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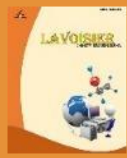

Correlation between Digital Literacy with Chemical Computational Ability: Chemistry Students at UIN Walisongo

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Abstract

This research aims to determine the relationship between digital literacy and chemical computing abilities of Chemistry Education students at UIN Walisongo Semarang. Although digital literacy has been widely recognized as a key competency supporting 21st century skills, empirical studies that specifically examine its relationship with chemical computing abilities in chemistry education, particularly in the Indonesian higher education context, are still limited. Digital literacy is an important competency that supports 21st century skills, including mastery of technology in chemistry learning. This research uses a quantitative approach with a correlational design. The research population was all 6th semester students taking the Computational Chemistry course, with a total sample of 56 students. The research instruments consisted of a digital literacy questionnaire, computational chemistry practice tests, observation sheets, and interviews. Data analysis was carried out using the Pearson correlation formula. The results showed that there was a positive and significant relationship between digital literacy and students' chemical computing abilities (r = 0.72; p < 0.05). This means that students with high digital literacy tend to have better chemical computing skills. Therefore, this study fills a gap in the literature by providing empirical evidence on the role of digital literacy in supporting chemical computing competencies among prospective chemistry teachers. This research recommends strengthening digital literacy in the technology-based chemistry learning curriculum.

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1. Introduction

The development of digital technology today has penetrated almost all aspects of human life, including the world of higher education. Digital transformation has drastically changed the way individuals learn, communicate, and access information. In the era of Industrial Revolution 4.0 and welcoming the era of Society 5.0, information technology skills have become a basic need in the world of work and education. One of the essential competencies that the 21st century generation must have is digital literacy, namely the ability to access, evaluate, use, manage and create information through digital technology wisely, critically and ethically (Gilster, 1997; UNESCO, 2018).

In the context of science education, especially chemistry, digital literacy is becoming increasingly important. This is due to the characteristics of chemistry learning which is complex, abstract, and requires high visualization skills. Chemical concepts such as molecular structure, geometric shapes, chemical bonds, and molecular reactions are often difficult to understand only through conventional text-based approaches or static images in books. Therefore, an approach is needed that can help students understand chemical phenomena in a more concrete and interactive way.

One approach that is increasingly developing in the world of modern chemistry education is computational chemistry, namely the use of software to simulate, visualize and analyze molecular structures and chemical reactions. By using programs such as Avogadro, ChemSketch, and GaussView, students can build three-dimensional molecular models, perform geometric optimization, and visualize interactions between atoms in real time (Cramer, 2013). This approach not only improves understanding of concepts, but also encourages students' critical thinking abilities and technology skills.

Empirical findings from previous studies indicate that although computational chemistry has strong potential to improve conceptual understanding, many students still face difficulties in its implementation. These difficulties include limited ability to operate software independently, challenges in interpreting computational outputs, and problems in connecting simulation results with underlying chemical theories (Dori & Barak, 2001; Sangi et al., 2020). Several studies also report that students’ success in computational chemistry learning is highly influenced by their level of digital literacy, particularly skills related to navigating digital interfaces, managing digital data, and critically evaluating information generated by software (Hatlevik & Christophersen, 2013; Tang & Austin, 2009). In the context of chemistry education, inadequate digital literacy has been identified as one of the main empirical challenges that hinder the optimal use of molecular modeling and simulation tools in learning activities (Sangrà & González-Sanmamed, 2010).

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For Chemistry Education students, who are being prepared to become science educators in the future, mastering chemistry-based educational technology such as molecular computing is an urgent need. Students are not only required to understand chemical content, but also must be able to integrate technology in the learning process to create a learning experience that is meaningful, fun, and relevant to current needs. In this context, digital literacy is an important foundation that supports these abilities (Hargittai, 2010; Wahyuni, 2020).

However, a number of previous studies have focused more on the influence of digital literacy on learning outcomes in general, without specifically reviewing its relationship to chemical computing abilities, especially among student teachers. In fact, understanding the relationship between these two aspects can be an important basis for designing more effective digital technology-based chemistry learning strategies in higher education environments.

Therefore, this research is focused on examining the relationship between digital literacy and chemical computing abilities in Chemistry Education students at UIN Walisongo Semarang semester 6. Specifically, the objectives of this research are:

a. Measuring the digital literacy level of 6th semester Chemistry Education students at UIN Walisongo;
b. Measuring students' ability to operate chemical computing software such as Avogadro and ChemSketch;
c. Analyze the relationship between digital literacy and computational chemistry skills statistically.

It is hoped that the results of this research can contribute to the development of curriculum and chemistry learning strategies that are relevant to the demands of the digital era and the needs of prospective teachers in the 21st century.

2. Materials and Methods

This study employs a quantitative approach with a correlational design, aiming to identify and analyze the extent of the relationship between two variables: digital literacy as the independent variable and computational chemistry ability as the dependent variable. The quantitative approach was chosen because this study focuses on measuring variables numerically and applying inferential statistical analysis, with the expectation of obtaining objective, measurable, and generalizable findings.

The correlational design was used because this study does not intend to manipulate any variables but merely to observe the natural relationship between them. In this context, correlation refers to a linear relationship, namely whether an increase in students' digital literacy is followed by an improvement in their computational chemistry skills. This correlational technique is useful in educational research to determine the extent to which two skills or attributes are related (Creswell, 2014). Using this method, the researcher can determine whether the relationship is positive, negative, or nonexistent, and measure the strength of the

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relationship using the Pearson correlation coefficient (r). Furthermore, a significance test (Sig. 2-tailed) was conducted to determine whether the correlation is statistically significant.

The population of this study consisted of sixth-semester students from the Chemistry Education Program, Faculty of Science and Technology, State Islamic University (UIN) Walisongo Semarang, who were enrolled in the Computational Chemistry course during the 2024/2025 academic year. The population was selected purposively, as these students were considered to have prior learning experience in using computational chemistry software and adequate exposure to digital learning technologies. The sample size of this study consisted of 56 students. To ensure the validity and reliability of the data collected, several systematically structured instruments were used to measure the variables under investigation—digital literacy and computational chemistry ability. These instruments were adapted to align with the quantitative approach and correlational design. The instruments are described as follows:

a. Digital Literacy Questionnaire

This instrument was designed to measure students' levels of digital literacy, based on the UNESCO (2018) Digital Literacy Global Framework. The questionnaire consisted of several closed-ended statements using a 4-point Likert scale (from *strongly agree* to *strongly disagree*), reflecting four key domains of digital literacy:

1) Accessing and Navigating Digital Information – measuring students' ability to search for, locate, and access information via the internet and digital platforms. *Example item:* "I can easily find academic information on the internet."
2) Evaluating Source Reliability – assessing students' ability to distinguish between credible and non-credible sources. *Example item:* "I can judge whether information comes from a valid source or not."
3) Producing Digital Content – evaluating students' ability to create or modify digital content such as documents, videos, graphics, or presentations for learning purposes. This domain reflects practical and creative technological skills.
4) Online Collaboration – measuring the extent to which students can collaborate and interact within digital environments, such as using Google Docs, discussion forums, or Learning Management Systems (LMS).

Each statement was designed to reflect the digital skills required in technology-based chemistry learning. Total scores were then classified into four categories: *very high*, *high*, *moderate*, and *low*.

b. Computational Chemistry Practice Test

This test aimed to assess students' ability to use computational chemistry software, particularly Avogadro and ChemSketch. Students were assigned several project-based practical tasks, including:

a. Building Three Molecular Structures: Students were asked to construct molecular models based on given chemical formulas. The process included:

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1) 2D and 3D Structures: Students first drew two-dimensional structures, then converted them into three-dimensional models using the software's available tools.
2) Structure Optimization: Using the energy optimization feature, students performed calculations to obtain the most stable molecular configuration theoretically.
3) Molecular Shape Analysis: Students analyzed molecular geometry based on VSEPR theory (Valence Shell Electron Pair Repulsion) and explained the shape according to the visualization results.

This test was designed to assess not only students' technical proficiency but also their conceptual understanding of molecular structure and its relationship to computational tools.

c. Technical Skills Observation Sheet

To complement the performance test, an observation sheet was used to evaluate students' practical skills during software operation. The sheet was filled out by the lecturer or observer while students completed the practical tasks.

The observed aspects included:

1) Skill in opening and operating the software
2) Accuracy in constructing molecular structures
3) Precision in optimization and data interpretation
4) Independence and efficiency in using program features

Observations were scored using a quantitative rating scale (e.g., 1–4), and the average score contributed to the assessment of computational ability.

d. Structured Interviews

In addition to quantitative data collection, structured interviews were conducted with 10 selected students, chosen based on score variations (*high*, *medium*, and *low* categories). The interviews aimed to explore:

1) Technical challenges encountered when using Avogadro or ChemSketch
2) Perceptions of the ease or difficulty of learning through computational approaches
3) Students' feedback and suggestions regarding the use of software in chemistry learning

The interview questions were prepared systematically and asked in the same order for all respondents. The interview data were analyzed descriptively to support and enrich the quantitative findings.

e. Data Analysis Techniques

Data analysis in this study was conducted to address the research questions and test the hypothesis regarding the relationship between digital literacy and students' computational chemistry ability. Since this study applied a quantitative correlational design, the data analysis techniques included descriptive statistical analysis and inferential statistical analysis.

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1) Descriptive Statistical Analysis

Descriptive statistics were used to describe the general profile of data for each variable—digital literacy and computational chemistry ability. The analysis included:

a) Minimum and maximum values
b) Mean score
c) Standard deviation
d) Score classification categories

According to Sugiyono (2017), descriptive statistics serve to "describe or provide an overview of the object under study through sample or population data as they are, without conducting analysis or making general conclusions."

Classifying scores into categories (*very high*, *high*, *moderate*, and *low*) helped the researcher group respondents and interpret results more meaningfully.

2) Inferential Statistical Analysis (Pearson Correlation)

To determine whether there is a significant relationship between the two research variables, the Pearson Product-Moment Correlation analysis was employed. This method was chosen because both variables are measured on an interval scale and are assumed to have a linear relationship with a normal distribution (Creswell, 2014).

According to Arikunto (2010), the correlation coefficient (*r*) can be interpreted according to the following categories:

Table 1. Interpretation of Pearson Correlation Coefficient (r)

r Value	Strength of Relationship
0,00 – 0,19	Very weak
0,20 – 0,39	Weak
0,40 – 0,59	Moderate
0,60 – 0,79	Strong
0,80 – 1,00	Very strong

After obtaining the *r* value, a statistical significance test was conducted by examining the p-value (Sig. 2-tailed). If the *p*-value is less than 0.05 ($p < 0.05$), the relationship between the two variables is considered statistically significant, meaning that the observed correlation is unlikely to have occurred by chance at the 95% confidence level (Priyatno, 2012).

3. Results and Discussions

To provide an overview of students' digital literacy and computational chemistry abilities, descriptive statistical analysis was conducted. The results are presented in the form of frequency and percentage distributions to classify students into different competency levels. Table 2 presents the categories of students' digital literacy levels, while Table 3 shows the distribution of students'

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computational chemistry abilities.

Table 2. Categories of Digital Literacy Levels

Digital Literacy Category	Number of Students	Percentage
Very high (≥85)	12	21,4%
High (75–84)	28	50,0%
Moderate (65–74)	13	23,2%
Low (<65)	3	5,4%

Table 3. Categories of Computational Chemistry Ability

Computational Chemistry Ability	Number of Students	Percentage
Excellent (≥85)	15	26,8%
Good (75–84)	27	48,2%
Fair (65–74)	12	21,4%
Poor (<65)	2	3,6%

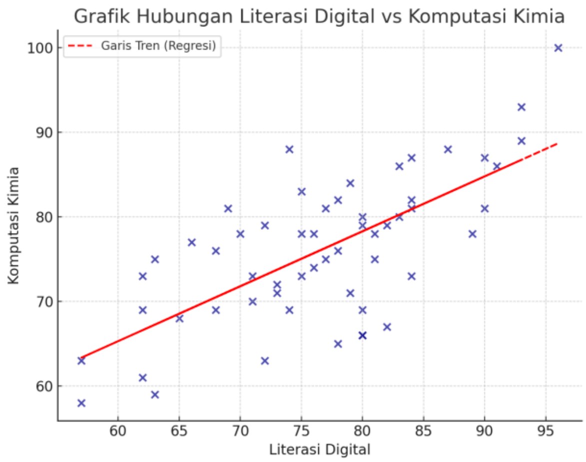

Figure 1. Graph of the Relationship Between Digital Literacy and Computational Chemistry Ability

The following graph shows the relationship between Digital Literacy scores and Computational Chemistry Ability among 56 students. The data indicate a tendency that students with higher levels of digital literacy tend to demonstrate better computational chemistry performance. The red dashed linear regression line illustrates the direction of a positive relationship between the two variables.

The results of the Pearson correlation test show that:

- $r = 0.72$
- Sig. (2-tailed) = $0.000 < 0.05$

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Interpretation: There is a strong and statistically significant positive correlation between students' digital literacy and their computational chemistry ability. This finding indicates that higher levels of digital literacy are associated with better performance in computational chemistry.

Correlations

		Literasi_Digital	Komputasi_Kimia
Literasi_Digital	Pearson Correlation	1	,723**
	Sig. (2-tailed)		,000
	N	56	56
Komputasi_Kimia	Pearson Correlation	,723**	1
	Sig. (2-tailed)	,000	
	N	56	56

**. Correlation is significant at the 0.01 level (2-tailed).

Source: IBM SPSS Statistics (Version 25)

The findings of this study indicate that students with higher levels of digital literacy tend to demonstrate better computational chemistry abilities. This is evidenced by a strong and significant correlation between the two variables—digital literacy and the ability to use chemistry software. In other words, students who are able to effectively access, evaluate, and manage digital information also exhibit stronger skills in operating applications such as Avogadro and ChemSketch for molecular representation and chemical structure analysis. This finding reinforces Gilster's (1997) theory of digital literacy, which asserts that digital literacy is not merely the technical ability to use digital tools, but also encompasses critical thinking, information navigation, and technology-based content creation. In the context of chemistry education, these competencies translate into technical proficiencies such as understanding software interfaces, performing molecular optimization processes, and interpreting visually based simulation results.

Consistent with Hargittai's (2010) study, the present research found that differences in digital literacy levels affect individuals' effectiveness in using educational technologies. Students with high digital literacy tend to adapt more quickly to new software, access online tutorials, troubleshoot technical issues independently, and creatively explore various software features. This is particularly important since computational chemistry software requires not only chemical understanding but also digital manipulation skills and spatial visualization capabilities. The results are further supported by Tang and Austin (2009), who revealed that the integration of technology in chemistry learning is effective only when students possess basic digital competence and motivation for self-directed learning. In their study, students familiar with visualization technologies achieved higher learning outcomes compared to those who used

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conventional approaches. In addition to digital literacy, several supporting factors were also found to influence students' success in computational chemistry tasks, including:

a) Prior computer experience, such as attending ICT training or being accustomed to digital-based assignments, which better prepared students to engage with new technologies.
b) Interest in technology, which serves as an internal motivator to experiment with and explore software features independently.
c) The use of Project-Based Learning (PjBL) by the course instructor, in which students not only learned theoretical content but were also required to produce tangible molecular visualization products. This approach has been proven to enhance both conceptual understanding and technical skills simultaneously (Thomas, 2000).

Structured interviews conducted during this study also revealed that high-performing students often had prior experience using other chemical visualization programs such as ChemDraw, MolView, or even general 3D modeling software like Blender. Early exposure to these tools helped them better understand the functions, navigation, and workflow of the chemistry software used in the course. Nevertheless, the study also identified several challenges faced by students, particularly those with lower levels of digital literacy. These challenges included:

a) Limited access to personal computers or laptops, such as inadequate RAM, insufficient storage, or incompatible operating systems that prevent the installation of modern chemistry software.
b) Technical problems during software installation, including missing support libraries, system errors, or lack of knowledge regarding installation procedures.
c) A shortage of practical guides in the Indonesian language, which caused confusion in understanding software instructions, especially for English-based programs containing specialized chemical terminology.

This situation supports Warschauer's (2003) concept of the *digital divide*, which refers not only to unequal access to technology but also to disparities in skills, technical support, and learning environments that enable optimal technology use. Therefore, although the potential for technology integration in chemistry education is considerable, its success largely depends on students' overall digital readiness, encompassing access to devices, digital competencies, and a supportive learning environment. Strengthening digital literacy and providing adequate infrastructure and support are thus strategic steps to enhance the quality of technology-based chemistry learning. To address these challenges and enhance the two main variables examined in this study, several strategies can be implemented in higher education settings, including:

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a) Digital literacy training at the beginning of the academic program.Universities should organize regular digital literacy workshops, especially for first-year students, to equip them with essential information and communication technology skills relevant to chemistry learning.
b) Development of project-based molecular visualization modules. Laboratory modules should be designed using a project-based learning approach, in which students are assigned to create digital visualizations of specific chemical compounds, conduct simulations, and present their results in digital reports. Such modules will simultaneously foster both digital and chemical competencies.
c) Regular utilization of campus computer laboratories. Considering that not all students have access to adequate personal devices, the use of university computer laboratories should be optimized for computational chemistry learning, with technical supervision provided by laboratory assistants or teaching staff.

5. Conclusions

The results of this study demonstrate a strong and significant relationship between digital literacy and computational chemistry ability among sixth-semester Chemistry Education students at UIN Walisongo Semarang. The high correlation coefficient indicates that the better students are at accessing, evaluating, and utilizing digital information, the higher their ability to operate computational chemistry software. Students with higher levels of digital literacy exhibited greater proficiency in using software such as Avogadro, ChemSketch, and MolView. They were able to understand software interfaces more quickly, perform molecular structure optimization, and conduct molecular shape analyses independently. This finding suggests that digital literacy influences not only cognitive abilities but also directly enhances students' technical skills in chemistry learning. These results affirm that digital literacy is a key competency for supporting modern science education, particularly in simulation-based and virtual laboratory practices. Digital literacy should not be viewed merely as a supporting tool, but as an integral component of 21st-century chemistry learning processes. These findings apply to students with prior exposure to computational chemistry tools and may vary across institutions with differing digital infrastructure.

Based on these findings, several actionable implications can be proposed for chemistry education in higher education. First, digital literacy modules should be explicitly integrated into computational chemistry courses to ensure that students possess the necessary competencies for effectively using simulation and modeling software. These modules may include training on digital information evaluation, software navigation, data management, and ethical use of digital resources. Second, lecturers are encouraged to design structured and progressive software-based tasks that guide students from basic operations to more complex computational activities, such as molecular modeling, geometry optimization, and result interpretation. Such structured assignments can help reduce students' initial difficulties and promote independent learning in computational chemistry environments. Third, digital literacy competencies should be embedded within course learning outcomes and assessment systems. This can be

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achieved by incorporating digital literacy indicators into rubrics for practical assignments, projects, and examinations, so that students' technological proficiency is formally evaluated alongside their conceptual understanding of chemistry. Finally, these implications suggest that strengthening digital literacy is not only a pedagogical enhancement but also a strategic step in preparing prospective chemistry teachers to design technology-integrated learning experiences that align with the demands of 21st-century science education.

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