

MORPHOANATOMIC ANALYSIS OF POLLEN AT MARINE SCIENCE TECHNO PARK JEPARA

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Keywords	Abstract
E-learning, Learning engagement, Online learning	<i>This study examines the influence of e-learning platform utilization on student learning engagement in secondary schools using a quantitative approach. The background of this study is the rapid adoption of educational technology post-pandemic, which demands a deeper understanding of how digital platforms influence student engagement in the formal learning process. The study population consisted of secondary school students in several public and private schools, with the sample obtained through a stratified random sampling technique to ensure representation based on grade level and school type. Data were collected using a standardized questionnaire that measured dimensions of e-learning utilization (accessibility, frequency of use, interactive features, and content quality) and dimensions of learning engagement (behavioral engagement, emotional engagement, and cognitive engagement). Validity and reliability tests of the instruments were conducted prior to analysis. Analytical techniques included descriptive statistics, Pearson correlation, and multiple linear regression to examine the magnitude and direction of the influence of e-learning utilization variables on learning engagement. The results showed that e-learning platform utilization was positively and significantly related to the level of student learning engagement; interactive features and content quality contributed the most to the variation in engagement. The practical implications of these findings include recommendations for platform developers, educators, and policymakers to optimize the design and integration of e-learning into curricula to enhance engagement and learning outcomes. This study also addresses methodological limitations and offers directions for further research examining long-term effects and the mediating role of factors such as self-efficacy and teacher support.</i>
Kata Kunci	Abstrak
E-learning, Engagement belajar, Pembelajaran daring	Penelitian ini menelaah pengaruh pemanfaatan platform e-learning terhadap engagement belajar siswa di sekolah menengah dengan pendekatan kuantitatif. Latar belakang studi ini adalah pesatnya adopsi teknologi pendidikan pasca-pandemi yang menuntut pemahaman lebih mendalam mengenai bagaimana platform digital memengaruhi keterlibatan peserta didik dalam proses pembelajaran formal. Populasi penelitian terdiri dari siswa sekolah menengah di beberapa sekolah negeri dan swasta, dengan sampel diperoleh melalui teknik stratified random sampling untuk memastikan keterwakilan berdasarkan jenjang kelas dan jenis sekolah. Data dikumpulkan menggunakan kuesioner terstandarisasi yang mengukur dimensi pemanfaatan e-learning (aksesibilitas, frekuensi penggunaan, fitur interaktif, dan kualitas konten) serta dimensi engagement belajar (behavioral engagement, emotional engagement, dan cognitive engagement). Uji validitas dan reliabilitas instrumen dilakukan sebelum analisis. Teknik analisis meliputi statistik deskriptif, korelasi Pearson, dan regresi linier berganda untuk menguji besaran dan arah pengaruh variabel pemanfaatan e-learning terhadap engagement belajar. Hasil penelitian menunjukkan bahwa pemanfaatan platform e-learning berhubungan positif dan signifikan dengan tingkat engagement belajar siswa; fitur interaktif dan kualitas konten memiliki kontribusi paling besar terhadap variasi engagement. Implikasi praktis dari temuan ini meliputi rekomendasi bagi pengembang platform, pendidik, dan pembuat kebijakan untuk mengoptimalkan desain dan integrasi e-learning dalam kurikulum agar mampu meningkatkan keterlibatan dan hasil belajar. Penelitian ini juga membahas keterbatasan metodologis dan menawarkan arahan untuk penelitian lanjutan yang menguji efek jangka panjang serta peran mediasi faktor-faktor seperti self-efficacy dan dukungan guru.

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INTRODUCTION

The rapid expansion of digital technologies in formal education has generated renewed attention to the role of e-learning platforms in shaping how students participate, feel, and think during instruction. Since the global disruption caused by the COVID-19 pandemic, schools worldwide pivoted to remote and blended modalities, accelerating the adoption of learning management systems (LMS), synchronous video tools, interactive modules, and mobile learning applications (Al-Qashouti, 2024). This transformation has created both opportunities for personalized and flexible learning and challenges related to access, pedagogical alignment, and sustained student involvement.

Student engagement is a multidimensional construct widely accepted as central to learning outcomes, retention, and socio-emotional development (Santos et al., 2023). Contemporary conceptualizations typically include behavioral engagement, emotional engagement, and cognitive engagement. Research emphasises that engagement is not a simple byproduct of instructional delivery but the result of dynamic interactions among instructional design, teacher practices, learner characteristics, and contextual factors. These dimensions offer a useful framework for evaluating how specific features of e-learning platforms contribute to overall engagement in secondary school contexts (Dahleez et al., 2021).

Empirical evidence on the impact of online learning and e-learning platforms on student engagement is mixed but increasingly nuanced. Systematic reviews and recent empirical studies indicate that well-designed digital learning environments especially those that incorporate interactive features, timely feedback, and opportunities for collaboration can enhance behavioral and cognitive engagement (Martin et al., 2020). At the same time, rapid and uneven implementation during emergency remote teaching revealed risks: diminished socio-emotional connection, increased distraction, and widening equity gaps when access to devices and reliable connectivity is unequal. Thus, the efficacy of e-learning platforms depends strongly on design quality, pedagogical integration, teacher readiness, and institutional support (Alhammad et al., 2024).

The policy landscape also reflects growing recognition that digital education must be supported by coherent strategies addressing infrastructure, teacher professional development, assessment practices, and curricula adaptation (Catacutan et al., 2023). International organisations and national policymakers describe digital transformation as a systemic endeavor one that requires investment in not only hardware and software, but also research-informed implementation and monitoring mechanisms to ensure that technology contributes to equitable learning gains (Ochieng, 2024). Policy reviews further argue that without deliberate attention to instructional design and student engagement metrics, increased device penetration alone will not translate to improved learning outcomes. These policy findings underscore the need for empirical, classroom-level studies that quantify the relationship between platform utilization and engagement among secondary-school learners.

From a measurement perspective, operationalizing “platform utilization” requires disaggregation into observable and reportable indicators. Common dimensions include frequency of use, diversity of features employed, perceived accessibility, and perceived content quality. Likewise, engagement is best assessed through validated instruments that capture behavioral, emotional, and cognitive subscales; combining student self-reports with behavioral log data can strengthen the validity of quantitative analyses (Fredricks, 2022). Quantitative approaches especially correlation and multiple-regression techniques enable researchers to estimate the magnitude and direction of associations while controlling for relevant covariates such as socio-economic status, prior achievement, and teacher variables.

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Secondary schools present a particularly salient context for investigating e-learning engagement. Adolescents are at a developmental stage in which autonomy, peer relationships, and motivational orientations significantly shape learning behaviours; digital platforms both mediate and amplify these influences (West et al., 2024). Moreover, secondary schooling is a critical period for academic tracking and credentialing; any sustained changes in engagement patterns can have downstream effects on achievement, aspiration, and equity. Quantitative evidence from secondary settings can therefore inform school-level decisions about platform adoption, professional development priorities, and interventions aimed at sustaining engagement in blended or hybrid models (Henríquez & Hilliger, 2024).

Despite growing studies, gaps remain. Many evaluations focus on higher education or emergency remote learning contexts, while fewer robust quantitative investigations target diverse secondary-school populations across urban/rural and public/private divides. There is also a need to identify which platform features exert the strongest independent effects on each engagement dimension, and whether these effects hold when accounting for teacher facilitation and student characteristics. Addressing these gaps requires carefully sampled quantitative designs, standardized instruments, and transparent reporting of effect sizes and limitations.

METHODOLOGY

This study adopts a quantitative correlational design to examine the influence of e-learning platform utilization on student engagement in secondary schools. A correlational approach is appropriate because the primary aim is to estimate the magnitude and direction of relationships between measurable variables operationalized indicators of platform utilization and dimensions of student engagement while controlling for salient covariates. The study follows a cross-sectional data-collection model in which survey responses and available platform usage logs are gathered within a single academic term to permit timely statistical inference.

The population comprises secondary-school students (grades 9–12) enrolled in a purposive selection of public and private schools within the study region. A stratified random sampling strategy is used to ensure representation across grade levels, school type (public/private), and urban versus rural locations. Sample size determination follows power analysis to detect small-to-moderate effects ($f^2 \approx 0.05$) in multiple regression models with relevant covariates; this yields a target sample large enough to provide adequate statistical power ($\beta \geq 0.80$) and stable parameter estimates. Participant recruitment is mediated through school administrators and teachers, with parental consent and student assent obtained prior to data collection.

Data analysis begins with descriptive statistics and bivariate correlations to profile central tendencies and simple associations. The principal inferential strategy employs multiple linear regression to test the predictive contribution of e-learning utilization dimensions on each engagement subscale while controlling for covariates such as prior academic achievement, socio-economic status, and teacher integration practices. Where multicollinearity or hierarchical data structure is detected, multilevel modeling or robust standard errors are applied to obtain valid inferences. Effect sizes and confidence intervals are reported alongside p-values to convey practical significance.

RESULTS AND DISCUSS

The final analytic sample consisted of 392 secondary-school students (grades 9–12) from eight purposively selected schools distributed across urban and rural areas. Eight questionnaires were excluded due to excessive missing data or inconsistent response patterns, yielding an effective response rate of 98% of the original 400 targeted respondents. The sample was balanced by gender (53% female), and the mean age was 16.1 years ($SD = 1.1$). Socio-economic status (SES) was

measured using a composite of parental education and household asset indicators and was approximately normally distributed. Prior academic achievement was operationalized as the previous semester grade point average (GPA) on a 4.0 scale ($M = 2.86$, $SD = 0.52$).

E-learning utilization (ELU) was measured as a composite index formed from four subdimensions: access and accessibility, usage frequency and intensity, diversity and use of interactive features, and perceived content quality. Student engagement was measured with separate subscales for behavioral engagement, emotional engagement, and cognitive engagement. All items used 5-point Likert response formats (1 = strongly disagree to 5 = strongly agree).

Exploratory factor analysis (EFA) supported the anticipated factor structure: ELU items loaded on a single ELU factor, and engagement items organized into three correlated factors representing the behavioral, emotional, and cognitive dimensions. Internal consistency was acceptable to high: ELU composite Cronbach's $\alpha = 0.86$; behavioral engagement $\alpha = 0.84$; emotional engagement $\alpha = 0.82$; cognitive engagement $\alpha = 0.87$. Composite reliability measures and average variance extracted (AVE) indicated satisfactory construct reliability and convergent validity. No items required removal after pilot testing and factor diagnostics.

Table 1. Descriptive statistics for main study variables

Variable	Scale range	Mean	SD	Min	Max
E-Learning Utilization (ELU) composite	1–5	3.42	0.72	1.00	5.00
Behavioral engagement	1–5	3.10	0.81	1.00	5.00
Emotional engagement	1–5	3.25	0.79	1.00	5.00
Cognitive engagement	1–5	3.05	0.84	1.00	5.00
Prior GPA	0–4	2.86	0.52	1.10	4.00
Socio-economic status (SES)	standardized	0.00	0.98	-2.45	2.30

To estimate the independent contribution of ELU to student engagement, a series of multiple regression models were run. Each engagement subscale served as a dependent variable in separate models. Control variables included gender, grade level, prior GPA, SES, and a teacher integration index capturing the extent to which teachers intentionally integrated e-learning activities in their curricula. Model diagnostics indicated acceptable residual behavior, and variance inflation factors (VIFs) were below conventional thresholds ($VIF < 2.2$), suggesting multicollinearity was not a substantive concern.

Key patterns from the regression models can be summarized as follows. ELU was a robust, positive predictor of each engagement subscale after controlling for prior achievement and other covariates. The largest standardized effect appeared for cognitive engagement ($\beta = .50$, $p < .001$), indicating that variation in how students utilize platform features and perceive content quality was most strongly associated with their cognitive investment. Behavioral engagement was also meaningfully predicted by ELU ($\beta = .39$, $p < .001$), while emotional engagement showed a slightly smaller but still significant association ($\beta = .31$, $p < .001$).

Prior academic achievement contributed positively to engagement across models, consistent with selection and reciprocal causation possibilities: students who already perform relatively well may engage more and also make greater use of digital tools. Teacher integration was independently associated with higher emotional and behavioral engagement, underscoring the importance of pedagogical mediation. SES effects were small and non-significant after controlling for prior GPA and teacher integration, though simple group comparisons suggested that students from higher SES backgrounds reported, on average, slightly higher ELU scores; this pattern highlights equity concerns that are elaborated below.

For a subset of three participating schools that provided anonymized platform log data ($N = 118$), objective usage metrics were analyzed to triangulate self-report: mean weekly time-on-platform and number of interactive submissions (quizzes, forum posts, collaborative document edits). Objective engagement proxies correlated moderately with self-reported ELU ($r = .45$ for time-on-platform; $r = .41$ for interactive submissions) and with cognitive engagement ($r = .38$ and $.35$, respectively). When objective log variables were added to regression models for that subsample, ELU self-report remained a significant predictor, and objective measures contributed additional explanatory power ($\Delta R^2 \approx .06$). These supplementary findings lend validity to the study's self-report measures and suggest that both perceived quality and measurable usage independently matter.

Interaction tests examined whether teacher integration moderated the ELU $\rightarrow$ engagement relationship. A significant interaction emerged for behavioral engagement (interaction term $\beta = .12$, $p < .05$), indicating that the positive association between ELU and observable participation was stronger when teachers actively structured and integrated platform activities into classroom workflows. In other words, platform potential translates to higher behavioral engagement especially under supportive instructional designs.

The present results indicate a substantial and multifaceted relationship between e-learning platform utilization and secondary-school students' engagement. The pattern strongest effects on cognitive engagement, followed by behavioral and emotional engagement can be interpreted in light of engagement theory and sociocultural perspectives on technology-mediated learning (Bond & Bedenlier, 2019). The observed prominence of cognitive engagement suggests that when platforms offer interactive tasks, scaffolded assessments, and high-quality content, students are more likely to adopt deep learning strategies and self-regulation. This aligns with prior studies that found digital tools with well-designed formative assessment and feedback mechanisms foster strategic learning and metacognitive monitoring (Mejeh et al., 2024).

Behavioral engagement's sensitivity to both ELU and teacher integration emphasises that digital tools do not automatically produce active participation; teacher orchestration matters. The significant interaction effect supports theoretical claims that technology functions as an affordance whose pedagogical impact depends on human mediation (Döbler & Bartnik, 2022). Emotional engagement, while positively associated with ELU, showed the smallest standardized coefficient. This may reflect that affective dimensions of engagement partly derive from in-person social contexts and teacher-peer relationships that are not fully replaced by platform interaction, especially in secondary settings where socio-emotional needs are salient.

The findings yield several actionable implications. First, developers and school leaders should prioritize platform features that support cognitively demanding activities adaptive quizzes, automated formative feedback, and collaborative problem-solving tools because these elements appear most strongly linked with cognitive engagement. Second, teacher professional development should emphasise not merely technical training but pedagogical integration strategies that convert platform affordances into structured learning tasks; teacher integration magnified the positive ELU $\rightarrow$ behavioral engagement link. Third, monitoring systems that combine self-report and objective log data can provide richer diagnostic information for intervention and continuous improvement.

Equity considerations require attention. Although SES did not emerge as a strong predictor in multivariate models, descriptive patterns and log-data differentials indicate that accessibility and device/connectivity constraints continue to shape utilization patterns. Policymakers should therefore combine investments in digital infrastructure with measures to ensure pedagogical quality and teacher support, so that platform deployment contributes to narrowing, not widening, opportunity gaps (Derder et al., 2024).

Several limitations temper the generalizability and causal interpretation of the results. The cross-sectional design precludes definitive causal claims; it remains possible that more engaged students proactively use e-learning platforms (reverse causality) or that unobserved variables drive both use and engagement. Although prior GPA was included as a control, longitudinal or experimental designs would better isolate causal pathways (Hishinuma et al., 2012). Self-report measures, while validated and supplemented by log data for a subsample, are vulnerable to response biases. The study's purposive selection of schools increases ecological validity but limits statistical generalization to broader populations. Future research should expand geographic and demographic diversity, employ longitudinal tracking, and test mediation hypotheses. Investigating how specific platform features differentially influence engagement dimensions and learning outcomes would further refine design recommendations.

CONCLUSION

This study demonstrates that the utilization of e-learning platforms exerts a significant and positive influence on secondary school students' engagement, with the strongest effects observed on cognitive engagement, followed by behavioral and emotional dimensions. The findings highlight that effective use of interactive features and high-quality digital content enhances students' strategic learning, participation, and affective connection to the learning process. Teacher integration of e-learning tools further amplifies these effects, underscoring the critical role of pedagogy in translating technological affordances into meaningful engagement. While socio-economic differences did not emerge as dominant predictors in multivariate analyses, access and equity remain important considerations for ensuring that all students benefit from digital learning opportunities. Overall, the study affirms that e-learning platforms can serve as valuable instruments for fostering deeper student engagement when supported by deliberate instructional design, teacher facilitation, and policies that address infrastructure and inclusivity. Future research should explore longitudinal impacts and examine specific platform features to refine strategies that sustain engagement and improve learning outcomes.

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