Digital Technology in Chemistry Education: Investigating Students' Engagement with Chemistry Software

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Abstract. The utilization of software as a form of digital technology proves beneficial in aiding students to comprehend abstract concepts in chemistry. The objective of this research is to investigate students' engagement in using software, such as simulations and molecular modelling, to support their chemistry education. The research participants consisted of 101 students enrolled in the chemistry education program for the academic year 2022/2023, representing eight universities in Indonesia (17 males and 84 females). Data were acquired through an online survey employing a Google Forms questionnaire. Based on the investigation results, it was found that the percentage of male' software knowledge is slightly higher than female students. All fourth-semester students are knowledgeable about chemistry software. Chemist–Virtual Chem Lab and Chem Draw emerged as the most frequently accessed software programs by students. The average utilization of chemistry software by students remains relatively low. The majority of students do not incorporate these chemistry software tools due to the fact that the lecturer has never introduced these applications. In conclusion, students' digital technology engagement related to the use of software in chemistry education is limited. The recommendation and limitation Chemistry lecturers can optimize the use of software in chemistry learning.

Keywords: digital technology, students' engagement, chemistry software

1 Introduction

Digital technology refers to electronic tools, systems, devices, and electronic resources that generate, store, or process data [1]. The rapid advancement of information technology has necessitated educational institutions to prepare future generations capable of adapting to digital technology. However, expectations regarding the adoption and implementation of digital technology in educational practices have not been fully realized [2]. There is a strong consensus that digital technology can enhance teaching and learning by motivating students through engaging, interactive, and enjoyable learning environments [3,4,5,6].

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The subject matter of chemistry emphasizes abstract concepts related to molecular modeling and chemical reactions. Researchers have found that technology has a positive impact on chemistry learning through the visualization of chemical structures and important chemical reactions [7,8,9,10]. Digital technology also opens up deeper educational opportunities, providing students with new avenues for learning [6]. Interactive digital tools, such as problem-solving games, modeling software, and 3D printing, support cognitive development and enable students to understand abstract concepts, visualize virtual objects, and create tangible artifacts. Engaging in a dynamic digital environment allows students to see and discuss key concepts from various perspectives.

Numerous studies have been conducted on the use of digital technology in chemistry learning. Most research employs digital technology in the form of simulations, multimedia, and modeling [11]. The research primarily focuses on leveraging digital technology to enhance students' learning performance. For instance, the utilization of digital technology in the form of simulations enhances concept comprehension [12,13,14,15] and representational skills [16]. Rodrigues investigated factors influencing student engagement in science simulations [17]. Other research relates to molecular modeling used to improve students' conceptual understanding [18,19,20], mental models [21], and explores teachers' perceptions of molecular modeling usage [22,23].

Research related to the utilization of open-source chemistry learning software (e.g., simulations and molecular modeling) by students in chemistry education has not been extensively explored. Therefore, this study aims to investigate students' engagement in using chemistry software, e.g., PhET Simulation, Chemist-Virtual Chem Lab, Chemagic, ChemDraw, and Molecular Workbench. The open-source software examined in this research includes simulation and molecular modeling software accessible to students, either in the form of Android applications or web-based platforms. Open-source software refers to computer programs and applications whose source code is made available to the public, allowing anyone to view, modify, and distribute the code. In open-source software, the source code, which is essentially the set of instructions that make a program function, is openly accessible and can be freely used and modified by individuals or organizations. Based on this objective, the research questions investigated are as follows:

R.Q. 1: What is the percentage of students who are aware of chemistry software in terms of gender and semester?
R.Q. 2: To what extent are students engaged in using chemistry software for learning?
R.Q. 3: What are the reasons why students do not use chemistry software?

2 Method

2.1 Research Design

This research employs a cross-sectional survey design in which the researcher gathers data at a one point in time. In a cross-sectional study, it is possible to investigate contemporary attitudes, beliefs, opinions, or practices. Attitudes, beliefs, and opinions represent the cognitive aspects of how individuals conceptualize matters, while practices pertain to their tangible actions [24].

2.2 Participants

The participants in this study were students from the chemistry and chemistry education programs at eight universities in Indonesia. These universities included four public universities, two private universities, and two Islamic universities. The participants were students of the chemistry education programs in the academic year 2022/2023, enrolled in the 2nd, 3rd, 4th, and 6th semesters. The total number of participants was 101, consisting of 17 males and 84 females. Researchers employed simple random sampling to select participants. In simple random sampling, individual has an equal probability of being selected from the population, although equal distribution is not always possible [25].

2.3 Data Collection

Data was collected through online questionnaires created using Google Forms. Online questionnaires are a survey instrument for data collection available on the internet and accessible through computers, tablets, smartphones, or other internet-enabled devices [24]. Online questionnaires were distributed via WhatsApp to lecturers, who then distributed them to students. The questionnaire consisted of close-ended questions, where students were required to select answers from the provided options. Close-ended questions were chosen to ensure that students' responses remained focused and to avoid irrelevant answers. Some questions allowed students the freedom to select more than one answer option. The research questions, questionnaire questions, and the types of answer choices provided in the survey questions are presented in Table 1.

2.4 Data Analysis

All data obtained from the answers to the questionnaire were calculated using the percentage formula (Formula 1) with the following formula [26]:

$$\text{Percentage} = \frac{\text{Total of respondents' choice}}{\text{Maximum Score}} \times 100\% \quad (1)$$

Furthermore, for the data from the second research question, categorization was conducted based on Table 2. This categorization helps to determine the level of students' engagement in using open-source software for learning chemistry.

3 Result and Discussion

The research data is presented based on the research questions.

RQ1. What is the percentage of students who are aware of chemistry software in terms of gender and semester?

The number of students, based on gender, who are familiar with software such as PhET Simulation, Chemist-Virtual Chem Lab, Chemagic, ChemDraw, and Molecular Workbench, is presented in Table 3.

Table 1. Research Questions, Questionnaire Questions, and Answer Choices

Research Question	Questionnaire Questions	Answer Choices
What is the percentage of students who are aware of chemistry software in terms of gender and semester?	From the list of software below, do you know of any software for studying chemistry? • PhET Simulation • Chemist-Virtual Chem Lab • Chemagic • ChemDraw • Molecular Workbench Answer options: • Known • Unknown	• Students should choose one option (known or unknown). The data was categorized by gender. • Students can choose more than one option. The data was categorized by semester.
To what extent are students engaged in using chemistry software for learning?	From the list of software below, which ones do you often use for studying chemistry? • PhET Simulation • Chemist-Virtual Chem Lab • Chemagic • ChemDraw • Molecular Workbench	Students can choose more than one option. The data was categorized by level of students' engagement.
What are the reasons why students do not use chemistry software?	Based on the previous question, what are your reasons for not using these software tools to study chemistry? • The lecturer has never introduced that software • Lack of motivation to use it • The lecturer has introduced it, but I have not explored it further	Students should choose one option.

Based on Table 3, it can be observed that the percentage of male and female students' knowledge regarding chemistry software (e.g., PhET Simulation, Chemist-Virtual Chem Lab, Chemagic, Chem Draw, and Molecular Workbench) is slightly different, although the percentage difference is only 1%. Nevertheless, the percentage of males who are familiar with chemistry software is slightly higher than that of females. This finding indicates that there is a gender-based difference in knowledge about chemistry software. The results of this research are in contrast to some other research findings. Zhitomirsky-Geffet and Blau stated that males exhibit significantly more functional/cognitive information-seeking behavior than females [27]. According to gender role beliefs, women are expected to have less interest in and lower proficiency in utilizing technology compared to men [28]. Furthermore, some research results on gender differences in technology knowledge show mixed results. There are situations where gender differences cannot be distinguished, despite the limited impact of gender on the intention to embrace new technology [29]. Gender plays a role in the adoption of technology in the context of using information technology, including computers, email

Table 2. Level of Students' Engagement

Percentage	Category
$x > 75$	High
$50 \leq x \leq 75$	Moderate
$x < 50$	Low

Table 3. Students' Knowledge About Open-Source Software Based on Gender

Answer	Percentage (Male)	Percentage (Female)
Known	59%	58%
Unknown	41%	42%

services, electronic data management systems, etc. Men are reported to be more technologically savvy than women [30,31,32]. Other research results indicate that there is no gender difference in social media contact, as males and females use social networking sites for distinct purposes. While men mostly use social networks to "make new friends," women primarily use them to "maintain existing relationships" [33,34].

Furthermore, data analysis regarding students' knowledge of chemistry software based on the semester level is presented in Figure 2.

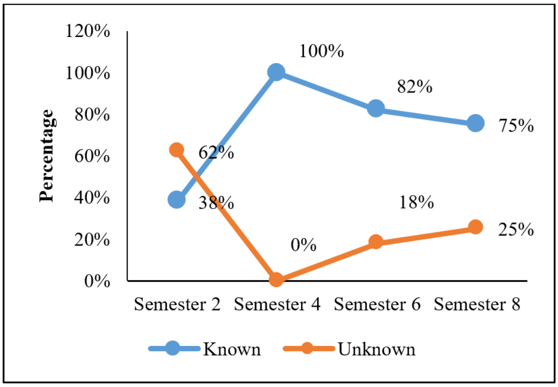

Fig. 1. Students' knowing about open-source software based on semester

Figure 1 provides information that all students in the 4th semester are aware of some chemistry software presented (e.g., PhET Simulation, Chemist-Virtual Chem Lab, Chemagic, ChemDraw, and Molecular Workbench). As many as 82% of 6th-semester students also demonstrate similar knowledge. Slightly lower than the 4th and 6th semesters, about three-quarters of 8th-semester students are aware of chemistry software. In contrast to the upper semester levels, 2nd-semester students actually exhibit lower knowledge of chemistry software at 38%. This is because 2nd-semester students are newcomers to the university, resulting in a lack of information acquired by students during their high school years. Jansen et al, stated that the expectations and readiness of first-year students affect both their first year at the university and the transition from high school to college [35]. However, they frequently are unable to identify and address potential learning behavior deficits on their own, which often negatively impacts students' success and dropout rates that can be attributed to unsatisfactory study experiences. As a result, problems managing the demands of university study may worsen [36].

RQ2. To what extent are students engaged in using chemistry software for learning?

Based on the data analysis results regarding students' engagement in using chemistry software, data is obtained as presented in Table 4.

Table 4. Students' Engagement About Open-Source Software

Name of Software	Percentage (%)	Category
Phet Simulation	17,9	Low
Chemist-Virtual Chem Lab	34,3	Low
Chemagic	14,9	Low
Chem Draw	37,3	Low
Molecular Workbench	6	Low

From Table 4, it can be seen that students often access the ChemDraw software, with a percentage of students accessing it being 37.3%, and the Chemist-Virtual Chem Lab software at 34.3%. Meanwhile, other software such as Phet Simulation, Chemagic, and Molecular Workbench are used by less than one-fifth of the students. Meanwhile, the average number of students accessing chemistry software is only 22.08%. This figure indicates that the percentage of students who frequently access chemistry software is low. These results suggest that the utilization of digital technology in the learning process is challenging. This finding is in line with the findings of [2], which state that the adoption and implementation of digital technology in educational practices have not been fully realized. Furthermore, specific personal strategies and competencies are necessary, which many students may not necessarily possess, to fully harness the potential of digital technologies for teaching and learning in higher education [37,38].

RQ3. What are the reasons why students do not use chemistry software?

The survey results regarding the reasons why students do not use chemistry software in their learning are presented in Figure 2.

Figure 2 shows that the primary reason students do not use chemistry software in their learning is because "the lecturer has never introduced that software," accounting for nearly three-fifths of the respondents. Meanwhile, almost one-third of the students cited that the lecturer had introduced the software, but they had not explored it further, and 9% of the students stated a lack of motivation to use the chemistry software. According to Lee et al, students require guidance on how to effectively utilize technology

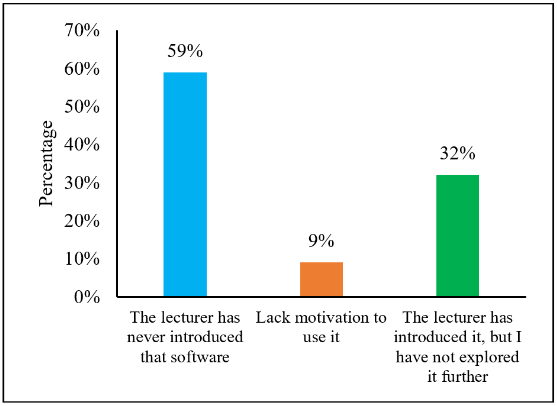

Fig. 2. Students' knowing about open-source software based on semester

for independent learning [39]. They need to be introduced to digital tools and processes for purposeful learning with Information and Communication Technology (ICT) [40,41,42]. Additionally, students must develop competencies and skills to successfully learn with technology.

4 Conclusion

Based on the results and discussion, it can be concluded that there are differences in students' knowledge of open-source chemistry software, both in terms of gender and semester. However, the difference in knowledge between male and female students is very small. Furthermore, students' engagement in using chemistry software is relatively low. The majority of students cite ”the lecturer has never introduced that software” as their reason for not using the software. Effective planning by lecturers is essential when implementing digital technology in education. This planning may involve the introduction and guidance on the appropriate use of digital technology in learning. Moreover, specific personal strategies and competencies are required for students. The findings of this research can provide information to chemistry educators to optimize the use of software in chemistry education. This study has limitations, including a limited sample size of only 101 students, which means that the results cannot be generalized. Future research with a larger sample size is needed to further explore similar studies.

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