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# Student Digital Literacy in Secondary Education: Patterns, Differences, and Associated Factors

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**Abstract**

Digital literacy is essential for secondary school students, yet competence may vary across dimensions and access conditions. This study examined multidimensional digital literacy patterns, group differences, and factors associated with digital literacy. A quantitative secondary analysis used a de-identified dataset of 350 secondary school students from four educational contexts in Southeast Asia. Digital literacy was assessed using a 35-item questionnaire covering seven dimensions. Descriptive statistics, t-tests, ANOVA, MANOVA, and hierarchical multiple regression were applied. The mean overall digital literacy score was 116.18 ($SD = 13.61$). Device and Digital Application Operation showed the highest score ($M = 19.37$, $SD = 2.43$), whereas Digital Safety and Ethics showed the lowest ($M = 15.19$, $SD = 2.47$). Device access showed a significant difference, $F(2, 347) = 3.40$, $p = .034$, $\eta^2 = .019$, while Internet access showed a stronger difference, $F(2, 347) = 16.05$, $p < .001$, $\eta^2 = .085$. The final regression model explained 11.4% of the variance, with digital-access variables adding 10.4%. Limited Internet access showed the strongest independent association ($\beta = -.301$, $p < .001$). Digital literacy was more strongly associated with access conditions than with demographic or contextual characteristics.

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## INTRODUCTION

Digital technologies have become integral to the educational experiences of secondary school students. Learning increasingly requires students to access information through digital platforms, communicate and collaborate online, create digital content, manage learning resources, and solve technology-related problems. This development has expanded opportunities for learning, but it has also increased the competencies required for students to participate effectively and responsibly in digital environments. The ability to operate devices or use applications is therefore only one component of digital literacy. Students must also be able to evaluate the credibility of information, protect personal data, communicate ethically, create digital content responsibly, and use technology strategically for learning and problem solving (Eshet-Alkalai, 2004; Ng, 2012; van Laar et al., 2017). Digital literacy should consequently be understood as a multidimensional competence rather than as simple familiarity with digital technologies.

This multidimensional perspective is reflected in major international frameworks. The UNESCO Digital Literacy Global Framework conceptualizes digital literacy as encompassing competencies related to devices and software operations, information and data management, communication and collaboration, digital content creation, safety, problem solving, and context-specific uses of technology (Law et al., 2018). Similarly, DigComp 2.2 describes digital competence through five interrelated areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem solving (Vuorikari et al., 2022). Both frameworks emphasize that meaningful digital participation depends on combinations of knowledge, skills, attitudes, and responsible practices. This conceptualization is particularly relevant in education because frequent technology use does not necessarily indicate the ability to use technology critically, safely, or productively.

The distinction between digital exposure and digital competence is especially important among adolescents. Secondary school students often engage intensively with smartphones, social media, digital learning platforms, search engines, and multimedia applications. However, intensive use does not guarantee proficiency in evaluating information, identifying misleading content, protecting privacy, or solving digital problems. Research has consistently challenged the assumption that young people are automatically digitally competent simply because they have grown up surrounded by technology (Ng, 2012). Digital skills and knowledge may contribute to young people's resilience when encountering misinformation, privacy risks, and other online challenges, but these outcomes depend on the quality of their competencies rather than merely the frequency of technology use (Livingstone et al., 2023; Vissenberg et al., 2022, 2023). International evidence similarly shows considerable variation in computer and information literacy among students despite the widespread integration of digital technology into their everyday lives (Fraillon, 2025).

A further issue concerns the unequal conditions under which students develop digital literacy. Initial discussions of the digital divide focused heavily on differences in physical access to computers and the Internet. As access expanded, research increasingly demonstrated that digital inequality also involves differences in skills, forms of use, opportunities for meaningful engagement, and benefits derived from digital technologies (Hargittai, 2002; Helsper, 2012; Scheerder et al., 2017; van Deursen & van Dijk, 2011). This development shifted attention from a first-level digital divide based primarily on access toward second- and third-level inequalities involving competence and outcomes. From this perspective, students who technically have Internet access may still experience disadvantages when connectivity is unstable, devices must be shared with family members, or available technologies do not adequately support learning.

These distinctions are particularly relevant to secondary education because the quality of digital access can affect how frequently and effectively students engage in technology-supported learning. Personal access to a suitable device may provide students with greater opportunities to practice digital skills, complete assignments, explore learning resources, and solve problems independently. Stable Internet connectivity can similarly support continuous access to educational platforms, multimedia learning materials, communication tools, and online information. In contrast, restricted device availability or unreliable connectivity may limit not only access itself but also opportunities to develop more advanced digital competencies. Research on educational digital inequality therefore increasingly emphasizes that material access, quality of connectivity, digital skills, and educational opportunities should be examined together rather than treated as separate phenomena (Dolan, 2016; Mirazchiyski, 2025; van de Werfhorst et al., 2022).

Demographic and educational characteristics may also contribute to variation in students' digital literacy, although previous findings are not uniform. Socioeconomic background has repeatedly been associated with differences in ICT and digital competence, but the magnitude of this relationship varies across educational settings and measurement approaches (Aesaert & van Braak, 2015; Ren et al., 2022; Scherer & Siddiq, 2019). Gender differences are similarly complex. A meta-analysis by Siddiq and Scherer (2019) showed that gender differences in students' ICT literacy cannot be adequately represented by a simple assumption that one gender consistently performs better than the other. More recent evidence also suggests that observed gender differences can vary across developmental stages, sociocultural environments, and the particular dimensions of digital literacy being assessed (Chen et al., 2026). Consequently, gender should be treated as an empirical explanatory variable rather than as a predetermined source of digital advantage or disadvantage.

Age and educational level may likewise shape students' experiences with digital technologies, but greater age or schooling does not necessarily lead to uniformly higher digital competence. Older students may have accumulated more experience with digital tools and may encounter more complex academic tasks requiring information searching, content creation, and independent learning. At the same time, competencies such as digital safety, information verification, and ethical digital participation may not develop automatically through repeated exposure. Educational level should therefore be examined alongside other conditions, particularly the opportunities students have to engage meaningfully and consistently with digital technologies.

Educational context represents another possible source of variation. Secondary education settings may differ in technological infrastructure, curricular priorities, teacher digital competence, access arrangements, and the extent to which digital learning is integrated into classroom practice. Evidence from diverse educational settings in Southeast Asia indicates that digital competence can be associated with demographic characteristics, patterns of Internet use, educational practices, and opportunities for digital participation (Maon et al., 2021; Ongardwanich, 2022; Prasetiyo et al., 2025; Wui et al., 2025). However, broad contextual membership does not itself explain why individual students differ in digital literacy. Considerable variation can occur within the same educational context because students experience different levels of Internet connectivity, device availability, school support, and opportunities to use technology for learning. Contextual differences should therefore be interpreted cautiously and considered alongside more proximal conditions of digital access and engagement.

Another important consideration is that digital literacy may not develop uniformly across competencies. Students may be proficient in operating devices and applications while showing weaker abilities in information evaluation, digital safety, content creation, or problem solving. Such a pattern matters because operational fluency alone is insufficient for responsible and effective digital participation. A student who can efficiently use digital applications but cannot critically evaluate online information or protect personal data cannot be considered equally competent across the full domain of digital literacy. Multidimensional assessment is therefore necessary to identify relative strengths and weaknesses that may be concealed when analysis relies only on a total score (Chang & Kuo, 2025; Tzafilkou et al., 2022).

To address the need for multidimensional assessment, Barrios et al. (2026) developed and preliminarily validated a Student Digital Literacy Questionnaire based on the UNESCO Digital Literacy Global Framework and DigComp 2.2. The questionnaire consists of 35 items distributed across seven dimensions: Device and Digital Application Operation, Information and Data Literacy, Digital Communication and Collaboration, Digital Content Creation, Digital Safety and Ethics, Digital Problem Solving, and Digital Use for Learning. The preliminary validation study reported strong overall internal consistency and adequate dimensional reliability, while exploratory factor analysis provided initial evidence for the proposed multidimensional structure. However, the authors also emphasized that dimensional interpretation should remain cautious because several items showed cross-loadings and the proposed measurement model had not yet been evaluated through confirmatory model-fit indices.

Importantly, the previous validation study concentrated on the psychometric characteristics of the instrument rather than on identifying the characteristics associated with students' digital literacy. Relationships between digital literacy and demographic characteristics, educational conditions, contextual membership, and digital-access factors were beyond its primary analytical scope. This distinction creates an opportunity to use the established scoring structure for a substantively different purpose: examining how digital literacy is distributed across student groups and educational contexts and determining which demographic, educational, contextual, and digital-access characteristics remain associated with students' scores when considered simultaneously.

## Novelty of the Current Study

The first contribution of the current study lies in shifting the analytical focus from instrument validation to substantive examination of student digital literacy. Whereas the preceding study established preliminary psychometric evidence for the Student Digital Literacy Questionnaire, the present study uses the instrument to investigate patterns of competence and differences among secondary school students. Rather than repeating validation analyses, the study examines whether students' digital literacy varies according to gender, educational level, study context, device access, and Internet access. This approach extends the use of the instrument from determining whether digital literacy can be measured adequately to examining how digital literacy is distributed across meaningful student, contextual, and access characteristics. The multidimensional structure of the questionnaire is also retained, allowing digital literacy to be interpreted as a profile of interrelated competencies rather than solely as a single total score.

Second, the study advances beyond isolated group comparisons by examining the relative contribution of demographic, educational, contextual, and digital-access characteristics within a multivariable framework. Digital-divide research has demonstrated that access, socioeconomic circumstances, demographic characteristics, and patterns of technology use may all be associated with digital competence, but these influences frequently overlap (Helsper, 2012; Ren et al., 2022; Scheerder et al., 2017; van de Werfhorst et al., 2022). The present study therefore distinguishes between descriptive differences among student groups and characteristics that remain associated with digital literacy after other variables are statistically controlled.

This distinction is particularly relevant for a heterogeneous sample drawn from multiple educational contexts in Southeast Asia. Students within such settings may differ not only according to broad contextual membership but also in the conditions under which they access and use digital technologies. Examining study context, device availability, and Internet connectivity simultaneously makes it possible to determine whether variation in digital literacy is more closely associated with broad contextual differences or with more proximal conditions of digital access. In doing so, the study provides a more differentiated account of digital literacy inequality in secondary education without assuming that contextual membership itself constitutes an explanatory mechanism.

## Research Questions and Objectives

The present study addresses three research questions:

1. What patterns characterize students' digital literacy, including their overall digital literacy and relative performance across the seven dimensions?
2. To what extent does students' digital literacy differ according to gender, educational level, study context, device access, and Internet access?
3. Which demographic, educational, contextual, and digital-access characteristics are independently associated with students' overall digital literacy when these characteristics are considered simultaneously?

Based on these questions, the study aims to describe the multidimensional patterns of digital literacy among secondary school students, examine differences across demographic, educational, contextual, and digital-access groups, and determine the characteristics independently associated with students' overall digital literacy through multivariable statistical analysis. By combining competency profiling, group comparisons, effect-size estimation, multidimensional analysis, and analysis of associated factors, the study seeks to distinguish variation associated with broad student or contextual characteristics from variation more closely related to students' conditions of digital access.

## METHODS

### Research Design

This study employed a quantitative cross-sectional secondary-analysis design to examine patterns, group differences, and factors associated with digital literacy among secondary school students. An existing survey dataset collected using the Student Digital Literacy Questionnaire was analyzed to investigate digital literacy as a substantive educational outcome rather than to conduct additional psychometric validation of the instrument. The cross-sectional nature of the original dataset allowed digital literacy, demographic characteristics, educational level, study context, and digital-access conditions to be examined within the same analytical framework.

The analytical strategy was organized around three related purposes. Descriptive analysis was first conducted to characterize students' overall digital literacy and the relative pattern of performance across the seven measured dimensions. Comparative analyses were then used to determine whether digital literacy differed according to gender, educational level, study context, device access, and Internet access. Multivariate analysis was additionally conducted to determine whether the combined seven-dimensional digital literacy profile differed across these characteristics. Hierarchical multiple regression was subsequently applied to identify characteristics that remained independently associated with students' overall digital literacy when demographic, educational, contextual, and digital-access variables were considered simultaneously. This sequence allowed the analysis to progress from competency patterns to group differences, multidimensional differences, and finally to the identification of factors associated with variation in digital literacy.

The analytical purpose of the present study was distinct from that of the previously published preliminary-validation study. The earlier investigation focused on preliminary construct structure, item validity, internal consistency reliability, exploratory factor structure, and specification of the measurement model of the Student Digital Literacy Questionnaire. The present study conducted a secondary analysis of the same survey dataset to address substantively different research questions concerning digital literacy patterns, differences among student groups and study contexts, and factors associated with variation in students' scores. No psychometric validation analyses from the preceding study were repeated as primary outcomes of the present investigation.

## Participants and Data Source

The analytical sample comprised 350 secondary school students drawn from four educational contexts in Southeast Asia. To preserve contextual anonymity in the present report, the four participating contexts are identified as C1, C2, C3, and C4. These codes function solely as analytical identifiers and do not indicate geographical order, relative educational performance, or any ranking of the participating settings.

The four contextual subsamples were relatively balanced, comprising 88 students in C1, 87 in C2, 88 in C3, and 87 in C4. The sample included 157 male students and 193 female students. In terms of educational level, 158 respondents were enrolled in lower-secondary education and 192 in upper-secondary education. Students ranged in age from 12 to 19 years.

Information on digital-access conditions was also available in the dataset. Most students reported personal access to a digital device, whereas smaller groups shared devices with family members or relied primarily on devices available through school or laboratory facilities. Internet-access conditions also varied, with students reporting stable, moderately stable, or limited connectivity. These characteristics were included because the present investigation sought to determine whether variation in digital literacy was associated not only with demographic, educational, and broad contextual characteristics but also with the more proximal conditions under which students accessed digital technologies.

Participant characteristics are summarized in Table 1. The four contextual categories identify only the participating subsamples and are not treated as representative estimates of the wider educational populations from which the students were drawn. Accordingly, differences among C1–C4 are interpreted as sample-specific contextual differences rather than as evidence of population-level differences across educational systems or geographical settings.

**Table 1.** Characteristics of the study participants

| Characteristic | Category | *n* | % |
|---|---|---|---|
| Study context | C1 | 88 | 25.1 |
| | C2 | 87 | 24.9 |
| | C3 | 88 | 25.1 |
| | C4 | 87 | 24.9 |
| Gender | Male | 157 | 44.9 |
| | Female | 193 | 55.1 |
| Educational level | Lower secondary | 158 | 45.1 |
| | Upper secondary | 192 | 54.9 |
| Device access | Personal device | 243 | 69.4 |
| | Shared with family | 85 | 24.3 |
| | School/laboratory access | 22 | 6.3 |
| Internet access | Stable | 180 | 51.4 |
| | Moderately stable | 133 | 38.0 |
| | Limited | 37 | 10.6 |
| Total | | 350 | 100.0 |

The same survey dataset had previously been used for the preliminary validation of the Student Digital Literacy Questionnaire. That investigation also involved 350 respondents but used the data primarily to examine item validity, reliability, exploratory factor structure, and measurement-model specification. The present secondary analysis addressed a distinct set of research questions by examining patterns of digital literacy, differences among student and contextual groups, and factors independently associated with overall digital literacy.

## Research Instrument

Students' digital literacy was measured using the Student Digital Literacy Questionnaire developed from the UNESCO Digital Literacy Global Framework and DigComp 2.2 (Barrios et al., 2026; Law et al., 2018; Vuorikari et al., 2022). The instrument conceptualizes digital literacy as a multidimensional competence extending beyond the operational use of devices and applications to include information evaluation, communication, content creation, safety and ethics, problem solving, and the use of technology for learning.

The questionnaire consists of 35 statements distributed across seven dimensions, with five items representing each dimension. Device and Digital Application Operation assesses students' ability to operate digital devices, applications, accounts, and basic digital functions. Information and Data Literacy assesses the ability to search for, select, evaluate, and use digital information critically. Digital Communication and Collaboration addresses appropriate interaction and collaboration in digital environments. Digital Content Creation evaluates students' ability to create, edit, select, and use digital content responsibly. Digital Safety and Ethics concerns privacy, personal-data protection, digital footprints, security, and responsible digital behavior. Digital Problem Solving assesses the ability to address technical problems and select technologies appropriate to learning needs. Digital Use for Learning measures the use of digital technology for independent learning, academic organization, exploration of learning materials, and self-development. The structure of the instrument is summarized in Table 2.

**Table 2.** Structure of the Student Digital Literacy Questionnaire

| Dimension | Items | Items number | Main competency assessed |
|---|---|---|---|
| Device and Digital Application Operation | Q1–Q5 | 5 | Operating digital devices, applications, accounts, and basic digital functions |
| Information and Data Literacy | Q6–Q10 | 5 | Searching, selecting, evaluating, and using digital information critically |
| Digital Communication and Collaboration | Q11–Q15 | 5 | Communicating and collaborating appropriately through digital environments |
| Digital Content Creation | Q16–Q20 | 5 | Creating, editing, selecting, and using digital content responsibly |
| Digital Safety and Ethics | Q21–Q25 | 5 | Protecting privacy and personal data and engaging in responsible digital behavior |

| Dimension | Items | Items number | Main competency assessed |
|---|---|---|---|
| Digital Problem Solving | Q26–Q30 | 5 | Addressing technical problems and selecting appropriate digital technologies |
| Digital Use for Learning | Q31–Q35 | 5 | Using digital technology for independent learning, academic organization, and self-development |

Previous preliminary validation demonstrated strong internal consistency for the overall instrument, with Cronbach's alpha of .924, while reliability coefficients for the individual dimensions ranged from .638 to .690. The instrument was therefore stronger for interpreting overall digital literacy than for drawing highly specific conclusions based solely on individual dimensional scores. Accordingly, the total digital literacy score was designated as the principal outcome variable in the present study, while dimensional scores were treated as complementary outcomes for examining the multidimensional competency profile.

### Response Scale and Scoring Procedure

All questionnaire statements were answered using a five-point Likert scale ranging from Strongly Agree to Strongly Disagree. Positively worded items were scored as 5 for Strongly Agree, 4 for Agree, 3 for Undecided, 2 for Disagree, and 1 for Strongly Disagree. Seven negatively worded items, namely Q4, Q9, Q14, Q19, Q24, Q29, and Q34, were reverse-scored so that higher scores consistently represented stronger digital literacy.

For negatively worded items, an original response score of 5 was transformed to 1, 4 to 2, 3 remained unchanged, 2 was transformed to 4, and 1 to 5. Each dimensional score was calculated by summing its five corresponding items, yielding a theoretical range from 5 to 25. The total digital literacy score was obtained by summing all 35 scored items, producing a theoretical range from 35 to 175. Higher scores represented stronger digital literacy.

Total and dimensional scores were treated as continuous variables in the primary statistical analyses. Retaining the scores in continuous form preserved variation among respondents and was more appropriate for group comparisons, multivariate analysis, and regression than relying exclusively on categorical classifications such as low, moderate, or high digital literacy.

### Study Variables

The total digital literacy score served as the primary dependent variable. The seven dimensional scores were treated as complementary dependent variables for examining the multidimensional pattern of students' competencies. Explanatory variables comprised age, gender, educational level, study context, device access, and Internet access.

Age, gender, and educational level represented demographic and educational characteristics. Study context was treated as a categorical contextual variable distinguishing the four participating subsamples, C1–C4. It was not treated as a direct measure of educational systems, policy environments, infrastructure, or other macro-level characteristics. Device access and Internet access represented the more proximal digital-access conditions experienced by the participating students. This distinction was important because the individual-level cross-sectional dataset did not provide sufficient evidence to attribute observed differences to particular institutional, geographical, or educational-system characteristics.

Categorical variables were analyzed as factors rather than assigned arbitrary numerical distances between categories. In the hierarchical regression analysis, variables containing more than two categories were represented through indicator coding. Female students, lower-secondary education, C1, personal device access, and stable Internet access served as the reference categories. C1 was used solely as the statistical reference for contextual comparisons and should not be interpreted as a normative or substantive benchmark. The conceptual grouping of explanatory variables determined their sequential entry into the regression models.

### Data Screening and Preliminary Analysis

Before inferential analysis, the dataset was examined for completeness, duplicate respondent codes, values outside the permitted response range, scoring inconsistencies, and potential data-entry errors. Questionnaire responses were required to fall within the valid range from 1 to 5. Reverse scoring of the seven negatively worded items was verified before dimensional and total scores were calculated. The resulting analytical dataset contained 350 complete respondent records.

The distributions of continuous variables were evaluated using means, standard deviations, observed ranges, skewness, kurtosis, histograms, and Q-Q plots where appropriate. Distributional assumptions were assessed using a combination of numerical and graphical evidence rather than relying exclusively on formal normality tests because such tests may become overly sensitive as sample size increases (Field, 2018; Tabachnick & Fidell, 2019).

Diagnostic procedures were also conducted before regression analysis. Linearity was evaluated by examining relationships between continuous predictors and the dependent variable. Homoscedasticity and residual distribution were evaluated through residual diagnostics, while independence of residuals was assessed using the Durbin-Watson statistic. Potentially influential observations were evaluated using standardized residuals, leverage statistics, and Cook's distance. Multicollinearity among explanatory variables was assessed using tolerance and variance inflation factor values (Hair et al., 2019). The relationship between age and educational level received particular attention because these variables were expected to be naturally associated. Their simultaneous inclusion was retained because the diagnostic statistics did not indicate multicollinearity severe enough to compromise coefficient interpretation.

For the multivariate analyses, the seven dimensional scores were evaluated jointly rather than as seven independent outcomes. Pillai's trace was selected as the principal multivariate test statistic because of its relative robustness to moderate departures from multivariate assumptions. Dimension-specific follow-up analyses were performed only when the corresponding omnibus multivariate test was statistically significant.

## Statistical Analysis

The statistical analysis was aligned with the three research questions established in the Introduction. Descriptive analysis was used to characterize students' overall and dimension-specific digital literacy patterns. Comparative analyses examined differences in overall digital literacy across demographic, educational, contextual, and digital-access groups. Multivariate analysis of variance was used to determine whether the combined profile of the seven digital literacy dimensions differed according to the same grouping characteristics. Hierarchical multiple regression was subsequently conducted to identify characteristics independently associated with overall digital literacy. The analytical framework is summarized in Table 3.

**Table 3.** Statistical analysis framework

| Research focus | Outcome variable | Explanatory or grouping variable | Statistical procedure | Main statistics reported |
|---|---|---|---|---|
| Digital literacy patterns | Overall score and seven dimensional scores | Not applicable | Descriptive statistics | Mean, SD, range, 95% CI, mean per item |
| Gender differences | Overall digital literacy | Gender | Independent-samples $t$-test | Mean, SD, $t$, $p$, Hedges' $g$ |
| Educational-level differences | Overall digital literacy | Educational level | Independent-samples $t$-test | Mean, SD, $t$, $p$, Hedges' $g$ |
| Contextual differences | Overall digital literacy | Study context (C1–C4) | One-way ANOVA | $F$, $p$, $\eta^2$ |
| Device-access differences | Overall digital literacy | Device access | One-way ANOVA with post-hoc comparisons | $F$, $p$, $\eta^2$, adjusted pairwise $p$ |
| Internet-access differences | Overall digital literacy | Internet access | One-way ANOVA with post-hoc comparisons | $F$, $p$, $\eta^2$, adjusted pairwise $p$ |
| Multidimensional group differences | Seven digital literacy dimensional scores | Gender, educational level, study context, device access, Internet access | MANOVA followed by Holm-adjusted univariate analyses when applicable | Pillai's $V$, $F$, $p$, dimension-specific $F$, adjusted $p$, $\eta^2$ |
| Associated factors | Overall digital literacy | Age, gender, educational level, study context, device access, Internet access | Hierarchical multiple linear regression | $B$, SE, $\beta$, 95% CI, $p$, $R^2$, adjusted $R^2$, $\Delta R^2$, VIF |

### Analysis of Digital Literacy Patterns

Students' digital literacy patterns were examined using descriptive statistics for the overall digital literacy score and each of the seven dimensions. Means, standard deviations, observed minimum and maximum scores, and 95% confidence intervals were calculated. Because all seven dimensions consisted of five items measured using an identical five-point response format, their summed dimensional scores were directly comparable. Mean-per-item values were additionally calculated to express dimensional performance on the original response metric.

The purpose of the dimensional analysis was to identify relative competency strengths and weaknesses rather than to reproduce the psychometric analyses reported in the preceding validation study. Dimensional findings were therefore interpreted as descriptive competency patterns and complementary educational evidence rather than as additional evidence of construct validation.

### Analysis of Group Differences

Differences in overall digital literacy according to gender and educational level were examined using independent-samples *t*-tests. Equality of variance was evaluated before interpretation of the conventional test statistic. Differences among the four contextual subsamples, device-access categories, and Internet-access categories were examined using one-way analysis of variance. For statistically significant omnibus comparisons involving more than two groups, Tukey-adjusted pairwise comparisons were used to identify the specific groups contributing to the overall difference.

Comparisons among C1–C4 were treated strictly as contextual comparisons among the participating subsamples. Statistical differences were not interpreted as evidence of population-level geographical or educational-system differences because the sampling strategy was not designed to generate representative estimates for the broader settings from which participants were drawn. The contextual codes were therefore used as analytical grouping variables rather than as explanatory mechanisms.

Group comparisons were interpreted using both statistical significance and effect magnitude. Hedges' *g* was used for comparisons involving two groups, while eta squared ($\eta^2$) was used for comparisons involving three or more groups. Confidence intervals, effect-size estimates, and *p* values were interpreted together because statistical significance alone does not indicate the substantive magnitude of a difference (Lakens, 2013).

In addition to comparisons of the overall digital literacy score, multivariate analysis of variance (MANOVA) was conducted to determine whether the combined profile of the seven digital literacy dimensions differed according to gender, educational level, study context, device access, and Internet access. The seven dimensional scores were entered simultaneously as dependent variables, while each student characteristic was examined as the grouping variable in the corresponding analysis. Pillai's trace was used as the primary multivariate statistic.

When an omnibus multivariate test was statistically significant, follow-up univariate analyses were conducted for the individual dimensions. Because seven dimension-specific tests were evaluated within each follow-up analysis, $p$ values were adjusted using the Holm procedure to control inflation of the familywise Type I error rate. Dimension-specific effect sizes were expressed using eta squared. These dimensional findings were interpreted cautiously because the preliminary validation study indicated more moderate reliability for the individual subscales than for the total digital literacy instrument.

### Hierarchical Multiple Regression Analysis

Hierarchical multiple linear regression was conducted to determine which characteristics were independently associated with students' overall digital literacy. The total digital literacy score served as the dependent variable, while explanatory variables were entered sequentially according to their conceptual roles rather than through an automated variable-selection procedure.

The first model incorporated age, gender, and educational level to account for demographic and educational variation. Study context was added in the second model as a broad contextual grouping characteristic. Device access and Internet access were entered in the third and final model so that their incremental contribution could be evaluated after demographic, educational, and contextual characteristics had been taken into account. This sequence allowed the additional explanatory contribution of proximal digital-access conditions to be evaluated beyond the variation explained by preceding blocks of variables.

Model interpretation considered $R^2$, adjusted $R^2$, the overall $F$ statistic, and the change in explained variance between successive models. The change in $R^2$ was used to determine whether addition of a conceptual block contributed explanatory information beyond variables already included in the preceding model. Individual predictors were evaluated using unstandardized coefficients ($B$), standard errors, standardized coefficients ($\beta$), 95% confidence intervals, and $p$ values. Variance inflation factors and tolerance statistics were used to assess multicollinearity.

Coefficients associated with C2, C3, and C4 were interpreted strictly as adjusted differences relative to the reference context, C1. They were not interpreted as causal effects of educational or geographical context because contextual membership may represent multiple unmeasured social, institutional, infrastructural, and educational characteristics that could not be separated using the available dataset.

More generally, regression coefficients were interpreted as associations rather than causal effects. The cross-sectional observational design did not establish temporal ordering or experimental control. Consequently, the statistical term *predictor* referred only to a variable's function within the regression model and did not imply that the corresponding characteristic caused variation in students' digital literacy.

### Statistical Decision Criteria

All inferential analyses used a two-tailed significance criterion of $\alpha = .05$. Exact $p$ values were reported where appropriate, while values below .001 were reported as $p < .001$. Statistical interpretation considered significance levels in conjunction with confidence intervals, effect sizes, and substantive educational relevance.

For follow-up analyses involving the seven digital literacy dimensions, the Holm procedure was applied to adjust *p* values for multiple testing and reduce inflation of the familywise Type I error rate. For other group comparisons, effect sizes were interpreted alongside statistical significance because statistically detectable differences may still represent relatively small substantive variation. Regression findings were similarly evaluated using individual coefficients, confidence intervals, changes in explained variance, and the overall explanatory power of successive models (Field, 2018; Lakens, 2013; Tabachnick & Fidell, 2019).

### Ethical Considerations

The present study involved secondary analysis of an existing coded survey dataset. No new participants were recruited and no additional data were collected specifically for the present analysis. The original questionnaire informed respondents that its purpose was to measure digital literacy in learning contexts, that there were no right or wrong answers, and that responses would be used only for research or educational evaluation and handled confidentially. Respondent records were identified using codes rather than student names, allowing the analytical dataset to be processed without direct personal identifiers.

For the present report, contextual information was further minimized by identifying the four participating educational contexts only as C1, C2, C3, and C4. The broader Southeast Asian setting was retained to provide sufficient geographical context for interpreting the study, while specific contextual identities were not reported. The analyses did not seek to identify individual students, schools, or other participating institutions. Contextual comparisons were interpreted only as characteristics of the participating subsamples and not as judgments about particular educational systems or geographical populations.

## RESULTS AND DISCUSSION

### Data Screening and Analytical Assumptions

The final analytical dataset consisted of 350 complete respondent records. No missing responses were identified across the 35 questionnaire items, no duplicate respondent codes were detected, and all item responses fell within the permitted range of 1 to 5. Verification of the seven negatively worded items confirmed that reverse scoring had been applied consistently before the dimensional and total scores were calculated. The observed total digital literacy scores ranged from 83 to 164, with a mean of 116.18 ($SD$ = 13.61) and a median of 116.00. The distribution was approximately symmetric, with skewness of 0.098 and kurtosis of -0.126. The 95% confidence interval for the overall mean ranged from 114.75 to 117.61.

The assumptions underlying the multivariable analyses were examined before interpretation of the regression models. Residuals from the final regression model showed little departure from symmetry, with residual skewness of 0.088 and kurtosis of 0.075. The Durbin-Watson statistic was 2.02, indicating no meaningful residual autocorrelation. The Breusch-Pagan test did not indicate heteroscedasticity, $p$ = .605, while the Ramsey RESET test was nonsignificant, $F(1, 338) = 0.97$, $p = .326$. Variance inflation factors ranged from 1.01 to 2.60, indicating no problematic multicollinearity among the explanatory variables. The maximum Cook's distance was .042, suggesting that no single observation exerted excessive influence on the fitted regression model. These diagnostic results supported the use of the planned parametric comparisons and hierarchical regression analyses.

## Overall and Multidimensional Patterns of Digital Literacy

The mean overall digital literacy score was 116.18 ($SD = 13.61$) on a theoretical range of 35 to 175. Examination of the seven dimensions showed that students' digital literacy was unevenly distributed across competency domains. Device and Digital Application Operation had the highest mean score, $M = 19.37$ ($SD = 2.43$), corresponding to a mean-per-item score of 3.87. Digital Communication and Collaboration ranked second, $M = 17.63$ ($SD = 2.31$), followed by Digital Use for Learning, $M = 17.22$ ($SD = 2.40$).

The remaining dimensions showed comparatively lower scores. Digital Problem Solving had a mean of 15.65 ($SD = 2.40$), Digital Content Creation 15.63 ($SD = 2.48$), and Information and Data Literacy 15.50 ($SD = 2.44$). Digital Safety and Ethics had the lowest mean score, $M = 15.19$ ($SD = 2.47$), corresponding to a mean-per-item score of 3.04. The difference between the highest- and lowest-scoring dimensions was 4.17 points on the five-item dimensional scale, equivalent to approximately 0.83 points per item. Detailed descriptive statistics are presented in Table 4.

**Table 4.** Descriptive statistics for overall and dimensional digital literacy

| Digital literacy measure | Mean | SD | Observed range | 95% CI | Mean per item | % max |
|---|---|---|---|---|---|---|
| Overall digital literacy | 116.18 | 13.61 | 83–164 | 114.75–117.61 | 3.32 | 66.39 |
| Device and Digital Application Operation | 19.37 | 2.43 | 13–25 | 19.11–19.62 | 3.87 | 77.46 |
| Information and Data Literacy | 15.50 | 2.44 | 10–25 | 15.24–15.76 | 3.10 | 62.00 |
| Digital Communication and Collaboration | 17.63 | 2.31 | 11–23 | 17.39–17.87 | 3.53 | 70.51 |
| Digital Content Creation | 15.63 | 2.48 | 9–23 | 15.37–15.89 | 3.13 | 62.50 |
| Digital Safety and Ethics | 15.19 | 2.47 | 8–22 | 14.93–15.45 | 3.04 | 60.78 |
| Digital Problem Solving | 15.65 | 2.40 | 10–23 | 15.40–15.90 | 3.13 | 62.59 |
| Digital Use for Learning | 17.22 | 2.40 | 11–25 | 16.97–17.47 | 3.44 | 68.87 |

*Note.* The theoretical range was 5–25 for each dimension and 35–175 for the overall digital literacy score.

Figure 1 provides a visual comparison of the seven dimensions and shows the variation in mean scores across competency domains.

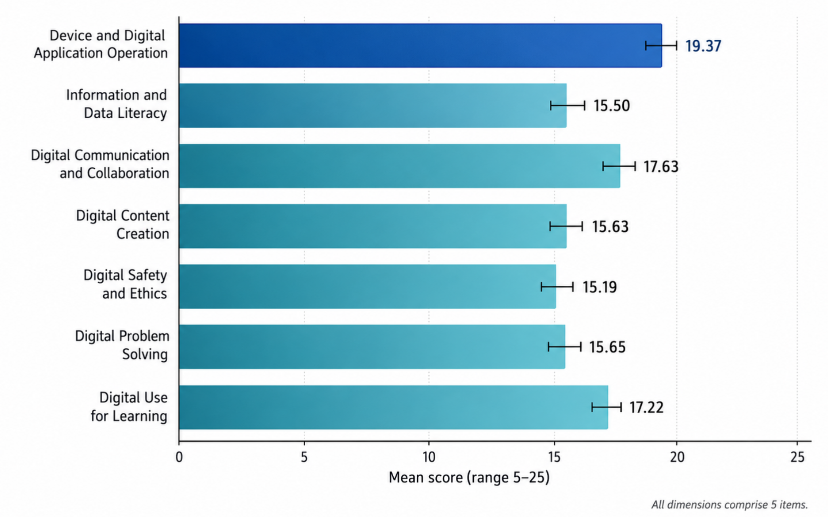


**Figure 1.** Multidimensional pattern of student digital literacy. Error bars represent 95% confidence intervals. Each dimension comprised five items and had a theoretical score range of 5–25

As shown in Figure 1, Device and Digital Application Operation had the highest mean score, whereas Digital Safety and Ethics had the lowest. Digital Communication and Collaboration and Digital Use for Learning occupied an intermediate range, while Information and Data Literacy, Digital Content Creation, and Digital Problem Solving showed closely clustered lower means. The confidence intervals around the dimensional means were relatively narrow.

## Differences in Overall Digital Literacy Across Student Groups

Comparative analyses showed small differences in overall digital literacy according to demographic and educational characteristics. Male students had a slightly higher mean score ($M$ = 117.07, $SD$ = 13.90) than female students ($M$ = 115.46, $SD$ = 13.37), but the difference was not statistically significant, $t(348) = 1.10$, $p = .270$, Hedges' $g = .12$. Lower-secondary students also obtained a slightly higher mean score ($M$ = 116.70, $SD$ = 13.17) than upper-secondary students ($M$ = 115.76, $SD$ = 13.98), but the difference was not statistically significant, $t(348) = 0.64$, $p = .521$, $g = .07$. Age was likewise not significantly correlated with overall digital literacy, $r = -.046$, $p = .391$.

Mean scores were also closely comparable across the four study contexts. C1 had a mean score of 114.98, C2 117.22, C3 116.68, and C4 115.85. The overall difference across C1–C4 was not statistically significant, $F(3, 346) = 0.45$, $p = .716$, $\eta^2 = .004$, indicating that contextual membership accounted for very little variation in overall digital literacy.

A different pattern was observed for digital-access conditions. Device access was significantly associated with overall digital literacy, $F(2, 347) = 3.40$, $p = .034$, $\eta^2 = .019$. Students with personal device access had the highest mean score, $M$ = 117.10, followed by students sharing devices with family members, $M$ = 115.27. Students relying primarily on school or laboratory devices had the lowest mean score, $M$ = 109.55. The effect size was small.

Internet access showed the largest unadjusted group difference among the characteristics examined. Students reporting stable Internet access obtained a mean digital literacy score of

119.04, those reporting moderately stable access obtained a mean of 115.14, and students with limited Internet access obtained a mean of 105.97. The overall difference was statistically significant, $F(2, 347) = 16.05$, $p < .001$, $\eta^2 = .085$, indicating that Internet-access categories accounted for approximately 8.5% of the observed variance in overall digital literacy.

**Table 5.** Differences in overall digital literacy across student characteristics

| Characteristic | Group | *n* | Mean | SD | Test statistic | *p* | Effect size |
|---|---|---|---|---|---|---|---|
| Gender | Male | 157 | 117.07 | 13.90 | $t(348) = 1.10$ | .270 | $g = .118$ |
| | Female | 193 | 115.46 | 13.37 | | | |
| Educational level | Lower secondary | 158 | 116.70 | 13.17 | $t(348) = 0.64$ | .521 | $g = .069$ |
| | Upper secondary | 192 | 115.76 | 13.98 | | | |
| Study context | C1 | 88 | 114.98 | 13.22 | $F(3, 346) = 0.45$ | .716 | $\eta^2 = .004$ |
| | C2 | 87 | 117.22 | 12.82 | | | |
| | C3 | 88 | 116.68 | 15.24 | | | |
| | C4 | 87 | 115.85 | 13.15 | | | |
| Device access | Personal device | 243 | 117.10 | 13.32 | $F(2, 347) = 3.40$ | .034 | $\eta^2 = .019$ |
| | Shared with family | 85 | 115.27 | 14.25 | | | |
| | School/laboratory | 22 | 109.55 | 12.79 | | | |
| Internet access | Stable | 180 | 119.04 | 13.47 | $F(2, 347) = 16.05$ | < .001 | $\eta^2 = .085$ |
| | Moderately stable | 133 | 115.14 | 12.96 | | | |
| | Limited | 37 | 105.97 | 11.26 | | | |

*Note.* C1–C4 represent the four contextual subsamples used as analytical grouping categories. They should not be interpreted as population-level estimates of the broader educational settings from which participants were drawn.

The progressive difference associated with Internet access is illustrated in Figure 2.

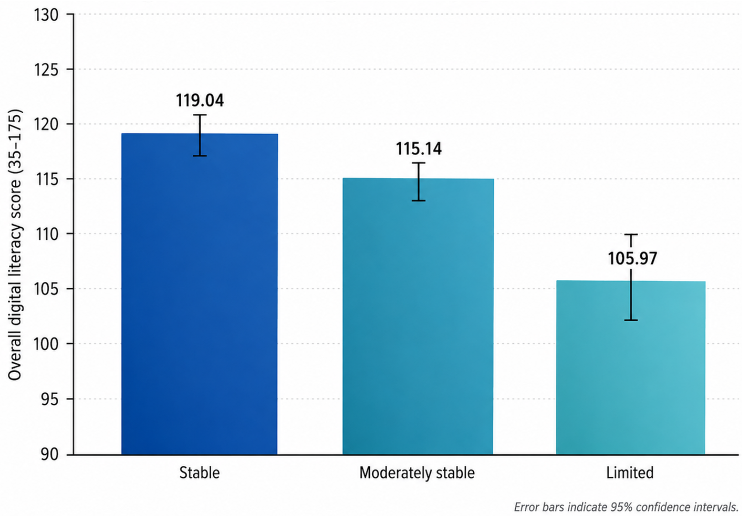


**Figure 2.** Overall digital literacy according to Internet-access conditions. Error bars represent 95% confidence intervals. The theoretical range of the overall digital literacy score was 35–175.

Figure 2 shows a monotonic pattern across the three connectivity categories. Students with stable Internet access recorded the highest mean score, those with moderately stable access occupied an intermediate position, and students with limited Internet access had the lowest mean score. The difference between the stable and limited groups was approximately 13 points on the total digital literacy scale.

### Post-hoc Comparisons of Digital-Access Groups

Post-hoc comparisons clarified the sources of the significant device- and Internet-access differences. Students with personal device access scored 7.55 points higher than students relying primarily on school or laboratory devices. This comparison remained statistically significant after Tukey adjustment, 95% CI [0.47, 14.64], $p = .034$. The difference between students with personal devices and those sharing devices with family members was not statistically significant, mean difference = 1.83, 95% CI [-2.18, 5.84], $p = .531$. The difference between students sharing devices with family members and those relying on school or laboratory devices was also not statistically significant, mean difference = 5.73, 95% CI [-1.89, 13.34], $p = .181$.

The Internet-access comparisons showed significant differences across all three categories. Students with stable Internet access scored 3.90 points higher than those with moderately stable access, 95% CI [0.39, 7.42], $p = .025$. Students with stable access also scored 13.07 points higher than those with limited connectivity, 95% CI [7.52, 18.62], $p < .001$. Students with moderately stable access scored 9.17 points higher than those with limited Internet access, 95% CI [3.46, 14.88], $p < .001$.

**Table 6.** Post-hoc comparisons for device and Internet access

| Variable | Comparison | Mean diff. | 95% CI | Adjusted *p* |
|---|---|---|---|---|
| Device access | Personal vs. shared with family | 1.83 | -2.18 to 5.84 | .531 |
| | Personal vs. school/laboratory | 7.55 | 0.47 to 14.64 | .034 |
| | Shared with family vs. school/laboratory | 5.73 | -1.89 to 13.34 | .181 |
| Internet access | Stable vs. moderately stable | 3.90 | 0.39 to 7.42 | .025 |
| | Stable vs. limited | 13.07 | 7.52 to 18.62 | < .001 |
| | Moderately stable vs. limited | 9.17 | 3.46 to 14.88 | < .001 |

Thus, the significant device-access difference was concentrated primarily between students with personal-device access and those relying on school or laboratory facilities. In contrast, Internet-access categories showed a statistically distinguishable gradient across all three levels of connectivity.

### Multidimensional Differences Across Student Groups

The seven digital literacy dimensions were subsequently examined jointly using multivariate analysis. No statistically significant multivariate difference was identified according to gender, Pillai's $V = .018$, $F(7, 342) = 0.88$, $p = .519$, or educational level, Pillai's $V = .020$, $F(7, 342) = 0.98$, $p = .443$. Device-access categories also did not show a statistically significant difference across the combined seven-dimensional profile, Pillai's $V = .059$, $F(14, 684) = 1.48$, $p = .112$.

In contrast, statistically significant multivariate differences were observed for study context and Internet-access conditions. The four contextual subsamples differed when the seven dimensions were considered jointly, Pillai's $V = .116$, $F(21, 1026) = 1.97$, $p = .006$. Internet access showed a stronger multivariate association, Pillai's $V = .141$, $F(14, 684) = 3.72$, $p < .001$. The complete multivariate results are presented in Table 7.

**Table 7.** Multivariate differences in digital literacy across student characteristics

| Grouping variable | Pillai's *V* | *F* | df | *p* |
|---|---|---|---|---|
| Gender | .018 | 0.88 | 7, 342 | .519 |
| Educational level | .020 | 0.98 | 7, 342 | .443 |
| Study context | .116 | 1.97 | 21, 1026 | .006 |
| Device access | .059 | 1.48 | 14, 684 | .112 |
| Internet access | .141 | 3.72 | 14, 684 | < .001 |

The significant multivariate result for study context was not followed by statistically significant differences in any individual digital literacy dimension after adjustment for multiple comparisons. The omnibus result therefore reflected a combination of relatively small differences distributed across the seven dimensions rather than a statistically isolated difference within a particular competency domain. No ranking of C1–C4 was therefore undertaken.

A clearer dimension-specific pattern was observed for Internet access. Follow-up analyses remained statistically significant across all seven digital literacy dimensions after Holm correction. The largest association was found for Digital Problem Solving, $\eta^2 = .101$, followed by Digital Safety and Ethics, $\eta^2 = .078$, and Digital Content Creation, $\eta^2 = .069$. Smaller but statistically significant associations were observed for Digital Use for Learning, $\eta^2 = .045$, Information and Data Literacy, $\eta^2 = .042$, Device and Digital Application Operation, $\eta^2 = .040$, and Digital Communication and Collaboration, $\eta^2 = .030$. Dimension-level results according to Internet-access conditions are presented in Table 8.

**Table 8.** Dimension-level differences in digital literacy according to Internet access

| Dimension | Stable *M* | Moderately stable *M* | Limited *M* | *F*(2, 347) | Holm-adjusted *p* | $\eta^2$ |
|---|---|---|---|---|---|---|
| Device and Digital Application Operation | 19.73 | 19.22 | 18.14 | 7.21 | .002 | .040 |
| Information and Data Literacy | 15.93 | 15.21 | 14.43 | 7.56 | .002 | .042 |
| Digital Communication and Collaboration | 17.90 | 17.56 | 16.57 | 5.32 | .005 | .030 |
| Digital Content Creation | 16.08 | 15.48 | 13.92 | 12.89 | < .001 | .069 |
| Digital Safety and Ethics | 15.70 | 15.00 | 13.43 | 14.61 | < .001 | .078 |
| Digital Problem Solving | 16.21 | 15.43 | 13.70 | 19.46 | < .001 | .101 |
| Digital Use for Learning | 17.49 | 17.25 | 15.78 | 8.09 | .001 | .045 |

*Note.* *M* = mean. Reported *p* values were adjusted using the Holm procedure to account for multiple dimension-level comparisons. $\eta^2$ represents the proportion of variance in each dimension associated with Internet-access category.

Students with stable Internet access obtained higher mean scores than students with limited access across all seven dimensions. The largest differences were observed in Digital Problem Solving, Digital Safety and Ethics, and Digital Content Creation, while the smallest dimension-specific association was observed for Digital Communication and Collaboration.

## Factors Associated with Overall Digital Literacy

Hierarchical multiple regression was conducted to determine whether digital-access characteristics remained associated with overall digital literacy after demographic, educational, and contextual characteristics were statistically controlled. The first model included age, gender, and educational level. These variables collectively explained 0.6% of the variance in overall digital literacy, $R^2 = .006$, adjusted $R^2 = -.003$, and the model was not statistically significant, $F(3, 346) = 0.67$, $p = .574$.

Study context was added in the second model. The proportion of explained variance increased slightly to 1.0%, $R^2 = .010$, adjusted $R^2 = -.007$. The model remained nonsignificant, $F(6, 343) = 0.57$, and the additional contribution of contextual membership was not statistically significant, $\Delta R^2 = .004$, $\Delta F(3, 343) = 0.48$, $p = .698$.

Device access and Internet access were added in the third model. The final model accounted for 11.4% of the variance in overall digital literacy, $R^2 = .114$, adjusted $R^2 = .087$, and was statistically significant, $F(10, 339) = 4.35$, $p < .001$. Digital-access variables contributed an additional 10.4% of explained variance beyond the demographic, educational, and contextual characteristics, $\Delta R^2 = .104$, $\Delta F(4, 339) = 9.92$, $p < .001$.

**Table 9.** Hierarchical regression models for overall digital literacy

| Model | Variables entered | $R^2$ | Adjusted $R^2$ | $\Delta R^2$ | Model $F$ | $\Delta F$ | $p$ for change |
|---|---|---|---|---|---|---|---|
| Model 1 | Age, gender, educational level | .006 | -.003 | .006 | 0.67 | 0.67 | .574 |
| Model 2 | Model 1 plus study context | .010 | -.007 | .004 | 0.57 | 0.48 | .698 |
| Model 3 | Model 2 plus device access and Internet access | .114 | .087 | .104 | 4.35 | 9.92 | < .001 |

*Note.* Model 1: $F(3, 346) = 0.67$. Model 2: $F(6, 343) = 0.57$. Model 3: $F(10, 339) = 4.35$.

The individual coefficients from the final model are presented in Table 10. Age, gender, educational level, and membership in C2, C3, or C4 relative to C1 were not independently associated with overall digital literacy. Sharing a device with family members also did not differ significantly from personal-device access after adjustment for the other variables.

**Table 10.** Final hierarchical regression model predicting overall digital literacy

| Predictor | $B$ | SE | β | 95% CI for $B$ | $p$ |
|---|---|---|---|---|---|
| Age | -0.43 | 0.59 | -.060 | -1.59 to 0.73 | .465 |
| Male | 1.45 | 1.40 | .053 | -1.32 to 4.21 | .304 |
| Upper secondary | 0.01 | 2.25 | < .001 | -4.42 to 4.44 | .998 |
| C2 | 1.70 | 1.97 | .054 | -2.19 to 5.58 | .390 |
| C3 | 0.91 | 1.98 | .029 | -2.98 to 4.79 | .646 |
| C4 | 0.50 | 1.97 | .016 | -3.38 to 4.38 | .801 |

| Predictor | *B* | SE | β | 95% CI for *B* | *p* |
|---|---|---|---|---|---|
| Shared family device | -1.63 | 1.65 | -.051 | -4.87 to 1.61 | .323 |
| School/laboratory device | -7.74 | 2.91 | -.138 | -13.46 to -2.02 | .008 |
| Moderately stable Internet | -3.69 | 1.50 | -.132 | -6.64 to -0.74 | .014 |
| Limited Internet | -13.30 | 2.35 | -.301 | -17.93 to -8.67 | < .001 |

*Note.* Reference categories were female, lower-secondary education, C1, personal device access, and stable Internet access. *B* = unstandardized regression coefficient; SE = standard error; β = standardized regression coefficient.

After simultaneous adjustment for the other characteristics, students relying primarily on school or laboratory devices scored an estimated 7.74 points lower than students with personal-device access, $B = -7.74$, 95% CI [-13.46, -2.02], $\beta = -.138$, $p = .008$. Students sharing devices with family members did not differ significantly from those with personal access.

Internet connectivity remained the strongest associated factor in the final model. Compared with students reporting stable Internet access, those with moderately stable access scored an adjusted 3.69 points lower, $B = -3.69$, 95% CI [-6.64, -0.74], $\beta = -.132$, $p = .014$. Students reporting limited Internet access scored an adjusted 13.30 points lower, $B = -13.30$, 95% CI [-17.93, -8.67], $\beta = -.301$, $p < .001$. The standardized coefficient for limited Internet access had the largest absolute magnitude among all explanatory variables included in the final model.

Across the analyses, demographic characteristics and study-context membership showed little association with overall digital literacy. Device access showed a smaller association that was primarily concentrated among students who relied on school or laboratory facilities. Internet-access quality showed the most consistent statistical association with digital literacy, appearing in the overall comparisons, across the seven-dimensional profile, and in the fully adjusted regression model.

## Discussion

The present study extends the preliminary validation of the Student Digital Literacy Questionnaire by using the instrument to examine substantive patterns, group differences, and factors associated with digital literacy among secondary school students. Three findings are particularly important. First, digital literacy was unevenly distributed across the seven competency dimensions. Students demonstrated their strongest performance in Device and Digital Application Operation, whereas Digital Safety and Ethics, Information and Data Literacy, Digital Content Creation, and Digital Problem Solving were comparatively less developed. Second, overall digital literacy differed little according to age, gender, educational level, or study-context membership. Third, digital-access conditions, particularly the quality and stability of Internet connectivity, showed the clearest and most consistent association with digital literacy. Taken together, the results indicate that variation in digital literacy within the participating Southeast Asian sample was more closely associated with students' immediate conditions of digital access than with broad demographic or contextual membership.

The uneven dimensional profile reinforces the conceptual distinction between being able to operate digital technologies and possessing comprehensive digital literacy. Digital literacy has consistently been conceptualized as a multidimensional competence incorporating technical, cognitive, informational, communicative, creative, problem-solving, safety-related, and ethical capabilities (Eshet-Alkalai, 2004; Ng, 2012; van Laar et al., 2017). This conceptualization is also reflected in the UNESCO Digital Literacy Global Framework and DigComp 2.2, which position information and data literacy, communication and collaboration, digital content creation, safety, and problem solving alongside operational skills (Law et al., 2018; Vuorikari et al., 2022). The present results illustrate the practical importance of this distinction. Students achieved approximately 77% of the maximum possible score for Device and Digital Application Operation, whereas several dimensions requiring more critical, strategic, or responsible engagement remained closer to 60%–63% of their maximum scores. Technical familiarity therefore did not correspond to equally developed competence across the broader digital literacy construct.

The comparatively strong operational dimension may reflect the frequency with which adolescents interact with smartphones, applications, online accounts, messaging platforms, and other digital technologies in everyday life. Repeated exposure may support fluency in routine device operation even when such experiences are not accompanied by systematic digital-literacy instruction. However, familiarity with technology should not be equated with sophisticated digital competence. Ng (2012) challenged the assumption that young people's routine engagement with technology automatically produces advanced digital literacy, while research on digital inequality has similarly demonstrated that access and frequency of use do not guarantee equivalent skills or educational benefits (Hargittai, 2002; van Deursen & van Dijk, 2011). The present pattern is consistent with this distinction because operational competence was stronger than competencies involving critical evaluation, responsible participation, content creation, and strategic problem solving.

Digital Safety and Ethics was the lowest-scoring dimension and therefore deserves particular educational attention. Digital safety encompasses privacy awareness, protection of personal data, cybersecurity practices, management of digital footprints, and recognition of risks in online environments. Ethical digital participation additionally requires students to communicate responsibly, respect intellectual and personal rights, and consider the consequences of their actions in networked environments. These competencies are increasingly important as students encounter social media, algorithmically selected information, persistent digital records, misinformation, and digital platforms that routinely collect and process personal information. The comparatively lower score in this dimension suggests a potential imbalance between students' ability to participate in digital environments and their preparedness to navigate those environments safely, responsibly, and critically. Research on young people's online resilience similarly emphasizes the importance of digital knowledge and skills for managing online risks and responding to misleading or problematic information (Livingstone et al., 2023; Vissenberg et al., 2022, 2023).

The comparatively modest performance in Information and Data Literacy is closely related to this concern. Accessing information and evaluating its quality are distinct competencies. Effective information literacy requires students to formulate searches, compare sources, assess evidence, identify potential bias, determine relevance, and make judgments about credibility. DigComp 2.2 treats these capabilities as foundational because effective digital participation depends not simply on information availability but on the ability to evaluate and use information critically (Vuorikari et al., 2022). This distinction has become increasingly consequential as students encounter information through search engines, social media, automated recommendation systems, and generative artificial intelligence. Greater access can increase the quantity and speed of information retrieval, but it does not necessarily improve the quality of students' judgments about that information.

Digital Content Creation and Digital Problem Solving were also among the comparatively weaker competencies. These dimensions generally demand more active and strategic engagement with technology than routine consumption or communication. Digital content creation requires students to organize ideas, select appropriate applications, transform information into new representations, revise products, and use digital resources responsibly. Digital problem solving similarly involves identifying difficulties, exploring alternatives, selecting appropriate tools, and adapting technological strategies to unfamiliar situations. Such competencies are consistent with broader conceptualizations of twenty-first-century digital skills that distinguish creativity, problem solving, information management, and strategic technology use from purely operational proficiency (van Laar et al., 2017). The findings therefore suggest that becoming an efficient technology user does not necessarily entail becoming an equally capable digital creator or problem solver.

The comparatively stronger scores in Digital Communication and Collaboration and Digital Use for Learning provide a complementary perspective. Students reported relatively stronger competence in digitally mediated interaction and learning activities than in several critical, creative, and safety-related dimensions. This pattern suggests that technology was used for more than routine device operation. At the same time, these dimensions remained below Device and Digital Application Operation, reinforcing the broader finding that digital competence was differentiated across domains rather than uniformly developed. Digital literacy should therefore be interpreted as a competency profile rather than reduced to a single distinction between digitally competent and digitally less competent students.

The absence of a statistically significant gender difference is another relevant finding. Male and female students had closely comparable overall scores, the standardized difference was small, and gender remained nonsignificant after adjustment for the other characteristics. This should not be interpreted as evidence that gender inequalities in digital competence are absent more generally. Previous research has produced heterogeneous findings depending on developmental stage, sociocultural environment, the particular digital skill being assessed, and whether competence is measured through self-report or performance-based tasks (Scherer & Siddiq, 2019; Siddiq & Scherer, 2019). More recent evidence similarly indicates that gender differences in digital literacy are generally modest and can vary across developmental and sociocultural contexts (Chen et al., 2026; Gnambs & Hawrot, 2025). The present findings therefore indicate only that gender was not a major differentiating characteristic within this analytical sample.

This interpretation was reinforced by the multivariate analysis, which found no significant gender difference in the combined seven-dimensional digital literacy profile. Thus, the absence of a gender difference was not restricted to the overall score. Evidence from Southeast Asian educational settings also suggests that gender differences can depend on the specific digital competency domain examined rather than following a consistent pattern across all aspects of digital literacy (Maon et al., 2021). Within the present dataset, neither overall digital literacy nor the combined competency profile appeared to be strongly differentiated by gender.

Age and educational level similarly showed little explanatory value. Overall digital literacy did not increase significantly with age, and lower-secondary and upper-secondary students had closely comparable scores. Although older students may have accumulated more years of exposure to digital technologies, duration of exposure is not necessarily equivalent to the quality or educational value of that exposure. Digital competency development depends on the activities students undertake, the complexity of those activities, the support available to them, and the extent to which technology is incorporated into meaningful learning experiences. Evidence that digital competencies develop unevenly throughout adolescence further challenges the assumption that digital literacy increases automatically with chronological age or educational progression (Gnambs & Hawrot, 2025). The present results therefore suggest that advancement through secondary education alone may not guarantee substantial development of comprehensive digital literacy.

Study-context membership also contributed little to variation in overall digital literacy. The four contextual subsamples showed closely comparable total scores, and contextual membership added only a small and nonsignificant increment to the hierarchical regression model. This finding should not be interpreted as evidence that the educational contexts represented in the dataset are equivalent. Rather, it indicates that broad contextual membership, as operationalized in this study, provided little additional information for explaining students' overall digital literacy. Educational contexts may differ in infrastructure, institutional support, pedagogical practices, socioeconomic composition, teacher competence, and digital-learning opportunities, but these characteristics were not directly measured in the present dataset.

The significant multivariate effect for study context adds nuance to this interpretation. Although the combined seven-dimensional profile differed statistically across C1–C4, no individual dimension remained significant after adjustment for multiple comparisons. The pattern therefore appears to reflect several small distributed differences rather than a clearly isolated contextual difference in one competency domain. This result should not be used to rank the four contextual subsamples. Comparisons involving multidimensional educational constructs require particular caution when measurement equivalence has not yet been established across heterogeneous groups. The preliminary validation study specifically identified the need for further confirmatory and invariance analyses before stronger cross-group interpretations are made (Barrios et al., 2026). Study context is therefore more appropriately treated here as a broad analytical grouping characteristic than as an explanatory mechanism.

This interpretation is also consistent with evidence from diverse Southeast Asian educational settings showing that digital competence is embedded in students' educational experiences, patterns of Internet use, classroom environments, and opportunities for digital participation (Maon et al., 2021; Ongardwanich, 2022; Prasetiyo et al., 2025; Wui et al., 2025). The present findings therefore support a shift from broad geographical categorization toward more proximal conditions that may help explain variation in student digital literacy.

Device access represented one such condition. Students relying primarily on school or laboratory devices had lower overall digital literacy than students with personal-device access, and this difference remained statistically significant after adjustment for the other variables. This finding is consistent with digital-divide perspectives that distinguish physical availability from autonomy, frequency, and quality of access. Digital inequality can persist even when basic technological access is available because learners differ in the opportunities they have to develop skills and engage meaningfully with digital resources (Hargittai, 2002; Helsper, 2012; van Deursen & van Dijk, 2011).

Dependence on school or laboratory devices may constrain when, where, and for how long students can interact with technology. Institutional access may be sufficient for completing particular classroom activities but may provide fewer opportunities for experimentation, independent exploration, repeated practice, or troubleshooting outside scheduled periods. Personal access may provide greater flexibility to revisit learning resources and integrate digital tools into everyday learning. However, this explanation remains inferential because the dataset did not directly measure frequency, duration, or autonomy of device use. The observed association should therefore be understood as evidence that the form of access matters within this sample, rather than as proof that device ownership itself produces stronger digital literacy.

This qualification is supported by the finding that students sharing devices with family members did not differ significantly from students with personal devices after adjustment. Personal ownership should therefore not be interpreted as an inherent requirement for digital literacy. Adequate and sufficiently flexible access may be more important than exclusive ownership. Contemporary digital-divide scholarship increasingly distinguishes material access from autonomy, skills, forms of use, and the benefits obtained from digital participation (Scheerder et al., 2017). Recent research on educational digital equity similarly emphasizes that equity involves the conditions through which learners can access, use, and benefit from digital technologies rather than hardware possession alone (Martin et al., 2026).

Internet connectivity produced the clearest and most consistent association in the study. Overall digital literacy decreased progressively from students reporting stable connectivity to those reporting moderately stable and limited access. Unlike the device comparison, all three

Internet-access categories were statistically distinguishable from one another. Internet access also showed a considerably larger effect size than gender, educational level, study context, or device access. After simultaneous adjustment for the other characteristics, students reporting limited connectivity scored approximately 13 points lower than those reporting stable Internet access, and limited connectivity had the largest standardized coefficient in the final regression model.

These results should nevertheless be interpreted as associations rather than causal effects. The cross-sectional design cannot establish whether stable Internet access contributes to stronger digital literacy, whether digitally more competent students obtain or seek better access, or whether both are influenced by other educational and socioeconomic conditions. Even with this limitation, the graded pattern across stable, moderately stable, and limited access is consistent with contemporary digital-divide research that moves beyond a binary distinction between connected and unconnected individuals toward differences in the quality, reliability, and usefulness of connectivity.

Stable connectivity may provide more frequent opportunities to search for information, participate in digital learning environments, communicate, create content, troubleshoot technological problems, and develop independent learning routines. Conversely, constrained connectivity may interrupt or limit these opportunities even when a digital device is technically available. Research on digital readiness similarly indicates that students differ not only in whether digital technologies are available but also in their capacity to participate effectively in digitally mediated education (van de Werfhorst et al., 2022). Recent evidence among secondary school students likewise continues to identify gaps in both access to and competence with digital technologies for learning (Nkwamah et al., 2026).

The association with Internet access was not restricted to overall digital literacy. Connectivity differed significantly across all seven dimensions, with the largest associations observed for Digital Problem Solving, Digital Safety and Ethics, and Digital Content Creation. This broad pattern suggests that Internet quality is related to multiple forms of digital engagement rather than to a single operational competency. These particular dimensions frequently require sustained interaction with digital environments, opportunities to explore, repeated exposure to online decisions, and access to resources that support active rather than routine technology use.

The comparatively strong association with Digital Problem Solving is theoretically plausible. Problem-solving competence involves encountering unfamiliar situations, diagnosing difficulties, searching for possible solutions, evaluating alternatives, and adapting technological strategies. Stable connectivity may provide greater access to tutorials, documentation, forums, online applications, peers, and other sources of support. Students experiencing limited connectivity may have fewer opportunities for such exploratory activity. This interpretation is consistent with the distinction between having basic access and having sufficient opportunities to appropriate technology in ways that develop more advanced digital skills (Scheerder et al., 2017; van Deursen & van Dijk, 2011).

The association between Internet access and Digital Safety and Ethics also warrants careful interpretation. Safe and ethical digital participation is shaped not only through formal instruction but also through encounters with privacy settings, communication choices, platform permissions, online identities, information credibility, and security decisions. Students with restricted connectivity may have fewer opportunities to develop experiential familiarity with these situations. However, greater connectivity does not automatically result in safer or more ethical behavior because increased participation can also increase exposure to risk. Connectivity should therefore be viewed as an opportunity condition that needs to be accompanied by explicit instruction in privacy, security, digital citizenship, and ethical participation.

A similar opportunity-based interpretation applies to Digital Content Creation. Producing digital content commonly requires sustained access to resources, applications, editing tools, file-sharing systems, and online information. Connectivity constraints may interrupt these processes more strongly than routine digital consumption. Research on digital inequality increasingly emphasizes that meaningful participation depends not simply on being connected but on whether users can engage in activities that produce educational and other beneficial outcomes (Helsper, 2012; Scheerder et al., 2017). The present results are compatible with this perspective, although longitudinal or experimental evidence would be required to establish the direction of these relationships.

The hierarchical regression analysis brings the different findings into a common explanatory framework. Demographic and educational characteristics explained less than 1% of the variance in overall digital literacy, while study-context membership contributed only an additional 0.4%. In contrast, adding device and Internet access increased explained variance by 10.4%. The final model accounted for 11.4% of the total variance. This difference indicates that digital-access conditions provided substantially more explanatory information within the present dataset than age, gender, educational level, or broad contextual membership.

At the same time, the final $R^2$ places an important boundary around the interpretation. Approximately 89% of the observed variance remained unexplained by the variables included in the model. Digital literacy should therefore not be reduced to technological access. Other individual, family, school, and learning-process characteristics are likely to contribute substantially. Previous research has associated digital competence with socioeconomic background, ICT self-efficacy, learning strategies, patterns of technology use, school opportunities, and educational support (Aesaert & van Braak, 2015; Hatlevik et al., 2018; Rohatgi et al., 2016; Scherer & Siddiq, 2019). Evidence from Southeast Asian educational settings also indicates that classroom environments and Internet-use characteristics may contribute to digital competence and participation (Prasetiyo et al., 2025; Wui et al., 2025). Digital access is therefore better understood as one enabling condition within a wider educational ecology rather than as a complete explanation of digital literacy.

This interpretation also guards against technological determinism. Improving access to devices and reliable connectivity may reduce important barriers, but infrastructure alone is unlikely to ensure strong information evaluation, ethical judgment, digital content creation, or problem-solving competence. Schools need both appropriate digital resources and pedagogical practices that require students to use those resources in intellectually meaningful ways. Digital competence can be supported through opportunities to search critically, compare evidence, communicate responsibly, create digital products, solve authentic problems, reflect on digital risks, and make informed technological choices. Digital equity therefore concerns both the availability of technological resources and the quality of the educational experiences those resources make possible (Helsper, 2012; Martin et al., 2026; van de Werfhorst et al., 2022).

The findings also have implications for digital-literacy assessment. If assessment emphasizes only device operation or general technology use, students may appear highly digitally competent while weaknesses in critical, creative, safety-related, or problem-solving competencies remain undetected. The seven-dimensional profile observed in this study demonstrates the value of examining multiple competency domains, even though the total score remains the more psychometrically robust outcome. The preliminary validation showed strong reliability for the total scale but more moderate reliability for the individual dimensions (Barrios et al., 2026). Dimension-specific findings should therefore remain cautiously interpreted, but they are educationally useful for identifying patterns that would be obscured by the overall score alone.

From an instructional perspective, increasing students' exposure to technology should not be treated as the sole objective of digital-literacy education. Secondary schools may need to design learning activities that explicitly target competencies students are less likely to develop through routine technology use. Such activities may require students to compare the credibility of competing sources, justify judgments about information quality, recognize misleading or manipulated content, manage privacy and security settings, consider ethical consequences of digital communication, create and revise original digital products, and troubleshoot unfamiliar technological problems. These practices align with the multidimensional conception of digital literacy represented in the UNESCO Digital Literacy Global Framework and DigComp 2.2 (Law et al., 2018; Vuorikari et al., 2022).

Instructional expectations should also be sensitive to students' actual digital-access conditions. Technology-intensive assignments can reproduce educational inequality when they assume stable connectivity or unrestricted device availability. Students dependent on institutional devices or limited Internet connectivity may require additional school-based access, downloadable or offline learning resources, flexible completion arrangements, and structured opportunities to develop competencies that otherwise depend on sustained digital engagement. Digital-literacy interventions should therefore combine competency development with realistic consideration of the technological conditions under which students are expected to learn.

Taken together, the findings support a view of student digital literacy as both multidimensional and opportunity-dependent. The participating students demonstrated comparatively strong operational competence, but this strength was not matched uniformly by critical, creative, safety-related, and problem-solving competencies. Age, gender, educational level, and broad study-context membership explained relatively little variation in overall digital literacy, whereas digital-access conditions, particularly Internet connectivity, showed more consistent associations. Within the limits of the cross-sectional design, the findings support educational approaches that consider not only whether students can access digital technologies but also whether they have sufficiently stable and meaningful opportunities to use those technologies for developing a broad range of digital competencies.

## CONCLUSION

This study shows that digital literacy among secondary school students is better understood as a multidimensional competency profile than as a single uniform ability. Device and Digital Application Operation was the strongest dimension, whereas Digital Safety and Ethics showed the lowest mean performance. Information and Data Literacy, Digital Content Creation, and Digital Problem Solving were also comparatively less developed. These findings indicate that operational familiarity with digital technologies does not necessarily correspond to equally strong critical, creative, safety-related, and problem-solving competencies.

Differences in overall digital literacy were small according to age, gender, educational level, and membership in the four participating study contexts. In contrast, digital-access conditions showed clearer associations with students' scores. Students relying primarily on school or laboratory devices had lower adjusted scores than students with personal-device access, whereas students sharing devices with family members did not differ significantly from those with personal access. Internet connectivity showed the most consistent association, with students reporting limited connectivity scoring substantially lower than those with stable Internet access. Differences according to Internet-access conditions were also evident across all seven digital literacy dimensions. The hierarchical regression further demonstrated that demographic, educational, and contextual characteristics contributed little explanatory information, whereas adding device and Internet access increased explained variance by 10.4%.

These findings support an opportunity-based understanding of digital literacy within the participating Southeast Asian sample. They do not establish that improved connectivity causes stronger digital literacy, but they indicate that the quality of students' digital-access conditions is closely associated with digital competence. Improving students' digital literacy therefore requires more than increasing exposure to technology or providing hardware. Educational efforts should combine sufficiently reliable and meaningful digital access with deliberate learning experiences that develop information evaluation, digital safety and ethics, digital content creation, communication, problem solving, and strategic technology use.

## LIMITATIONS

Several limitations should be considered when interpreting the findings. The cross-sectional secondary-analysis design does not establish temporal ordering and therefore does not permit causal conclusions regarding the relationship between device access, Internet connectivity, and digital literacy. The four contextual subsamples were not designed to provide representative estimates of individual educational systems or of secondary school students across Southeast Asia, so C1–C4 should be interpreted only as analytical representations of the participating contexts. The study also relied on questionnaire-based measures that reflect students' reported competencies rather than direct performance on authentic digital tasks. Although the overall Student Digital Literacy Questionnaire demonstrated strong internal consistency, the reliability coefficients for individual dimensions were more moderate, requiring greater caution when interpreting dimension-specific findings. In addition, the available dataset did not include potentially relevant explanatory variables such as socioeconomic background, parental support, teacher digital competence, school digital infrastructure, ICT self-efficacy, frequency and purposes of technology use, learning strategies, and instructional opportunities. This limitation is reflected in the final regression model, which explained 11.4% of the variance in overall digital literacy.

## RECOMMENDATIONS

Future research should extend these findings through longitudinal and multi-site designs that can clarify how digital literacy develops over time and strengthen interpretation of the relationship between digital-access conditions and competency development. Larger and more systematically selected samples would provide a stronger basis for examining variation across educational contexts, while confirmatory factor analysis and measurement-invariance testing would strengthen cross-group interpretation of the seven-dimensional structure. Future studies should also combine self-report questionnaires with performance-based digital literacy tasks and include a broader range of explanatory variables, including socioeconomic background, parental support, teacher digital competence, school digital infrastructure, ICT self-efficacy, patterns and purposes of technology use, learning strategies, and opportunities for technology-supported learning. At the educational level, improving connectivity and access should be accompanied by explicit digital-literacy instruction that develops information evaluation, digital safety and ethics, content creation, responsible communication, and technology-based problem solving. Schools should also account for differences in students' actual access conditions by providing additional school-based access, downloadable or offline learning resources, flexible completion arrangements, and structured opportunities for students who depend on institutional devices or experience unstable Internet connectivity.

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The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

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**Conflict of Interests**
The authors declare no conflict of interest.

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