findings indicate that IFP-supported mathematics learning was associated with higher digital literacy scores and student engagement. In terms of digital literacy, the assessment covered eight aspects, including using digital features to solve learning problems, producing digital solutions, and presenting problem-solving results digitally. The experimental group achieved a higher mean digital literacy score (31.57) than the control group (21.83). These findings suggest that IFP-supported learning may provide opportunities for students to interact with digital learning features while participating in mathematics activities. However, because indicator-specific descriptive data were unavailable, improvements in particular skills, such as digitally presenting mathematical problem-solving results, cannot be confirmed independently. The findings should therefore be interpreted as a difference in overall digital literacy scores rather than direct evidence of improvement in each specific competency.

This relationship is particularly relevant to elementary school mathematics, which requires visualization and concrete learning experiences. The research data indicate that IFP enables content such as geometry, measurement, arithmetic operations, and other abstract concepts to be presented in a more visual and interactive manner. This condition provides students with opportunities not only to observe representations of instructional content but also to manipulate them and solve problems through digital devices. The findings also strengthen the results of Aisyah & Zahro, (2025), who demonstrated that IFP can transform conventional mathematics instruction into a more interactive and student-centered learning process. In addition, positioned IFP as a medium capable of supporting students' learning motivation and collaboration, whereas demonstrated that IFP/Smartboards can provide collaborative activities and access to various digital learning resources.

Taken together, the three statistical analyses demonstrated a consistent and significant pattern. The first analysis showed that the use of IFPs significantly influenced students' digital literacy ($p = 0.000$). The second analysis likewise confirmed a significant effect of IFP use on student engagement ($p = 0.000$). Furthermore, the MANOVA results indicated that IFPs produced a significant combined effect on both digital literacy and student engagement, with a significance value of 0.000. Accordingly, the findings provide empirical support for all three proposed hypotheses. The results demonstrate that the use of IFP in mathematics instruction is relevant not only as an instructional media innovation but also as a means of providing students with direct experience in using technology and creating more active learning interactions. These findings are consistent with previous research on IFP while providing an additional contribution by specifically demonstrating its effects on students' digital literacy and engagement both individually and simultaneously within the context of elementary school mathematics instruction.

CONCLUSION

The findings of this study demonstrate that the use of Interactive Flat Panels (IFPs) in elementary mathematics instruction significantly contributes to the development of students' digital literacy and engagement. The IFP-based learning environment provides students with direct opportunities to operate digital features, access and use digital information, solve learning problems, and present their work through technology. At the same time, interactive activities supported by the IFP encourage students to participate more actively through asking and answering questions, engaging in learning activities, and communicating their understanding. The simultaneous analysis further confirms that IFP use significantly influences both digital literacy and student engagement, indicating that its contribution extends beyond the function of instructional media toward the creation of an interactive learning environment that integrates technological competency with active participation. Thus, the three proposed hypotheses are empirically supported, and IFP can be considered a relevant instructional innovation for strengthening digital competencies and engagement in elementary mathematics learning. As a practical implication, elementary school teachers are encouraged to integrate IFPs into mathematics instruction to support the development of 4C skills: collaboration, communication, creativity, and critical thinking. Learning activities should engage students in solving contextual mathematical problems, exchanging ideas, working collaboratively, and presenting creative solutions. Future research should examine the contribution of IFPs to 4C skills across diverse learning contexts and grade levels, using larger samples and longer intervention periods to assess the consistency and sustainability of learning outcomes.

DECLARATION OF GENERATIVE AI

The authors declare that no generative AI or AI-assisted technologies were used.

CONFLICTING INTEREST STATEMENT

The authors declare no conflicts of interest.

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Wuri Handayani, Muhajir, and Nuril Huda contributed to the preparation, development, and completion of this manuscript. All authors reviewed and approved the final manuscript.

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