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Assessing Digital Competence and Inter-Area Correlation among Undergraduate Chemistry Education Students Using DigComp 3.0

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Abstract
In order to mitigate hazards like misinformation and cybercrime, digital competence in the twenty-first century requires more than just frequent device use. Using the most recent DigComp 3.0 framework for 2025, this study aims to assess the digital competency profile of chemistry education students and assess its implications for future learning design. Eighty-eight chemistry students from Universitas Sebelas Maret and Universitas Negeri Malang were surveyed as part of a quantitative approach. A 22-item self-assessment tool encompassing five domains of digital proficiency was used to gather the data, which were then evaluated using descriptive statistics and the Spearman correlation test. The findings show that students reached advanced proficiency in Areas 1 (Information Search, Evaluation and Management), 2 (Collaboration and Communication), and 4 (Safety, Wellbeing, and Responsible Use), while Areas 3 (Content Creation) and 5 (Problem Identification and Solving) remained at the intermediate level. Most inter-area correlations were weak and positive, while the correlation between Areas 4 and 5 was moderate. In conclusion, students who are exposed to technology on a daily basis do not always become highly skilled in digital abilities. To enhance the capacity to produce digital chemistry material and resolve challenging technological issues in a college setting, certain educational interventions and training programs are therefore required.

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INTRODUCTION

Digital technology skills and knowledge are essential for the twenty-first century generation (Farias-Gaytan et al., 2023). Students' success is no longer determined just by their regularity and familiarity with digital devices, but also by their knowledge, skills, and attitudes toward using digital devices for everyday purposes. Digital transformation entails more than just implementing technologies. For higher education students, digital transformation is a human-centered process that involves culture, procedures, and well-being strategies (Fischer et al., 2020). Although university students generally exhibit higher technical and communication skills compared to younger students, they remain part of a Generation Z (hence referred to as Gen-Z) cohort that often prioritizes the social relevance of information over its accuracy (Yesmin, 2024). While daily exposure to digital gadgets pervades practically every part of their lives, teenagers frequently evaluate information not only for its correctness or veracity, but also for its relevance to their personal lives, relationships, and capacity to navigate their social contexts (Diepeveen & Pinet, 2022; Hassoun et al., 2025). Students understand and evaluate online content based on their social environment, which includes classmates, family, and long-established online communities.

Research indicates that students often evaluate information collectively through social groups, increasing their susceptibility to misinformation and cybercrime (Hassoun et al., 2025; Park et al., 2024). In chemistry education, digital competence is a prerequisite for effective learning design, enabling future educators to solve technical problems and represent concepts creatively (Bariyyah et al., 2025). This mastery includes safety and responsible use, which are critical for predicting digital risks and protecting personal data (Cosgrove & Cachia, 2025). Ultimately, ethical technology use that maximizes benefits while minimizing hazards (Tomczyk, 2019, 2020) defines good digital citizenship through cautious navigation and protection from digital threats (Estellés & Doyle, 2025).

The existence of a comprehensive competency framework is crucial given the urgency of safeguarding Gen-Z from these diverse digital risks. The Digital Competence Framework (DigComp) has been outlining the information, abilities, and attitudes people need to be digitally competent and functional in today's environment for about 12 years (Cosgrove & Cachia, 2025). Up until the current framework, DigComp 3.0, was released in 2025, the DigComp framework was continuously improved. The framework and tools used in this study are based on the most recent iteration of DigComp 3.0. This framework encompasses five areas, representing a refinement and streamlining of DigComp 2.1, which comprises a total of seven areas (Law et al., 2018), namely: (1) Information Search, Evaluation, and Management; (2) Communication and Collaboration; (3) Content Creation; (4) Safety, Wellbeing, and Responsible Use; and (5) Problem Identification and Solving.

Digital competence is becoming acknowledged in Indonesia as a necessary ability for engagement in society, the business, and education. Among those who utilize the internet the most are Indonesians. According to Angeline et al. (2021), Simanjuntak et al. (2025), and Yuvita et al. (2023), Indonesian students' digital competence differ according to age, educational level, and socioeconomic background. Due to limited access to technology, junior high and senior high school students' digital proficiency levels are lower than those of college students, who typically exhibit advanced digital competence, especially in technical skills, information utilization, and communication (Brata et al., 2022; Marwiyah et al., 2025; Muhfizaturrahmah et al., 2023; Redhana et al., 2022; Simanjuntak et al., 2025).

After ten years of assessing students' digital competency, there is a research gap because digital competence assessments are primarily concerned with measuring individual skills in using digital devices technically (Noh, 2017; Oz et al., 2015; Pizzul & Caliandro, 2025), creating digital content (Kaeophanuek et al., 2018; Polizzi, 2020; Suwana, 2021), and information literacy from digital platforms (Peng & Yu, 2022). After ten years of use, the DigComp report makes three recommendations: (1) it is crucial to keep raising awareness of the relevance and variety of digital competency contexts in which DigComp can be used; (2) encouraging and promoting the adoption of DigComp 3.0 among stakeholders through, for instance, awareness-raising and training activities, sharing of practices, and peer learning would empower people with digital skills to face these challenges; and (3) it is crucial that the framework be reviewed and updated as technology advances (Clifford et al., 2020). As a result, DigComp 3.0, which was published in 2025, has never been used to assess chemistry students' digital competency. This has never been investigated, emphasizing the study's novelty.

Consequently, the objective of this study is to evaluate the digital competence levels of chemistry education students using the DigComp 3.0 framework. The primary research question in this study is, "What is the digital competency profile of chemistry students and how does it relate to future chemistry learning designs?" To answer this question, we divide it into many research questions, specifically:

RQ1: What is the current digital competency level of chemistry students?

RQ2: Which areas of digital competence are the weakest among chemistry students?

RQ3: How is the correlation between areas in students' digital competency?

METHOD

Research Design

In order to develop future chemistry learning designs, the study's objectives are to examine the digital competency profiles of chemistry students and assess their implications. A quantitative approach using a survey design was the research methods selected to achieve the study's goals (Creswell, 2019). Convenience sampling was used to choose the participants, so everyone had an equal chance to take part. Year groups received the survey, and anyone could take part in the sample at any time (Fowler, 2019). Figure 1 shows the overall research design.

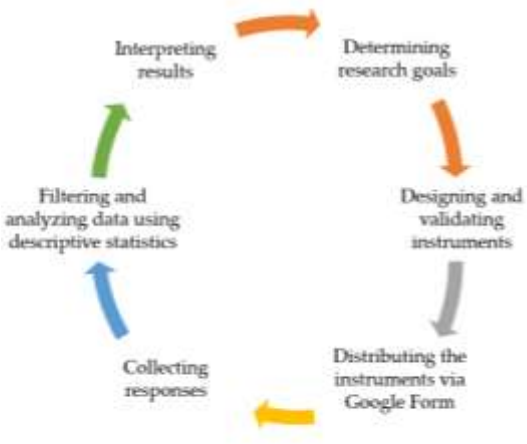

Figure 1. Research Flow of the Study

Data Collection

A self-assessment survey tool was used to collect data, which was mentioned in DigComp 3.0. Table 1 shows the survey instrument's details, which include 22 items covering five areas of digital competency: (1) information search, evaluation, and management; (2) communication and collaboration; (3) content creation; (4) safety, wellbeing, and responsible use; and (5) problem identification and solving, with each area subdivided into knowledge, skills, and attitudes. The self-assessment is measured on a 1–4 scale based on the proficiency rubric of the Digital Competence Framework for Citizens (Carretero, et al., 2017). This scale aligns with the framework's four aggregated categories, where a score of 1 represents Basic, 2 represents Intermediate, 3 represents Advanced, and 4 represents Highly Specialized.

Table 1. The DigComp 3.0 Self-Assessment Instrument

Aspect	Area	Competence	Item (Sub-area)
Attitude	1 Information search, evaluation, management	Purposefully investigate new digital search tools and functions.	1 (1.1)
Knowledge		Recognize that AI systems may produce erroneous results, even if they appear realistic.	2 (1.2)
Skills		Manage, store, and delete data from your digital devices, external storage, and cloud services.	3 (1.3)
Attitude	2 Communication and collaboration	Participate in debates about digital citizenship issues.	6 (2.3)
		Encourage and support inclusive and courteous behaviour in digital contexts.	8 (2.5)
Knowledge		Describe effective and ethical methods for sharing information and material in a range of digital settings.	5 (2.2)
		Identify features and functions for managing digital identity, such as device and app settings, online accounts, activity tracking, and social media platforms.	10 (2.6)
Skills		Interact with and manage individuals, groups, and channels using the various features of digital communication platforms.	4 (2.1)
		Use and mix a wide range of digital collaboration tools to fulfill the demands of projects, tasks, and groups.	7 (2.4)
Attitude	3 Content creation	When using and distributing digital content, give ethical and legal considerations, such as transparency and copyright, top priority.	13 (3.3)
Knowledge		Identify the structure, format, and audience requirements for a digital material integration or re-elaboration effort.	12 (3.2)
		Recognize that there are processes that must be taken to create, validate, and deploy a computer program or AI system.	14 (3.4)
Skills		Create and edit digital content using a range of tools (text, image, video, and/or audio).	11 (3.1)
Attitude	4 Safety, wellbeing, and responsible use	Examine how digital technologies, such as social media, enable and propagate bias, stereotyping, and exclusion on a regular basis.	17 (4.3)

Aspect	Area	Competence	Item (Sub-area)
Knowledge		Identify fundamental strategies to reduce energy and data consumption in digital technologies, such as restricting the usage of energy-intensive apps and refraining from using digital technologies when they are not required.	18 (4.4)
Skills		Assist users with basic device security measures such as antivirus software, screen locking, strong passwords, and multi-factor authentication.	15 (4.1)
		Manage personal data and privacy in a variety of digital environments, including the implementation of privacy technology.	16 (4.2)
Attitude	5 Problem identification and solving	Recognize the advantages of investigating changes to digital environment setups and characteristics of digital help tools.	20 (5.2)
		To satisfy the demands for digital competence, engage in continuous self-development.	22 (5.4)
Knowledge		Describe the merits, shortcomings, and ethical implications of digital technology, particularly AI systems, in terms of human creativity and problem-solving.	21 (5.3)
Skills		Troubleshoot technical issues in digital environments employing a range of search and problem-solving techniques (whether human or digital technology-assisted).	19 (5.1)

The experts from Universitas Negeri Malang and Universitas Sebelas Maret reviewed the instrument to ensure content accuracy, presentation, and language suitability with DigComp 3.0 framework. This review was critical to ensure the items effectively captured not only technical skills but also the human-centered capabilities required for digital well-being and safety Cronbach's alpha was used to test reliability, and the result was r = 0.966, indicating that the amount of internal consistency is sufficient to provide reliability because it is greater than 0.7 (Morales et al., 2003). The final version of the whole test still had 22 items, one of which was a response credibility control, and had an internal consistency check of r = 0.922, indicating high reliability.

The digital competencies survey was distributed to 102 chemistry students from Universitas Sebelas Maret (N=78) and Universitas Negeri Malang (N=24), but after data sorting, 88 responses were collected. The sorting procedure was based on item 9, a question item that, by default, requires respondents to select a specific level option, *"In this section, please select option 1 (basic). This question is used to ensure the credibility of the survey data"* so that respondents who choose other than those advised are excluded. These two universities were selected for two reasons: first, they share a distinct similarity in offering a Chemistry Education study program designed to train future chemistry teachers; and second, they are ranked among the top seven finest educational campuses in the Times Higher Education World University Rankings (THE WUR) by Subject 2026 (THE, 2026), making it critical to understand their digital competence. The poll was done between March 2026 for the preliminary test and April 2026 for the final test. Students' responses were practically anonymous (respondents simply provided their initials), and they took the test digitally using Google Form. During the data analysis process, three respondents were purposefully chosen for restricted interviews via Zoom to ensure that those who chose the majority of high levels (levels 3 and 4) actually have the required skills. Table 2 shows the distribution of responder demographic data.

Table 2. Responders' Demographic Data

Characteristic	Description	Frequency
Age	18 y.o	22
	19 y.o	43
	20 y.o	21
	> 20 y.o	2

Characteristic	Description	Frequency
Daily Internet Access Frequency (General)	< 7 hours a day	7
	7-12 hours a day	60
	> 12 hours a day	21
Daily Frequency of Internet Access for Learning	< 7 hours a day	32
	7-12 hours a day	51
	> 12 hours a day	5
Institution	Universitas Sebelas Maret	71
	Universitas Negeri Malang	17
Socio-economic Background	Intermediate/ middle class	88

Data Analysis

Data analysis was systematically carried out using a sequential mixed-methods approach to address each research question (RQ). First, to answer RQ1 and RQ2, quantitative descriptive analysis was performed using IBM SPSS version 24 to determine the median, mode, and frequency distributions of students' digital competencies, which were then visually mapped using a radar chart to illustrate competence distribution.

Table 3. The Spearman's Correlation Strength Criteria (ρ)

ρ Coefficient	Category
0,00 – 0,09	Insignificant relationship
0,10 – 0,39	Weak relationship
0,40 – 0,69	Moderate relationship
0,70 – 0,89	Strong relationship
0,90 – 1,00	Very strong relationship

(source: Schober et al., 2018)

Second, to address RQ3, a Spearman bivariate correlation test was conducted to establish the links between competence areas, assuming non-parametric data due to the ordinal nature of the variables (Schober et al., 2018), with correlation strengths (rho) interpreted based on Table 3. Finally, qualitative data from short interviews with three respondents were integrated to supplement, triangulate, and enrich the overall quantitative findings.

RESULTS AND DISCUSSION

Result

RQ 1. Chemistry Students' Digital Competency Level

The digital competence self-assessment survey data is ordinal. To assess the level of student competence, the median and mode values are used, as shown in Table 4. The mode is used to show the majority of students' levels, with specifics of Area 1 (mode = 3, frequency = 51.5%), Area 2 (mode = 3, frequency = 41.7%), Area 3 (mode = 2, frequency = 37.5%), Area 4 (mode = 3, frequency = 38.9%), and Area 5 (mode = 2, frequency = 40.3%). The main finding indicates that students achieved an advanced level of digital competence in Areas 1, 2, and 4, while their skills in Areas 3 and 5 remained at an intermediate level. Figure 2 shows a radar graphic that helps to visualize the level of digital competence of chemistry students.

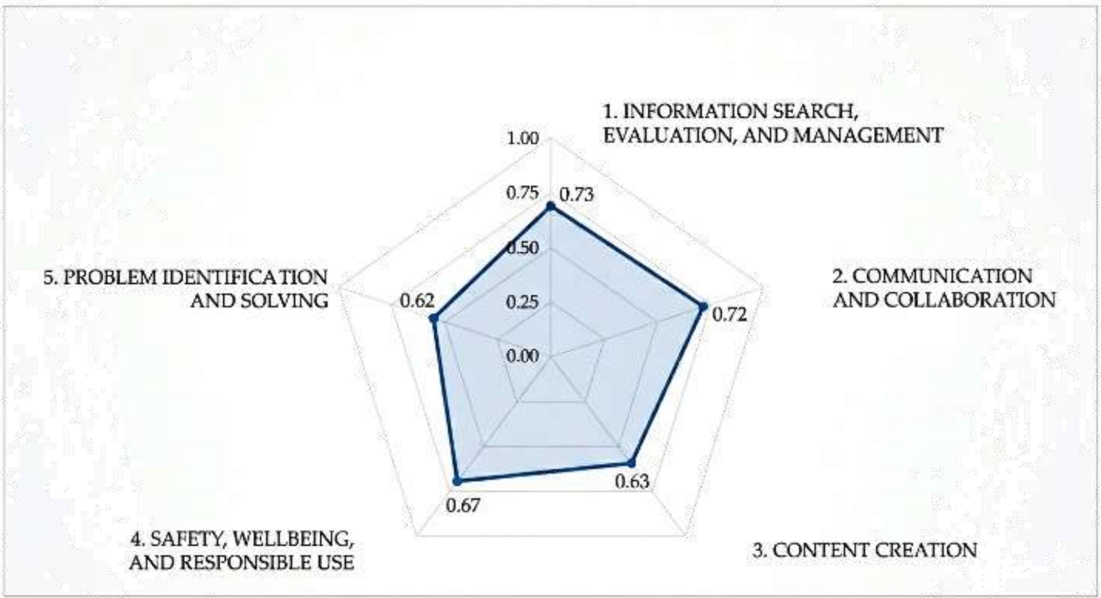

Figure 2. Radar Chart Map of Students' Digital Competence Levels

Table 4. Chemistry Students' Digital Competency Profile

Statistics		Area 1	Area 2	Area 3	Area 4	Area 5
N (Valid)		264	528	352	352	352
Median		3.00	3.00	3.00	3.00	2.00
Mode		3	3	2	3	2
Std. Deviation		.724	.815	.892	.877	.850
Minimum		1	1	1	1	1
Maximum		4	4	4	4	4
Based on mode:	**Frequency**	136	220	132	137	142
	Percentage	51.5%	41.7%	37.5%	38.9%	40.3%
	Proficiency Level	Advanced	Advanced	Intermediate	Advanced	Intermediate

RQ 2. Chemistry Students' Weaknesses in DigComp 3.0

Table 4 and Figures 2 in RQ1 clearly show that chemistry students have difficulties in DigComp 3.0 Areas 3 and 5. Table 5 provides information on these skills.

Table 5. The Highest Competence Achieved in Areas 3 and 5

Area	Mode (frequency; percentage)	Skills at Level 3 (Advanced)	Skills at Level 4 (Highly-specialized)
Area 3 Content Creation	2 (132 of 352; 37,5%)	Choose and mix digital content creation tools to suit complex task and audience needs.	Promote accessible, diverse, and ethical AI use in digital content development.
		Apply legal and ethical norms when exchanging digital AI content.	Lead or contribute to digital environment copyright policies.
Area 5 Problem Identification and Solving	2 (142 of 352; 40,3%)	Personalize digital environments and assistive tech for diverse needs.	Improve digital assistance tools, accessible environments, and assistive tech.
		Apply ethical, human-centric digital technology to complex challenges.	Help others use digital technology for complex problem-solving.

RQ 3. DigComp 3.0 Inter-Area Correlation

The correlation between DigComp 3.0 areas can be seen in Figure 3. Most inter-area correlations were weak and positive, while the correlation between Areas 4 and 5 was moderate. (Schober et al., 2018).

Correlations

			Area 1	Area 2	Area 3	Area 4	Area 5
Spearman's rho	Area 1	Correlation Coefficient	1.000	.328**	.266**	.329**	.326**
		Sig. (1-tailed)	.	<,001	<,001	<,001	<,001
		N	264	264	264	264	264
	Area 2	Correlation Coefficient	.328**	1.000	.334**	.270**	.295**
		Sig. (1-tailed)	<,001	.	<,001	<,001	<,001
		N	264	528	352	352	352
	Area 3	Correlation Coefficient	.266**	.334**	1.000	.346**	.299**
		Sig. (1-tailed)	<,001	<,001	.	<,001	<,001
		N	264	352	352	352	352
	Area 4	Correlation Coefficient	.329**	.270**	.346**	1.000	.429**
		Sig. (1-tailed)	<,001	<,001	<,001	.	<,001
		N	264	352	352	352	352
	Area 5	Correlation Coefficient	.326**	.295**	.299**	.429**	1.000
		Sig. (1-tailed)	<,001	<,001	<,001	<,001	.
		N	264	352	352	352	352

**. Correlation is significant at the 0.01 level (1-tailed).

Figure 3. DigComp 3.0 Inter-Area Correlation

Discussion

RQ 1. Chemistry Students' Digital Competency Level

Students acquire advanced information search, evaluation, and management skills (Area 1), communication and collaboration abilities (Area 2), safety, wellbeing, and responsible use skills (Area 4), content creation skills (Area 3), and problem identification and solving skills (Area 5) in that order, according to the highest to lowest competency levels. The advanced competency level in **Area 1** shows that students can at least combine a range of digital search tools and strategies to address complex information needs, such as combining information from websites owned by reputable organizations, asking generative AI, and combining results from reading digitally available chemistry articles.

The advanced competency level in **Area 2** indicates that students can actively engage in scientific discussions regarding the ethical, political, and social ramifications of digital technologies. Within chemistry education, this is demonstrated through their ability to evaluate how digital tools promote empowerment, such as debating the bias in machine learning models for chemical synthesis, sharing insights via digital chemistry forums, or collaborating on cloud-based molecular modeling projects.

The intermediate competency level in **Area 3** shows that students can only explain the advantages and drawbacks of employing digital technology, such as AI systems, for content creation in a selective and ethical manner. The limited interview data suggest that while students can basically navigate digital laboratory reports, they still require specific training to proficiently choose and combine advanced tools, such as digital chemistry simulations, molecular visualization tools, and AI-supported chemistry content creation to meet the demands and handle complex content creation tasks.

The advanced proficiency level in Area 4 indicates that students can assist others in identifying harmful digital behavior, content, and misleading designs. Interestingly, limited interview findings suggest that in the context of chemistry education, students find it difficult to encounter typical harmful content, except for misleading reports or sensationalized news concerning nuclear radiation and toxic substances.

In contrast, **Area 5**'s intermediate competency level shows that students can only use a range of search and problem-solving techniques (whether human-assisted or digital technology-assisted) to troubleshoot technical issues in digital settings. Students will be able to solve complicated technical issues in digital environments using a variety of solution-finding techniques as their digital competency improves.

RQ 2. Chemistry Students' Weaknesses in DigComp 3.0

There are a number of significant aspects that merit discussion based on the data findings in Table 3. **First**, it is often challenging to attain the maximum level of digital competence (highly specialized) through regular usage of digital platforms. To increase students' digital competency, direct interventions or interventions based on digital skills are required, according to a number of related research (Hassoun et al., 2025). In particular, in order to explicitly teach students how to develop digital chemistry content utilizing a range of sophisticated digital tools while putting legality, netiquette, and well-being first, changes or revisions to the learning model are required in chemistry education (Putri et al., 2025).

Second, the majority of chemistry learning material creation assignments (Area 3) involve making digital posters and infographics, according to a small number of interviews with chemistry students. Students frequently rely only on AI and its sources, which is a drawback of this kind of content (Hwang & Lee, 2025). This does not offer many opportunities for students to develop abilities, particularly at a highly specialized level, such encouraging and supporting inclusion and accessibility and the ethical and selective use of AI systems in the production of digital material.

Third, like Area 5, there aren't always significant issues with chemistry-specific digital platforms or apps that need to be troubleshooted. "Supporting others to develop their capabilities to use digital technologies for complex or specialized problem-solving tasks" (Cosgrove & Cachia, 2025) is an example of a top-tier skill. It calls for teachers to be creative in order to provide extremely difficult chemistry problems that call for the use of several digital devices and chemistry applications. Teachers now have a new challenge in helping students develop their digital problem-solving abilities.

Fourth, this result may indicate a reaction to ineffective use of digital technology. According to research by Černohorská et al. (2025), participants consistently expressed the feeling that some of the time they spend on digital devices is squandered, regardless of gender or place of residence. This might not be as easy as "reducing" the use of digital devices because it has been demonstrated that limiting use with reminders and app usage length limitations increases feelings of guilt and shame (Prasad & Quinones, 2020). Perhaps what is needed instead is a change in perspective that allows us to see and value the advantages that digital time offers, such using it for educational or learning purposes.

RQ 3. DigComp 3.0 Inter-Area Correlation

Important information on trends and patterns in students' knowledge of digital competencies can be found in the correlation between DigComp 3.0 domains. Figure 3's Spearman correlation test results allow for the following conclusions to be made:

(1) In Areas 2, 3, 4, and 5 (with weak categories), students with strong digital competency in **Area 1** also have comparatively strong digital competency. These findings logically show that students' proficiency in teamwork, communication, security, and digital problem-solving is greatly impacted by high levels of digital information literacy. High levels of digital information literacy, however, may not always equate to students' inventiveness when producing digital content.

(2) Students with strong digital competencies in **Area 2** also have comparatively strong digital capabilities in Areas 1, 3, 4, and 5 (with a weak category). As seen by high levels of information oversharing and vulnerability to cybercrime threats that accompany collaborative activities, students who are proficient in communication and collaboration do not necessarily have appropriate safety skills.

(3) Students with strong digital competencies in **Area 3** also have comparatively strong digital competencies in Areas 1, 2, 4, and 5 (with a poor category). Because content development frequently necessitates several online collaborations and careful usage of materials, such as licensing, content creation competencies are frequently thought to be strongly tied to collaboration and safety.

(4) Students with good digital competency in Area 4 also have moderately good digital competency in Areas 1, 2, and 3 (with a weak category) and good digital competency in Area 5 (with a moderate category). Once more, information literacy skills in organizing and assessing information sources, producing digital content, and safely resolving digital issues are linked to student safety competency.

(5) Students with good digital competency in Area 5 also have reasonably good digital competency in Areas 1, 2, and 3 (with a weak category) and good digital competency in Area 4 (with a moderate category). These findings are consistent with the theory that students can demonstrate strong problem-solving competency because they have good information literacy, such as the ability to locate suitable and exact information required in the problem-solving process.

Almost all areas have a weak connection with one another, with the exception of Areas 4 and 5, which have a moderate association. This moderate link is due to a pretty sensible cause-and-effect relationship between Areas 4 and 5, namely that students with high safety awareness are always cautious of digital risks, and as a result, they tend to take good preventive and curative measures. These preventive and curative steps represent Area 5, in which students understand exactly what is required to prevent the onset of technical difficulties and what to do when they do exist.

CONCLUSION

In addressing the first research question (RQ1) regarding the students' digital competency profile, this study found that chemistry education students showed advanced competence in Areas 1, 2, and 4, but only intermediate competence in Areas 3 and 5, highlighting the critical need for university training programs to enhance digital content creation and media skills (Farias-Gaytan et al., 2023). Regarding the second research question (RQ2) on the weak correlations among specific areas, the analysis reveals that information-seeking abilities are closely linked to social needs and identity formation, resulting in a weak but distinct relationship among Areas 1, 2, and 3 (Hassoun et al., 2025). To answer the third research question (RQ3) concerning the most significant correlation, the strongest relationship was found between safety-related competence

(Area 4) and problem-solving competence (Area 5), demonstrating that students prudently apply preventive and curative actions when facing emergent technological issues. Ultimately, these findings underscore the urgent necessity to systematically integrate digital competencies into the chemistry learning through instructional designs that explicitly target all five DigComp 3.0 areas simultaneously.

RECOMMENDATION

A acknowledged limitation of this study is its reliance on a limited sample size, restricted interview data, and a self-assessment approach, which may introduce subjective bias and restrict the generalizability of the findings across broader chemistry education contexts. To address these insights, several practical recommendations are proposed. First, **chemistry lecturers** should deliberately integrate digital content creation activities and advanced technological problem-solving tasks into the curriculum to bridge the competency gaps in Areas 3 and 5. Second, **higher education** institutions must establish robust support systems, including targeted training programs and workshops, that foster students' digital creation, critical thinking, and ethical technology adoption. Finally**, future researchers** are encouraged to investigate Areas 3 and 5 through more rigorous, comprehensive assessment methodologies, such as performance-based metrics, think-aloud protocols, or mixed-methods approaches with larger cohorts to capture a deeper, more authentic understanding of students' actual digital proficiencies.

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