The Role of Technological Knowledge in Student Engagement, Mediated by Self-Efficacy among Students at High School X

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ABSTRACT

This study aims to examine and analyze the role of technological knowledge on student engagement mediated by self-efficacy among students of Senior High School X. Technological knowledge refers to an individual's proficiency in understanding and utilizing various information technologies to accomplish tasks. Student engagement is described as the level of student's participation in learning and teaching activities that lead to student's learning outcomes and goals. Self-efficacy is defined as an individual's belief in their ability to achieve desired goals. A total of 270 students participated in this study. The sampling technique used was non-probability sampling with a random sampling method. Multiple regression analysis was conducted to examine the relationships among variables. The results indicated that self-efficacy partially mediates the role of technological knowledge on student engagement. Based on the comparative analysis, younger students were found to have higher average levels of technological knowledge and student engagement compared to older students. Additionally, tenth-grade students demonstrated higher average levels of technological knowledge, self-efficacy, and two dimensions of student engagement. Furthermore, students who chose online learning showed higher average levels of technological knowledge and self-efficacy, while students who chose hybrid learning demonstrated higher emotional engagement.

Introduction

The Coronavirus Disease-19 (COVID-19) pandemic has caused fundamental disruptions across various sectors of life, including education. Globally implemented social restriction policies forced educational institutions to discontinue face-to-face learning and transition to online learning or Distance Learning. In Indonesia, the Ministry of Education and Culture responded by issuing Circular Letter No. 15 of 2020 concerning Guidelines for Learning from Home during the COVID-19 Emergency Period. This policy required

students to study from home, with the expectation that distance learning would continue to provide meaningful learning experiences without burdening students with the obligation to complete all curriculum targets for grade promotion or graduation.

Schools, including Senior High School X which is the focus of this study, were required to rapidly adapt their infrastructure and pedagogy to meet students' learning needs (Fernandez, 2020). However, this abrupt transition was not without challenges. Although various applications and Learning Management Systems (LMS) were utilized to support distance learning, the learning environment differed significantly from face-to-face classroom interactions. Basar (2021) noted that teachers experienced difficulties in interaction and content delivery due to the limitations of virtual learning environments.

These challenges were not only experienced by educators but were also strongly felt by students and parents. While distance learning offers flexibility in time and place, field realities revealed a decline in motivation and an increase in psychological burden. Bestari (2020) and Cahyani et al. (2020) reported that students felt overwhelmed by the accumulation of assignments, which subsequently reduced learning motivation and academic performance. This phenomenon was also observed at Senior High School X. Preliminary interviews conducted in October 2021 revealed that students struggled to maintain focus and concentration during distance learning. The large volume of assignments led to physical and mental fatigue (burnout) and rapid onset of boredom (A. V., personal communication, 2021). Complaints regarding dense learning schedules also emerged as a factor lowering student morale.

These conditions clearly resulted in decreased student engagement. Teachers at Senior High School X reported a significant decline in students' responsiveness during class discussions. Behavioral indicators of disengagement included frequent lateness in joining virtual classes, reluctance to turn on cameras as proof of attendance, and multitasking behavior during lessons (E. T., personal communication, 2021). Some students also experienced cognitive difficulties in understanding learning materials delivered through distance learning, leading to suboptimal learning outcomes.

This phenomenon indicates the presence of negative engagement or disaffection. Skinner et al. (2008) described disaffection as behavioral manifestations such as giving up on tasks, distraction, lack of preparedness, and emotional manifestations including boredom, frustration, anger, sadness, and anxiety. This issue is critical given that student engagement is a major predictor of student achievement and a key element connecting students to their learning activities (Dixson, 2015; Zapata-Cuervo et al., 2021). Zapata-Cuervo et al. (2021) found that distance learning often results in lower student engagement compared to face-to-face learning due to reduced interaction effectiveness and supervision.

To address declining engagement, the role of technology and internal psychological factors becomes crucial. At Senior High School X, learning was conducted using Chromebook laptops and the Google for Education ecosystem. Therefore, students' technological knowledge (TK) became a fundamental prerequisite. Koehler and Mishra

(2009) defined technological knowledge as an individual's proficiency in understanding and using various information technologies to complete tasks and adapt productively to technological changes. Previous studies (Schindler et al., 2017; Wardoyo et al., 2021) have shown that technological mastery positively influences student engagement and learning outcomes.

In addition to technical skills, self-efficacy also plays an important role. Bandura (1994) defined self-efficacy as an individual's belief in their capability to organize and execute actions required to achieve specific goals. In online learning contexts, students with high self-efficacy tend to demonstrate greater curiosity, ask more questions, and persist in the face of difficulties (Nurrindar & Wahjudi, 2021). Akturk and Ozturk (2019) also found that individuals with high self-efficacy use technology more effectively in learning processes.

The relationship among technological knowledge, self-efficacy, and student engagement is theoretically and empirically complex. Chen (2014) found that students confident in their technological abilities exhibit stronger learning motivation. However, other studies (Lindsey, 2017; Olivier et al., 2019) reported inconsistent findings, where self-efficacy was not always significantly correlated with engagement or achievement. These inconsistencies reveal a research gap, particularly in the Indonesian COVID-19 pandemic context where technology adoption occurred rapidly and massively.

This study aims to investigate this mechanism by proposing a mediation model. It is hypothesized that technological knowledge influences student engagement not only directly but also indirectly through self-efficacy. Students with strong technological skills are expected to develop greater confidence in their abilities, which subsequently promotes active learning engagement. This study contributes theoretically to educational psychology and industrial engineering (particularly cognitive ergonomics and learning system design), and practically to schools in designing effective digital-era learning strategies. The novelty of this study lies in integrating the TPACK framework (technological knowledge dimension) with Bandura's Social Cognitive Theory within the context of senior high school students engaged in hybrid and online learning models in Jakarta.

Method

This study employed a quantitative approach with a non-experimental correlational design to examine relationships among variables without manipulating research subjects. The research framework was developed to explain the influence of the independent variable on the dependent variable, both directly and indirectly through a mediating variable. The independent variable in this study was Technological Knowledge (TK), defined as the level of students' technical knowledge and proficiency in using information technology. The dependent variable was Student Engagement (SENG), referring to students' levels of participation in behavioral, emotional, and cognitive aspects during the learning process.

The mediating variable was Self-Efficacy (SEFF), defined as students' confidence in their ability to complete academic tasks.

The main hypothesis of this study proposed that technological knowledge plays a role in student engagement mediated by self-efficacy among students of Senior High School X, under the assumption that higher technological competence leads to higher self-confidence, which ultimately contributes to increased engagement in learning activities.

Research Stages

The population of this study consisted of students enrolled at Senior High School X during the 2021/2022 academic year. The school implemented technology-based learning using Chromebook devices and Google for Education, with two learning modes conducted in parallel: fully online and hybrid (a combination of limited face-to-face and online learning).

The sampling technique used was non-probability sampling with a simple random sampling method. This method was chosen because the student population was relatively homogeneous in terms of exposure to school policies and technology usage, allowing each student an equal chance of participation without exclusion criteria related to gender, religion, or socioeconomic background. A total of 270 students provided valid data for analysis.

Demographically, the participants consisted of 122 male students (45.2%) and 148 female students (54.8%), aged 15–18 years, with age distribution as follows: 22.2% aged 15, 30% aged 16, 38.9% aged 17, and 8.9% aged 18. Class distribution showed 36.3% Grade 10, 35.6% Grade 11, and 28.1% Grade 12 students. The majority of students selected the online learning mode (74.1%), while 25.9% opted for hybrid learning.

Additionally, most students (87.4%) had never participated in formal ICT courses outside of school, indicating that their technological skills were primarily acquired through self-learning or school curriculum integration. Regarding parental background, most fathers worked as private employees (53.7%) or entrepreneurs (42.6%), with dominant education levels of Diploma–Bachelor (74.1%). Most mothers were homemakers (57.8%), with education levels also predominantly Diploma–Bachelor (63.3%).

Measurement Instruments

This study employed three psychological measurement scales that had been adapted into Indonesian and validated through expert judgment and empirical reliability testing.

Student Engagement Measurement (SENG)

Student engagement was measured using the Student Engagement Scale (SES) developed by Gunuc and Kuzu (2014) based on Kuh's (2009) theoretical framework. The instrument consists of 39 favorable items rated on a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The SES comprises three dimensions: cognitive engagement, emotional engagement, and behavioral engagement. Cognitive engagement

includes 10 items measuring students' psychological investment in learning, motivation to master challenging materials, and self-regulation strategies (e.g., "I motivate myself to study"), with a Cronbach's Alpha coefficient of 0.784. Emotional engagement consists of 19 items assessing students' positive and negative affective reactions toward teachers, peers, and the school environment, including their sense of belonging (e.g., "I feel that I am part of a group of students"), yielding a Cronbach's Alpha coefficient of 0.889. Behavioral engagement comprises 10 items measuring observable participation in academic activities, compliance with classroom rules, and attendance (e.g., "I listen carefully to my teacher in class"), with a Cronbach's Alpha coefficient of 0.790. All items demonstrated acceptable validity, as indicated by corrected item–total correlation values exceeding 0.20.

Technological Knowledge Measurement (TK)

Technological knowledge was measured using the Technological Knowledge subscale from the TPACK.xs instrument developed by Schmid et al. (2020), based on the TPACK framework (Koehler & Mishra, 2009). This scale consisted of 7 favorable items assessing technical understanding and adaptability to new technologies (e.g., "I have the technical skills to use technology"), measured using a 5-point Likert scale. Reliability testing yielded a Cronbach's Alpha coefficient of 0.778, with all items meeting validity criteria.

Self-Efficacy Measurement (SEFF)

Self-efficacy was measured using the General Self-Efficacy Scale (GSES) developed by Schwarzer and Jerusalem (1995), adapted into Indonesian by Novrianto et al. (2019). This unidimensional scale consists of 10 favorable items measuring individuals' global confidence in handling difficult situations (e.g., "I can usually handle whatever comes my way"). The reliability test showed a Cronbach's Alpha coefficient of 0.827, with construct validity supporting a single-factor model.

Procedure and Data Analysis

The research procedure began with a preparation phase, including literature review, instrument adaptation, and research permission. Data collection was conducted from April 25 to May 23, 2022, using an online questionnaire distributed via Google Forms through class communication groups. All participants were required to complete an informed consent form prior to answering the questionnaire. As an incentive, participants received a digital wallet balance of IDR 25,000. Data analysis was performed using IBM SPSS Statistics Version 28.0.1. Analytical procedures included descriptive statistics (mean, standard deviation, minimum, maximum, and categorization), followed by classical assumption tests: normality (One-Sample Kolmogorov–Smirnov), linearity (Deviation from Linearity), multicollinearity (VIF and Tolerance), and heteroscedasticity (Glejser test).

Hypothesis testing employed regression analysis and mediation analysis using PROCESS Macro Model 4 (Hayes), with 5,000 bootstrap samples to estimate direct, indirect, and total

effects using confidence intervals. Additional analyses using Independent Sample T-Test and One-Way ANOVA were conducted to examine differences across demographic variables.

Results
Descriptive Statistical Overview

Descriptive statistics provide an overview of the levels of Technological Knowledge (TK), Student Engagement (SENG), and Self-Efficacy (SEFF) among students of Senior High School X. Variable categorization was based on the hypothetical mean, where the midpoint of the 1–5 Likert scale is 3. Scores above 3.66 were categorized as High, scores between 2.33 and 3.66 as Moderate, and scores below 2.33 as Low.

Table 1. Descriptive Statistics of Research Variables

Variable	N	Min	Max	Mean	SD
Student Engagement (Total)	270	2.52	5.00	4.134	0.395
- Cognitive Engagement	270	2.20	5.00	4.045	0.505
- Emotional Engagement	270	1.79	5.00	4.149	0.480
- Behavioral Engagement	270	2.70	5.00	4.207	0.454
Technological Knowledge	270	2.71	5.00	4.099	0.527
Self-Efficacy	270	2.10	5.00	4.001	0.513

Based on Table 1, the results indicate that the overall level of student engagement among students of Senior High School X falls within the high category, with a mean score of 4.134. A total of 241 students (89.3%) were classified in the high engagement category. Among the three dimensions, behavioral engagement demonstrated the highest mean score (4.207), indicating that students showed strong compliance with classroom rules, consistent task completion, and good attendance. Both cognitive engagement and emotional engagement also fell within the high category, suggesting that students were not only physically present but also mentally and emotionally involved in the learning process.

The technological knowledge variable showed a mean score of 4.099, with 228 students (84.4%) categorized as having high technological competence, reflecting successful adaptation to the technological ecosystem implemented by the school. Meanwhile, self-efficacy yielded a mean score of 4.001, with 216 students (80%) classified in the high category, indicating strong confidence in students' ability to cope with and complete academic demands.

Classical Assumption Testing

Prior to hypothesis testing, a series of classical assumption tests were conducted to ensure that the regression model met the criteria of the Best Linear Unbiased Estimator (BLUE). Normality testing using the One-Sample Kolmogorov–Smirnov Test indicated that all variables were normally distributed, with Technological Knowledge ($Z = 0.077$, $p = 0.062$), Self-Efficacy ($Z = 0.092$, $p = 0.116$), and Student Engagement ($Z = 0.055$, $p = 0.152$), all exceeding the 0.05 significance threshold.

Multicollinearity testing revealed a Tolerance value of 0.819 (greater than 0.10), a Variance Inflation Factor (VIF) of 1.220 (less than 10), and a Condition Index of 49.661. Although the Condition Index exceeded 30, the low VIF value indicated that multicollinearity was not a concern in the regression model. Heteroscedasticity testing using the Glejser method showed that both Technological Knowledge ($t = -1.313$, $p = 0.190$) and Self-Efficacy ($t = -1.686$, $p = 0.093$) were not significant predictors of the absolute residuals, indicating homoscedasticity.

Linearity testing using the Test for Linearity in ANOVA showed linear relationships between the independent and dependent variables, with deviation from linearity values of 0.198 for the TK–SENG relationship and 0.272 for the SEFF–SENG relationship, both exceeding 0.05. These results confirm that the regression model satisfied all classical assumptions and was suitable for further analysis.

Correlation and Simple Regression Analysis

Pearson correlation analysis revealed significant positive relationships among all variables examined in this study. The correlation between Technological Knowledge (TK) and Self-Efficacy (SEFF) yielded a coefficient of $r = 0.425$ ($p < 0.001$), indicating that higher levels of technological knowledge were associated with higher self-efficacy. The relationship between TK and Student Engagement (SENG) was also positive and significant ($r = 0.392$, $p < 0.001$), suggesting that increased technological competence was accompanied by greater student engagement.

The strongest correlation was observed between Self-Efficacy and Student Engagement, with a coefficient of $r = 0.556$ ($p < 0.001$), highlighting the central role of self-efficacy in promoting student involvement in learning activities. Partial determination coefficient analysis showed that Technological Knowledge explained 18.05% of the variance in Self-Efficacy and 15.40% of the variance in Student Engagement, while Self-Efficacy explained 33.85% of the variance in Student Engagement, indicating a more dominant influence of self-efficacy on engagement.

Mediation Analysis

Mediation analysis was conducted using PROCESS Macro Model 4 developed by Hayes to examine whether self-efficacy mediates the relationship between technological

knowledge and student engagement. This analysis decomposed the total effect into direct and indirect effects. The results are presented in Table 2.

Table 2. Mediation Regression Results Using PROCESS Model 4

Path	Coefficient	SE	t	p	LLCI	ULCI
Path a (TK → SEFF)	0.4135	0.0538	7.6832	0.000	0.3076	0.5195
Path b (SEFF → SENG)	0.3653	0.0423	8.6298	0.000	0.2819	0.4486
Total Effect (c) (TK → SENG)	0.2940	0.0421	6.9842	0.000	0.2111	0.3769
Direct Effect (c′) (TK → SENG)	0.1430	0.0412	3.4703	0.001	0.0619	0.2241
Indirect Effect (ab)	0.1511	0.0316	–	–	0.0931	0.2159

The mediation analysis yielded several important findings. First, technological knowledge had a significant positive effect on self-efficacy (path a: b = 0.4135, p < 0.001), indicating that higher technological competence was associated with higher confidence in academic abilities. Second, self-efficacy significantly predicted student engagement (path b: b = 0.3653, p < 0.001). Third, the total effect of technological knowledge on student engagement was significant (path c: b = 0.2940, p < 0.001).

After including self-efficacy in the model, the direct effect of technological knowledge on student engagement decreased but remained significant (path c′: b = 0.1430, p = 0.001). This reduction indicates that self-efficacy partially explains the relationship between technological knowledge and student engagement. The indirect effect (ab = 0.1511) was statistically significant, as the 95% bootstrap confidence interval (LLCI = 0.0931, ULCI = 0.2159) did not include zero. Therefore, self-efficacy was confirmed as a partial mediator in the relationship between technological knowledge and student engagement. The standardized mediation effect size was 0.2016.

Additional Demographic Analysis

This study also explored differences in variables based on demographic characteristics to gain deeper insights.
Differences by Age and Grade Level

One-Way ANOVA results revealed significant differences in Technological Knowledge (TK), Self-Efficacy (SEFF), and Student Engagement (SENG), particularly in the cognitive and behavioral dimensions, across age groups and grade levels. Students aged 15 years and those in Grade 10 demonstrated significantly higher technological knowledge compared to older students in Grades 11 and 12. A similar pattern emerged for self-efficacy, with Grade 10 students showing the highest average scores.

In terms of student engagement, Grade 10 students exhibited significantly higher levels of cognitive and behavioral engagement. However, no significant differences were found in emotional engagement across grade levels (p = 0.179).

Tabel 3. Mean Differences by Grade Level

Variable	Grade 10	Grade 11	Grade 12	p-value
Technological Knowledge	4.207	3.987	4.103	0.014
Self-Efficacy	4.117	3.932	3.938	0.019
Cognitive Engagement	4.190	3.923	4.015	0.001
Emotional Engagement	4.215	4.087	4.144	0.179
Behavioral Engagement	4.301	4.060	4.271	0.001

Independent Sample T-Test analysis revealed significant differences based on learning mode. Students who participated in fully online learning demonstrated significantly higher levels of technological knowledge (Mean = 4.14) and self-efficacy (Mean = 4.04) compared to students in hybrid learning (Mean TK = 3.99; Mean SEFF = 3.88). Conversely, students in hybrid learning exhibited significantly higher emotional engagement (Mean = 4.24) than those in online learning (Mean = 4.12). No significant differences were found in cognitive or behavioral engagement between online and hybrid learning modes. Additionally, no significant differences were observed across other demographic variables such as gender, ICT course experience, parental occupation, or parental education level ($p > 0.05$), indicating relatively equal access to technology and learning engagement across demographic groups.

Discussion

The findings of this study confirm the presence of partial mediation, indicating that technological knowledge influences student engagement through both direct and indirect pathways. The direct pathway suggests that technological mastery facilitates engagement by reducing technical barriers during learning activities. In line with the TPACK framework and previous studies (Schindler et al., 2017), students who are proficient in using learning technologies can focus their cognitive resources on learning content rather than on resolving technical difficulties, thereby enhancing cognitive and behavioral engagement.

The indirect pathway highlights the psychological mechanism underlying this relationship. Technological competence serves as an enactive mastery experience, which is the most influential source of self-efficacy according to Bandura's Social Cognitive Theory. When students perceive themselves as capable of effectively using learning technologies, this confidence generalizes to academic tasks, increasing persistence, motivation, and willingness to engage actively in learning activities. High self-efficacy thus acts as a motivational driver that strengthens overall student engagement.

An interesting finding of this study is that Grade 10 students exhibited the highest levels of technological knowledge, self-efficacy, and student engagement. Contrary to

expectations that older students would demonstrate higher competence due to longer exposure, this pattern may be explained by greater digital adaptability among younger students, novelty effects associated with entering a new educational stage, and reduced digital fatigue compared to students in higher grades. Students in Grades 11 and 12 may experience prolonged exposure to online learning, academic pressure, and exam preparation stress, which could reduce engagement and self-efficacy over time.

Differences between online and hybrid learning modes further highlight the importance of instructional design. Online learning appeared to strengthen technological competence and self-efficacy due to increased reliance on digital tools and learner autonomy. In contrast, hybrid learning promoted higher emotional engagement, underscoring the irreplaceable role of face-to-face interaction in fostering social connection and a sense of belonging. These findings support the notion that emotional engagement is more effectively cultivated through direct interpersonal interaction.

The absence of significant differences across gender and socioeconomic background suggests that the standardized provision of learning devices and technological infrastructure at Senior High School X successfully minimized digital inequality. This finding challenges traditional assumptions regarding gender disparities in technological competence and underscores the importance of institutional support in creating equitable learning environments.

Conclusion

Based on the results and discussion, several key conclusions can be drawn:

1. Confirmed Mediation Effect: Technological knowledge significantly influences student engagement both directly and indirectly through self-efficacy. Students with higher technological competence tend to develop stronger confidence in their abilities, which subsequently enhances their engagement in learning activities.
2. Developmental Differences: A declining trend in technological knowledge, self-efficacy, and student engagement was observed across higher grade levels. Grade 10 students demonstrated the most optimal psychological and technical profiles.
3. Learning Mode Trade-off: Online learning fostered higher technological competence and self-efficacy, whereas hybrid learning promoted stronger emotional engagement.
4. Equity Across Demographics: No significant differences were found based on gender or parental socioeconomic background, indicating equitable access to technology and engagement opportunities.

Recommendations for Schools and Educators:

Schools are encouraged to maintain the integration of technology in post-pandemic learning environments, as technological knowledge serves as a foundation for both self-efficacy and student engagement. Special attention should be given to students in higher grade levels who may experience engagement decline and academic burnout. Psychological support programs, academic motivation interventions, and adaptive instructional strategies

are recommended. Teachers conducting online classes should incorporate more socially interactive elements to enhance emotional engagement, while hybrid classes should strengthen independent, technology-based assignments to improve technological competence and self-efficacy.

For Future Research:

Future studies are encouraged to explore additional mediating variables such as self-regulated learning or intrinsic motivation. Longitudinal research designs are recommended to distinguish between developmental effects and prolonged exposure to distance learning. Expanding the sample to include public schools or institutions with greater socioeconomic diversity would further test the generalizability of these findings.

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