

Measuring Digital Competence among University Students in Guangdong Province: A DigComp 2.2–Aligned Scale and Baseline Profile

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Abstract

Digital competence has become a key outcome in higher education, yet assessment tools suited to Chinese private universities remain limited. This study developed a DigComp 2.2–aligned self-assessment scale and used it to describe the baseline digital competence of students in Guangdong Province. Data came from a cross-sectional survey of 1,092 students from three private undergraduate universities in the Guangdong–Hong Kong–Macao Greater Bay Area. The final instrument included 21 items across five domains: information and data literacy, communication and collaboration, digital content creation, safety, and problem solving. Results showed a clear five-domain structure and acceptable internal consistency. Students’ overall competence was moderate ($\bar{x}=3.00$, $SD=0.94$), with the highest mean in information and data literacy and the lowest in problem solving. Lower-scoring areas included information management, appropriate digital communication, copyright and licensing, device protection, and creative digital use. The scale provides a practical basis for diagnosis, benchmarking, and targeted educational support.

Keywords: Digital Education, Digital Competence, University Students, DigComp 2.2

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Introduction

Digital technologies are now embedded in university learning, communication, and knowledge production. Students are expected not only to access online information, but also to evaluate it, collaborate through digital tools, create digital outputs, and manage privacy and security in academic contexts. Digital competence has therefore become an important educational outcome linked to learning, employability, and participation in digital society (Ilomäki et al., 2016; OECD, 2019; World Economic Forum, 2023).

At the same time, frequent technology use does not necessarily indicate strong digital competence. University students may be familiar with digital tools while still showing weaknesses in critical judgement, ethical use, creative problem solving, and safe participation in digital environments. Previous studies have reported uneven competence patterns across domains and student groups, with stronger confidence in routine use than in more demanding forms of application (Spante et al., 2018; van Laar et al., 2017). This issue has become more urgent in China under policy initiatives such as the Education Informatization 2.0 Action Plan and China's Education Modernization 2035, which emphasise measurable outcomes and evidence-based educational planning (Central Committee of the Communist Party of China & State Council of the People's Republic of China, 2019; Ministry of Education of the People's Republic of China, 2018).

A further difficulty concerns definition and measurement. Related terms such as digital literacy, ICT competence, and 21st-century skills are often used interchangeably, and studies frequently adopt different domain structures and instruments, making findings difficult to compare (Ilomäki et al., 2016; Spante et al., 2018). Recent higher education research has continued to note this problem and the need for stronger assessment tools (Zhao et al., 2021; Tzafilkou et al., 2022). To provide a clearer basis for measurement, this study adopts the European Commission's Digital Competence Framework for Citizens (DigComp). DigComp offers a structured taxonomy for defining digital competence, and DigComp 2.2 retains five domains and 21 competence areas while updating examples for current socio-technical conditions (Carretero Gomez et al., 2017; Ferrari, 2013; Redecker, 2017;

Vuorikari et al., 2022). Even so, framework adoption alone is not sufficient; instruments still require contextual adaptation and validation before results can be used responsibly for diagnosis or planning (Law et al., 2018).

These concerns are especially relevant in Guangdong Province and the Guangdong–Hong Kong–Macao Greater Bay Area, where private undergraduate universities play a significant role in expanding access and preparing practice-oriented talent for regional development. Yet two gaps remain evident in this setting: the limited availability of locally validated instruments aligned with DigComp 2.2 and the lack of baseline evidence on students’ domain-level digital competence in private universities. To address these gaps, this study develops and validates a DigComp 2.2–aligned self-assessment scale for private undergraduate students in Guangdong Province and uses it to establish a baseline profile of digital competence across domains. In this way, the study contributes both a practical measurement tool and empirical evidence for diagnosis, benchmarking, and targeted competence-development planning.

Research Objectives

This study aims to develop and validate a DigComp 2.2–aligned self-assessment scale for private undergraduate students in Guangdong Province and to use it to describe their domain-level digital competence profile.

Conceptual Framework

This study adopted the European Commission’s DigComp 2.2 as the basis for defining digital competence. DigComp 2.2 views digital competence as a combination of knowledge, skills, and attitudes used in learning, work, and social participation (Ferrari, 2013; Vuorikari et al., 2022). It was selected because it offers a recognized five-domain structure, updated examples for current digital contexts, and a practical basis for item development (Carretero Gomez et al., 2017; Vuorikari et al., 2022).

DigComp 2.2 organises digital competence into five related domains—Information and data literacy, Communication and collaboration, Digital content creation, Safety, and Problem solving—covering 21 competence areas in total

(Vuorikari et al., 2022). In this study, these areas served as the content basis for instrument construction. Figure 1 presents the framework used in the paper. This domain-based approach supports diagnosis and educational support more effectively than a single undifferentiated score.

For higher-education measurement, the framework was operationalized around undergraduate learning tasks. The five domains were used to represent information handling, digital interaction, content creation, safe participation, and adaptive problem solving in academic settings. This retained the logic of DigComp while adapting it to self-assessment in university contexts.

Based on this framework, the study assumed a five-factor measurement structure in which each domain functioned as a first-order latent dimension represented by domain-specific items. The instrument was designed to provide both domain scores and an overall score, with domain-level interpretation dependent on internal-structure evidence. This position is consistent with validity-based approaches to score use (American Educational Research Association et al., 2014; Kane, 2013; Messick, 1995). Because previous higher education studies have reported uneven competence profiles, domain-level profiling was considered practically useful (Spante et al., 2018; van Laar et al., 2017).

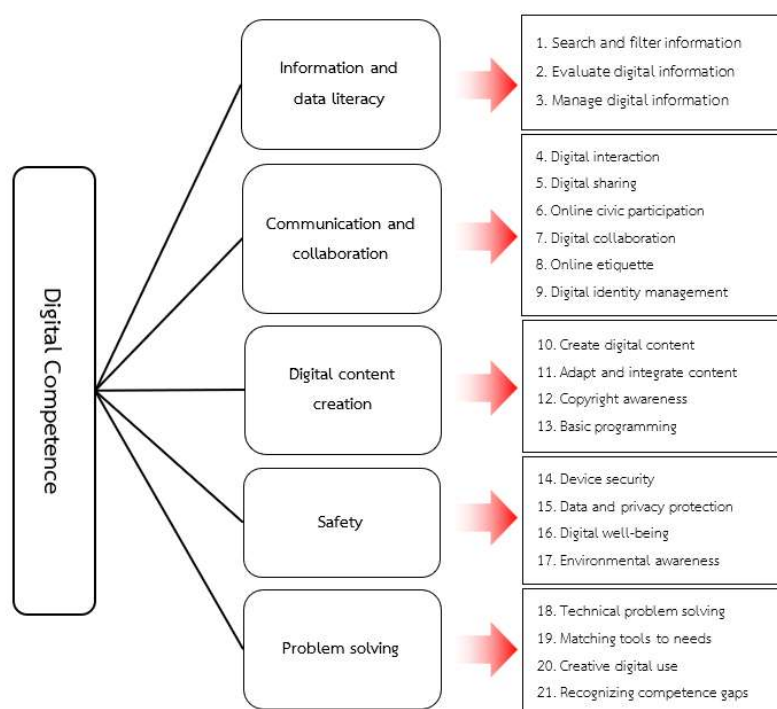


Figure 1 Conceptual framework adapted from DigComp 2.2

Research Methodology

Research design. This paper reports the quantitative phase of a broader sequential explanatory mixed-methods project (Creswell & Creswell, 2018). Two tasks were addressed in this phase: the development of a DigComp 2.2-aligned self-assessment instrument for university students and the establishment of a baseline profile of digital competence in Guangdong Province. A cross-sectional survey design was adopted because it allowed large-scale collection of self-reported data for scale validation and descriptive profiling. As the instrument relied on self-assessment, the study focused on perceived rather than directly observed competence. To reduce response bias, participation was anonymous and voluntary, and standardised instructions were used across data-collection settings.

1. Participants and sampling

Research setting and target population. The study was conducted in three private undergraduate universities in the Guangdong–Hong Kong–Macao Greater Bay Area. The target population comprised full-time undergraduate students enrolled in these institutions. Based on enrolment statistics published on the official websites of the three participating universities for the 2025 academic year, the total target population was estimated at approximately 95,000 students.

Sampling strategy. A four-stage stratified random sampling design was employed to improve representativeness while keeping fieldwork manageable. Stratification was implemented by institution, grade level, and major category, after which classes and/or students were randomly selected within strata. Proportional allocation was used so that the sample more closely reflected the underlying student distribution.

Sample size and response rate. Krejcie and Morgan's (1970) formula was used as a minimum reference point for sample adequacy. For a population of approximately 95,000, the minimum recommended sample was about 383. This threshold was treated as a lower bound rather than the final target. A larger sample was intentionally sought to strengthen the stability of exploratory factor analysis for a newly developed 21-item instrument, preserve proportional

representation across sampling stages, support subgroup profiling, and compensate for invalid or incomplete responses. In total, 1,128 questionnaires were distributed, of which 1,092 remained after screening, producing an effective response rate of 96.81%.

Sample characteristics. Table 1 presents the composition of the final sample. Respondents were drawn from GDUST (n = 408, 37.36%), ZCST (n = 341, 31.23%), and GZIST (n = 343, 31.41%). The sample included 591 males (54.12%) and 501 females (45.88%). All four grade levels were represented, with juniors forming the largest group (28.39%). Major categories included science and engineering, humanities and history, economics and management, art, medicine, and other fields. Most students reported an urban family location (67.95%), and household income was concentrated in the RMB 50,000–200,000 range.

Table 1 Sample characteristics (N = 1,092), n (%)

Variable	Category	n (%)
University	GDUST	408 (37.36)
	ZCST	341 (31.23)
	GZIST	343 (31.41)
Gender	Male	591 (54.12)
	Female	501 (45.88)
Grade	Freshman	280 (25.64)
	Sophomore	215 (19.69)
	Junior	310 (28.39)
	Senior	287 (26.28)
Major category	Science and Engineering	323 (29.58)
	Humanities and History	265 (24.27)
	Economics and Management	169 (15.48)
	Art	167 (15.29)
	Medicine	116 (10.62)
	Others	52 (4.76)
Family location	Urban	742 (67.95)
	Rural	350 (32.05)
Annual household income (RMB)	Below 50,000	160 (14.65)
	50,000–100,000	364 (33.33)

Variable	Category	n (%)
	100,000–200,000	414 (37.91)
	200,000–500,000	126 (11.54)
	Above 500,000	28 (2.56)

2. Instrumentation

Instrument development and localization. Questionnaire development followed a framework-to-item approach based on DigComp 2.2 (Vuorikari et al., 2022) and general principles of scale development (DeVellis, 2017). The aim was to preserve conceptual alignment with DigComp while adapting wording to the academic experiences of students in private universities. Content validity was examined through the Index of Item-Objective Congruence (IOC). Five experts in digital education and educational technology reviewed the draft instrument for domain coverage, alignment with DigComp competence areas, and language clarity. Across the full questionnaire, IOC values ranged from 0.60 to 1.00, and all items were judged valid. For the 21 digital competence items reported in this study, all IOC values were 1.00, indicating strong agreement between the items and their intended constructs. After expert review, a pilot test with 30 students was conducted to examine clarity and preliminary measurement behaviour. Item distributions, item–total relations, and initial internal consistency were checked, and unclear or weak items were revised or removed before the formal survey.

Questionnaire structure. The full questionnaire contained demographic items, the digital competence self-assessment scale, and additional sections on participation, satisfaction, and open-ended suggestions. Only the digital competence self-assessment section is reported in this paper.

DigComp 2.2–aligned digital competence self-assessment scale. The core instrument was a 21-item self-assessment scale covering the five DigComp domains and their related competence areas (Vuorikari et al., 2022): Information and data literacy (3 items), Communication and collaboration (6 items), Digital content creation (4 items), Safety (4 items), and Problem solving (4 items). Responses were recorded on a five-point Likert-type scale ranging from 1 (“very low”) to 5 (“very high”), with ratings interpreted as students’ perceived capability in each competence area

(Likert, 1932). Because the instrument used self-assessment, it was designed to reflect perceived competence rather than observed performance.

3. Data collection procedure and quality control

Administration. Data were collected from October to November 2025 through both onsite and online administration. The online questionnaire was distributed via Wenjuanxing, and controlled links were used to reduce duplicate submissions. Standardized instructions were provided in all settings. Participants were also informed that the survey was anonymous and for research purposes only, which was intended to reduce social desirability and evaluation-related bias.

Data screening. Responses were screened using preset quality-control rules, including completeness checks and checks for clearly careless responding. Only cases meeting these criteria were retained, resulting in a final analytic sample of 1,092.

Ethical considerations. Participation was voluntary and based on informed consent. Data were de-identified and stored securely to protect anonymity and confidentiality. Ethical approval was obtained through the relevant institutional procedure before data collection. The study also followed widely used testing standards (American Educational Research Association et al., 2014) and aligned in principle with China's Personal Information Protection Law (Personal Information Protection Law of the People's Republic of China, 2021).

4. Data analysis

IBM SPSS Statistics 28.0 was used for quantitative analysis, with manual calculation where necessary (IBM Corp., 2021). Frequencies and percentages described participant characteristics, and means with standard deviations were used for digital competence at the item, domain, and overall levels. Reliability was examined using Cronbach's alpha and item diagnostics, including corrected item-total correlations and alpha-if-item-deleted values (Cronbach, 1951; Taber, 2018). Exploratory factor analysis (EFA) was then used to examine internal structure after checks of sampling adequacy and factorability with the Kaiser-Meyer-Olkin index and Bartlett's test of sphericity (Bartlett, 1950; Kaiser, 1974). Factor retention was based on eigenvalues, the scree plot, and theoretical interpretability, with attention to loadings and cross-loadings (Costello & Osborne, 2005). Convergent validity

was assessed through composite reliability (CR) and average variance extracted (AVE), and discriminant validity through the Fornell–Larcker criterion (Fornell & Larcker, 1981; Hair et al., 2019).

Results

A total of 1,092 valid questionnaires were included in the analysis. This section first presents evidence on the reliability and validity of the DigComp 2.2-aligned scale and then reports the baseline digital competence profile at the domain and item levels.

1. Reliability of the DigComp 2.2-aligned scale

Table 2 Internal consistency reliability (Cronbach’s alpha)

Dimension	Items	Cronbach’s alpha
Information and data literacy	3	0.861
Communication and collaboration	6	0.879
Digital content creation	4	0.873
Safety	4	0.876
Problem solving	4	0.868
Overall scale	21	0.892

The scale showed strong internal consistency. Cronbach’s alpha was 0.892 for the full instrument, and domain coefficients ranged from 0.861 to 0.879 (Table 2). Item diagnostics did not indicate the need to remove any item. The data were also suitable for factor analysis: the KMO value was 0.902 and Bartlett’s test of sphericity was significant, $\chi^2(210) = 11577.665$, $p < .001$ (Table 3).

Table 3 KMO and Bartlett’s test of sphericity

Test indicator	Statistic
KMO measure	0.902
Bartlett’s chi-square	11577.665
df	210
p-value	< 0.001

2. Construct validity: Exploratory factor structure

Table 4 Eigenvalues and variance explained by extracted factors (EFA)

Factor	Eigenvalue	Variance (%)	Cumulative variance (%)
1	6.711	31.96	31.96
2	2.187	10.41	42.37
3	2.113	10.06	52.43
4	1.962	9.34	61.77
5	1.821	8.67	70.44

The exploratory factor analysis supported the expected five-domain structure. Five factors were retained and together explained 70.44% of the total variance (Table 4). The rotated solution was clear, with primary loadings from 0.725 to 0.870, cross-loadings below 0.30, and communalities between 0.596 and 0.800. Table 5 shows that all domains were strongly represented by their intended items.

Table 5 Summary of rotated factor loading ranges by domain (cutoff criterion = 0.40)

Domain	Items	Loading range (primary factor)
Information and data literacy	Q8–Q10	0.851–0.870
Communication and collaboration	Q11–Q16	0.725–0.765
Digital content creation	Q17–Q20	0.810–0.839
Safety	Q21–Q24	0.802–0.835
Problem solving	Q25–Q28	0.802–0.852

3. Convergent validity and discriminant validity

Table 6 Composite reliability (CR) and average variance extracted (AVE)

Domain	Number of items	CR	AVE
Information and data literacy	3	0.895	0.739
Communication and collaboration	6	0.885	0.562
Digital content creation	4	0.893	0.677
Safety	4	0.893	0.676
Problem solving	4	0.893	0.675

Further evidence supported the separability and coherence of the five domains. CR values ranged from 0.885 to 0.895, and AVE values ranged from 0.562 to 0.739 (Table 6), supporting convergent validity. Inter-domain correlations

were positive but modest, ranging from 0.242 to 0.361 (Table 7). The highest shared variance was about $r^2 = 0.13$, which remained below the AVE of every domain, supporting discriminant validity.

Table 7 Correlation matrix of digital competence domains

	ID	CC	DCC	SA	PS
ID	1.000	0.335	0.242	0.265	0.242
CC	0.335	1.000	0.358	0.361	0.326
DCC	0.242	0.358	1.000	0.318	0.259
SA	0.265	0.361	0.318	1.000	0.301
PS	0.242	0.326	0.259	0.301	1.000

Note. ID = information and data literacy; CC = communication and collaboration; DCC = digital content creation; SA = safety; PS = problem solving.

4. Baseline digital competence profile at the domain level

Students' overall digital competence was moderate on the five-point scale ($\bar{X} = 3.00$, $SD = 0.94$) (Table 8). Among the five domains, information and data literacy had the highest mean, followed by safety, while problem solving ranked lowest. This pattern suggests stronger confidence in routine information-related practices than in more adaptive forms of digital use.

Table 8 Descriptive statistics of digital competence domains

Domain	$\bar{X}$	SD	Level	Rank
Information and data literacy	3.06	1.51	Moderate	1
Communication and collaboration	2.99	1.28	Moderate	3
Digital content creation	2.99	1.43	Moderate	4
Safety	3.00	1.42	Moderate	2
Problem solving	2.97	1.40	Moderate	5
Total	3.00	0.94	Moderate	

5. Item-level diagnostic profile

Item means were examined to identify within-domain variation (Tables 9–13). Most items clustered around the midpoint, but lower-ranked items revealed several weaker areas. Within information and data literacy, Q8 ranked highest and Q10 lowest, indicating stronger confidence in searching than in organizing and retrieving information.

Table 9 Item-Level Descriptives for Information and Data Literacy (N = 1,092)

Item	Brief descriptor	$\bar{X}$	SD	Rank
Q8	Identify needs and search effectively	3.09	1.70	1
Q9	Evaluate source credibility	3.07	1.72	2
Q10	Organise and retrieve information	3.01	1.70	3
Total		3.06	1.51	

Within communication and collaboration, Q15 ranked highest and Q11 lowest, suggesting that students felt more confident in respectful online conduct than in effective communication across digital tools.

Table 10 Item-Level Descriptives for Communication and Collaboration (N = 1,092)

Item	Brief descriptor	$\bar{X}$	SD	Rank
Q11	Appropriate digital communication	2.94	1.63	6
Q12	Online participation and engagement	2.98	1.65	5
Q13	Sharing digital resources	3.00	1.63	3
Q14	Online collaboration and co-creation	3.00	1.63	4
Q15	Respectful online conduct	3.03	1.60	1
Q16	Digital identity and reputation	3.01	1.62	2
Total		2.99	1.28	

Within digital content creation, Q18 had the highest mean and Q19 the lowest, pointing to a weaker legal and ethical dimension within this domain.

Table 11 Item-Level Descriptives for Digital Content Creation (N = 1,092)

Item	Brief descriptor	$\bar{X}$	SD	Rank
Q17	Create and edit digital content	2.99	1.66	3
Q18	Adapt and combine existing content	3.02	1.70	1
Q19	Copyright and licensing awareness	2.97	1.68	4
Q20	Basic programming tasks	3.00	1.69	2
Total		2.99	1.43	

Within safety, Q23 ranked highest and Q21 lowest, indicating stronger awareness of health-related risks than of device and content protection.

Table 12 Item-Level Descriptives for Safety (N = 1,092)

Item	Brief descriptor	$\bar{X}$	SD	Rank
Q21	Device and content protection	2.96	1.66	4
Q22	Personal data and privacy	3.02	1.66	2
Q23	Health and risk awareness	3.03	1.68	1
Q24	Environmental impact awareness	2.99	1.65	3
Total		3.00	1.42	

Within problem solving, Q26 had the highest mean and Q27 the lowest, suggesting that students were more comfortable selecting tools than using them creatively in less structured situations.

Table 13 Item-Level Descriptives for Problem Solving (N = 1,092)

Item	Brief descriptor	$\bar{X}$	SD	Rank
Q25	Technical troubleshooting	2.97	1.67	2
Q26	Selecting tools for needs	3.00	1.63	1
Q27	Creative digital problem solving	2.93	1.66	4
Q28	Recognising learning needs	2.97	1.67	3
Total		2.97	1.40	

Discussion

1. Measurement evidence and the validity argument

This study developed a DigComp 2.2-aligned self-assessment scale for private undergraduate students in Guangdong Province and provided initial support for its use in this context. The results were consistent with a five-domain structure and showed satisfactory internal consistency, suggesting that the instrument can be used for low-stakes diagnosis and institutional monitoring. This matters because research on digital competence still uses overlapping concepts and uneven measurement approaches. By adapting DigComp 2.2 to a local higher education setting, the study offers a practical basis for domain-level profiling. At the same time, the present evidence is still preliminary. Because validation in this study relied mainly on internal structure, future work should extend the evidence base through confirmatory factor analysis, cross-validation, and measurement invariance testing.

2. Baseline profile shows a mid-range but uneven pattern

The baseline results place students' digital competence at a moderate level overall. Information and data literacy ranked highest, safety followed, and problem solving ranked lowest. This pattern suggests that routine exposure to digital tools does not automatically translate into more advanced competence. Students appear more confident in familiar forms of digital use than in tasks that require adaptation, creativity, or higher-level judgement. The main issue, therefore, is not simple access to technology, but uneven development across domains.

3. Item-level results: specific gaps and cautious interpretation

The item-level results point to several weaker areas, including information organization and retrieval, appropriate digital communication, copyright and licensing, device protection, and creative digital use for innovative purposes. Although these belong to different domains, they share a similar feature: they require judgement, responsibility, and transfer beyond basic operation. The relatively low result for creative problem solving is especially important, as it suggests that students may cope better with routine or clearly defined tasks than with open-ended digital demands. These findings should still be interpreted carefully, because the scale captures perceived rather than demonstrated competence. In more complex areas, self-reported confidence may not fully match actual performance.

4. Implications for institutional diagnosis and monitoring

The study also adds baseline evidence from private universities in Guangdong, a setting that has received limited DigComp 2.2-aligned attention. For practical use, the domain-based profile is more informative than a single overall score because it helps identify where support is most needed. In this case, the relatively weak problem-solving results point to the value of project-based, problem-based, and open-ended digital tasks. Lower performance in digitally mediated communication suggests the need for more structured opportunities for online teamwork, communication, and netiquette practice. In a similar way, weaker results for copyright and licensing indicate that legal and ethical aspects of digital content creation should be taught more explicitly, while lower device-protection results point to the need for practical cybersecurity training rather than general

awareness alone. Overall, the findings support a domain-sensitive approach to digital competence development in higher education.

5. Limitations and future research directions

Several limitations should be noted. The study used a cross-sectional design, relied on self-report data, and focused mainly on internal-structure evidence. The findings are therefore more suitable for diagnosis, monitoring, and planning than for causal explanation or broad generalization. Future research could strengthen the evidence base by combining self-assessment with performance-based measures, applying confirmatory approaches, and testing whether the scale functions similarly across gender, discipline, and institutional groups. These steps would improve both the interpretive strength of the instrument and its value for longitudinal and comparative research.

Suggestions

1. Use domain-based goals and regular diagnosis

Digital competence development should be guided by domain-level goals rather than by a single overall score. DigComp 2.2 can be used as a reference for staged learning outcomes and for periodic low-stakes diagnosis during students' progression. This is especially relevant here because the results showed uneven performance across domains, with relatively weaker results in problem solving, digitally mediated communication, and copyright and licensing. Connecting these weaker areas to course outcomes, assessment rubrics, project work, and portfolio tasks would make digital competence development more focused and more visible in the curriculum.

2. Increase authentic practice for higher-order competence

The weakest performance appeared in problem solving, especially in the creative use of digital technologies. This suggests a need for more open-ended learning tasks in which students must choose tools, respond to changing task demands, and develop solutions rather than follow fixed procedures. Project-based, problem-based, and interdisciplinary activities would be especially useful for this purpose. The lower results in information management and digital communication

also indicate the value of more structured practice in organizing digital resources, collaborating online, and communicating appropriately across platforms. Such experiences are more likely to strengthen transferable competence than one-off technical training.

3. Strengthen ethical, safe, and sustainable digital participation

Lower results in copyright and licensing and device protection show that digital competence support should extend beyond technical operation. Universities should provide clearer teaching on responsible content use, copyright, licensing, privacy, and cybersecurity, and these topics should be integrated into regular teaching rather than treated as separate add-ons. Safety education should also emphasise practical routines that students can apply in everyday academic and personal digital settings. At the institutional level, teacher support, monitoring arrangements, and student guidance services should be strengthened so that digital competence is treated as an ongoing educational responsibility rather than a one-time training topic.

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