

DIGITAL LITERACY IN CHEMISTRY LEARNING: *SYSTEMATIC LITERATURE REVIEW*

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Abstract

Digital literacy can be utilized in chemistry learning to support the learning process and enhance students' understanding and learning outcomes about chemistry. This study aims to analyze digital literacy in chemistry learning. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is a technique used to analyze research results from articles that have been published on students' digital literacy in chemistry in national and international journals as many as 20 articles with a span of 2019 to 2024. The results of the analysis concluded that, students' digital literacy skills tend to be used in online learning, while in college students it tends to be used to search for information and complete academic assignments. Digital literacy has a positive effect on learning outcomes. Several media and learning models have been developed to improve digital literacy that can support the chemistry learning process.

Keywords: *Digital Literacy, Chemistry, Chemistry Learning*

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INTRODUCTION

Education is a conscious and planned effort in order to develop a person's physical and spiritual potential to become independent (Hidayat & Abdillah, 2019). Therefore, education is important for every individual to be ready to face the future. Along with the rapid advancement of technology, information, and communication, humans should adapt to enhance their abilities and skills in order to adapt in this modern era (F. Mulyani & Haliza, 2021). This development of technology, information, and communication affects many fields, one of which is education. Technological advancement makes it easier to obtain information through the internet media. Information sources can be obtained real time anywhere and anyone. This is a challenge in the world of education in the 21st century, where every individual must have reasoning skills, technological skills, information, computer-based education, the ability to manage media and data, and the ability to interact and innovate (Umayah & Riwanto, 2020). Therefore, the role of digital literacy in education is key so that students can sort digital information wisely.

Literacy comes from Latin, namely "*littera*" which means letters it can be interpreted as a mastery of a system in the form of writing and the conventions which accompany it (Hartati, 2017). Literacy is the ability to process, identify, interpret, create, communicate, calculate, and understand information when reading and writing. Furthermore, according to Fallon, digital literacy is a combination of various types of literacy, including information technology, media literacy, and visual literacy (Falloon, 2020). In addition, digital literacy is an individual's ability to manage, sort, and deeply understand the contents of the digital information they acquire.

With the increasingly rapid advancement of technology, and the importance of utilizing information and communication technology in learning activities, digital literacy skills are greatly needed to help the world of education continue to develop. Therefore, with the ability to use, manage, and utilize effective technology, it will have an impact in the form of progress for education. This digital literacy ability not only helps in learning activities, but it also provides knowledge about more advanced digital technology in the future.

In chemistry learning, the use of digital literacy is considered as one of the important skills which supports students in understanding chemical concepts and principles through the use of rapidly developing digital technology. Digital literacy includes the ability to search, evaluate, and utilize digital information effectively, and use technological tools to support chemistry learning. Research shows that there is a relationship between digital literacy skills and student success in distance learning which utilizes digital technology and supports continued academic success. In addition, digital literacy skills can enhance critical thinking, collaboration, and student engagement in digital learning environments (Sari, 2024). With the background which has been mentioned, further research is needed to consistently investigate digital literacy in chemistry learning. By collecting and analyzing various scientific journals, it is expected that important

patterns and results can be found which can provide new insights regard to effective application of digital literacy in chemistry learning.

RESEARCH METHOD

This article was written by using the Systematic Literature Review (SLR) research method. It is a research model conducted by searching for various information by reviewing relevant literature on the topic. This study focuses on important aspects of digital literacy in chemistry learning discussed in national and international journals (Triandini, Jayanatha, Indrawan, Werla Putra, & Iswara, 2019). The literature data were analyzed by using the Meta-Analysis method, namely by knowing the argumentation pattern and drawing conclusions directly from published works (Chigbu, Atiku, & Du Plessis, 2023). The use of Systematic Literature Review and Meta-Analysis is known as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). It is a set of literature review guidelines designed in order to improve transparency, the quality of systematic reviews and meta-analyses (Tedja, Al Musadieq, Kusumawati, & Yulianto, 2024). Originally published in 2008, PRISMA provides a structured framework which is useful for researchers to ensure that their systematic reviews are comprehensive, reproducible, and useful for further research.

Literature was obtained with the help of the Publish or Perish application sourced from Google Scholar and manual searches on the internet with Google Chrome, then manually selected. The literature used was articles from 2019 to 2024. The keywords used in the literature search were, "Literasi Digital", "Digital Literacy", "Kimia", "Chemistry", "Pembelajaran Kimia", and "Chemistry Learning". The search results from publish or perish resulted 1000 articles, then they were selected by taking articles which had the words "Literasi Digital", "Digital Literacy", "Kimia", dan "Chemistry" in the title of the article, and 19 articles were obtained. Added from the results of a manual search on the internet with Google Chrome, 9 articles were obtained. From 28 articles selected, those which relevantly discussed digital literacy in chemistry learning were obtained, and 20 articles were obtained. This step shows the availability of a large number of literature discussing digital literacy in chemistry learning during the specified time period. From the result of the search, it will be identified about the profile of digital literacy, the effect of digital literacy on learning outcomes, and learning models and media in order to enhance digital literacy skills in chemistry learning.

RESEARCH RESULTS AND DISCUSSION

From the analysis results, the 20 articles can be categorized according to the research objectives into four discussion categories that are the profile of digital literacy of students in chemistry learning in high school, the profile of digital literacy of college students in chemistry learning in universities, the effect of digital literacy on learning outcomes, media and models to enhance digital literacy skills in chemistry learning. The four discussion categories are based on the topic of the article.

Students Digital Literacy Profile in Chemistry Learning

Table 1. Students Digital literacy profile in chemistry learning

No	Journal Title	Author	Publication Year	Article Source
1	Spatial Ability and Digital Literacy Profiles: Preceding Survey on the Need of Augmented Reality Media in Chemistry Instruction	Yuyun Yulianti, Indarini Dwi Puspitasari, Irvan Permana	2022	Indonesian Journal of Education Research and Review
2	Profil Literasi Digital Siswa Kelas XI Pada Pembelajaran Jarak Jauh Mata Pelajaran Kimia	Abdul Latip, Nursida Sutantri	2021	Jurnal Pendidikan
3	Profile of Interactive Learning Media Based Digital Literacy Needs on Elemental Chemistry Concepts	Hayuni Retno Widarti, Diah Triwidiastuti, Deni Ainur Rokhim	2022	Jurnal Tadris Kimiya

In a study conducted on 74 grade XI students at SMAN 4 Bandung during the distance learning period, a profile of digital literacy skills and its aspects was obtained. The first aspect is the ability to use digital media related to the high level of student activity in the learning activities. Second, the aspect of the ability to manage digital platforms related to the ability to manage online learning platforms in online learning activities; such

as, creating, designing, assessing, and uploading digital content, as well as learning activities which suitable to online learning styles. The third aspect of the ability to use advanced digital media is related to expertise in leading discussions with video conferences, reviewing digital media information, accessing the right website to get information, making descriptions, and creating shareable links. Fourth, the aspect of ethics and security in surfing online media. Furthermore, the aspect of the ability to use digital media of students is in the high category and it is proved by the average score of 79.95. Meanwhile, the aspect of the ability to manage digital platforms of students is placed in the high category and it is proved by the average score of 76.29. The aspect of the ability to use advanced digital media is placed in the moderate category and it is proved by the average score of 68.48. The ethical and security aspects in using digital media for students are placed in the high category and they are proven by the average score of 79.77 (Latip & Sutantri, 2021).

From the four aspects of the study, it can be seen that students' digital literacy skills in online chemistry learning are considered in high category. It is due to the increased use of digital platforms during the online learning period in the COVID-19 pandemic. As a result, students' digital literacy skills in using digital learning platforms can be unintentionally impacted (Latip & Sutantri, 2021). The large role of digital platforms in learning activities means that these digital literacy skills need to be developed in order to support learning.

Another study which had been conducted on 922 high school students and 35 educators in Sukabumi showed that students' digital literacy skills are at a moderate to good level. Moreover, the study showed that students' spatial abilities are still in the low category, which caused students to have difficulty understanding the abstractness of chemical concepts and principles at the submicroscopic level; besides, in that place there is no media which supports improving students' spatial abilities and digital literacy (Yulianti, Indarini Dwi Pursitasari, & Irvan Permana, 2022). Moreover, the results of a study which had been conducted on chemistry teachers and students in the Trenggalek area stated that educators need communicative and interactive learning media in order to explain abstract chemical concepts, and can be integrated with computers which are able to combine technology and art that support digital literacy skills (Widarti, Triwidiastuti, & Rokhim, 2022). In addition, the need for learning media which supports students' digital literacy skills needs to be developed in order to help chemistry learning activities in the digital era.

Students Digital Literacy Profile in Chemistry Learning

Table 2. Students digital literacy profile in chemistry learning

No	Journal Title	Author	Publication Year	Article Source
1	The Urgency of Digital Literacy for Generation Z Students in Chemistry Learning	Citra Ayu Dewi, Pahriah, and Ary Purmadi	2021	International Journal of Emerging Technologies in Learning
2	Digital Literacy Analysis of Chemistry Education Students in Using The Chemdraw Application	Ella Izzatin Nada, Wiwik Kartika Sari	2020	JKPK (Jurnal Kimia dan Pendidikan Kimia)
3	Chemistry Students' Digital Literacy Skills on Thermochemistry Context "Hydrogen Fuel Issue"	Putu Anindita Widhiya Putri, Sri Rahayu, Hayuni Retno Widarti, Yahmin Yahmin	2022	Eurasia Journal of Mathematics, Science and Technology Education
4	Persepsi Calon Guru Kimia Mengenai Literasi Digital Sebagai Keterampilan Abad 21	Puspa Mawarni, Burhanudin Milama, and Rizqy Nur Sholihat	2021	Jurnal Inovasi Pendidikan Kimia
5	Analisis Literasi Digital Calon Guru Kimia Dalam Pelaksanaan PPL Berbasis Virtual Di Masa Pandemi COVID-19	Ella I Nada, and Wiwik K Sari	2020	ORBITAL: Jurnal Pendidikan Kimia

In a study involving college students from the Chemistry Education Study Program at Mandalika University of Education, it shows that digital literacy skills are important in the chemistry learning process; especially, in meeting students' needs in accessing the internet as a means of obtaining educational information. The importance of college students' digital literacy skills in chemistry learning is related to the use of the internet to access or search for information related to learning; besides, to help students complete assignments

or homework. In addition, it is related to the use of digital media to communicate, create content, and solve chemistry problems. In chemistry learning, complete information on the internet will be able to provide solutions to various problems in order to improve the quality of chemistry education. The application of college students' digital literacy is able to improve the quality of chemistry learning through the technical aspects of digital literacy, cognitive aspects of digital literacy, and social aspects of digital literacy. Moreover, the technical aspects of digital literacy are related to the ability to utilize, use, and manage digital platforms in learning. The cognitive aspects of digital literacy are related to expertise in utilizing digital platforms in order to analyze programs, then choose the best features/functions for problem solving, or demonstrate an understanding of the chemical knowledge gained. Meanwhile, the social aspect of digital literacy is related to communication skills; such as, searching for information, uploading learning outcomes to the internet, and interacting with people on the internet (Dewi, Pahriah, & Purmadi, 2021).

Several studies also show that the digital literacy skills of chemistry students have varying levels. The study which conducted in the chemistry education department of UIN Walisongo Semarang to examine the level of digital literacy of college students with the ability to use ChemDraw is that college students with high ChemDraw skills have moderate digital competence, college students with moderate ChemDraw skills have moderate digital competence, and college students with low ChemDraw skills have low digital competence (Nada & Sari, 2020). Moreover, a similar study on 60 college students of 7th semester of the Chemistry Education study program at UIN Walisongo Semarang who underwent PPL, obtained a percentage that represented the level of digital literacy of chemistry education students from each indicator. The information indicator obtained a value of 87%, the communication indicator obtained a value of 82%, the content-creator indicator obtained a value of 78%, the safety indicator obtained a value of 82%, and the problem solving indicator obtained a value of 82% (W. K. Sari & Nada, 2020).

In addition, the results of a survey of college students of the chemistry education study program and students of the chemistry study program at the University of Indonesia totaling 74 students showed that most of the college students' skills are at the basic and intermediate levels. The achievements of college students' digital literacy skills after and interviews were still very diverse. Most chemistry students have level 1 (basic) skills that are processing information and data, this sub-competency showed the ability to evaluate the credibility of information sources, create digital content, and safety which regulates the privacy/accessibility of digital content, problem solving, and career-related competencies. Most other chemistry students have level 2 (intermediate) skills in operating devices and software. This sub-competency shows information and data literacy skills in determining keywords, selecting information, and assessing the usefulness of information from a source, and ethics of communicating on digital platforms and communicating and collaborating online through digital platforms. Meanwhile, no chemistry students have level 3 (advanced) or level 4 (highly specialized) skills in any digital literacy competency (P. A. W. Putri, Rahayu, Widarti, & Yahmin, 2022).

College students use digital literacy more to access educational information and complete academic assignments. College students' digital literacy skills tend to have varying levels. Digital literacy of high school students is often used in the context of distance learning, where they need to manage online learning platforms; yet, there is a need for learning media which supports students' digital literacy skills. Digital literacy is very much needed in chemistry learning activities, both at the high school and university levels. The reason is because information and communication technology is developing rapidly so that it shows the importance of using digital technology in the chemistry learning process to enhance the quality of learning. Aspects of digital literacy are not only needed in learning, but are always needed in the process of using and utilizing digital technology. Moreover, the results of a survey of 187 Chemistry Education Students of UIN Syarif Hidayatullah Jakarta, batches of 2016, 2017, and 2018 showed show that in the media and information literacy component, prospective chemistry teachers have a very good perception with an average percentage of 81.06%, likewise in the ICT literacy component, prospective chemistry teachers have a very good perception criterion with a percentage value of 84.47%. (Mawarni, Milama, & Sholihat, 2021). Therefore, digital literacy skills should be considered as one of the important skills and provisions in facing academic challenges in the future.

The Effect of Digital Literacy on Learning Outcomes

Table 3. The Effect of Digital Literacy on Learning Outcomes

No	Journal Title	Author	Publication Year	Article Source
1	The effect of digital literacy on student learning outcomes in chemistry learning	Abdul Latip, Nursida Sutantri, Aristo Hardinata	2022	Jurnal Inovasi Pendidikan IPA
2	Penerapan Literasi Digital pada Hasil Belajar Kimia Siswa SMA	Catur Fathonah Djarwo, Irwandi Yogo Suaka, Ima Nur Safitri, Intan Mentari Putri	2024	Jurnal Kependidikan Kimia
3	Hubungan Literasi Digital Dengan Hasil Belajar Siswa Pada Materi Koloid	Nina Nuraini Mabubah, Indah Wigati, Resti Tri Astuti	2022	Jurnal Al'ilmi: Jurnal Pendidikan MIPA
4	The Correlation Between Digital Literacy And Scientific Literacy Abilities With Students' Learning Outcomes On Chemistry Material In Everyday Life	Tutik Sri Wahyuni, Mochamad Abdi Rohman Firdaus, Ifah Silfianah	2024	QUANTUM: Jurnal Inovasi Pendidikan Sains
5	Pengaruh Literasi Digital dan Media Youtube Terhadap Hasil Belajar Kimia	Hadori	2022	Jurnal Ilmiah Wahana Pendidikan

A three-month study involving 74 high school students in grade XI who took chemistry lessons with a distance learning system was conducted to examine the relationship between the level of digital literacy skills of students and their chemistry learning outcomes. It showed that students' digital literacy skills vary widely. With different digital literacy skills, different learning outcomes are produced in distance learning chemistry. Students with high digital literacy skills will achieve better learning outcomes than those with moderate digital literacy skills (Latip, Sutantri, & Hardinata, 2022).

The main aspects which cause differences in chemistry learning outcomes of students in the high digital literacy group and students in the moderate literacy group are information management skills, facilities, and learning motivation. High digital literacy skills have an impact on being able to manage learning facilities and distance learning materials well, so that students obtain good information and they are able to build an understanding of the concepts learned through the information obtained (Latip et al., 2022). Students with high digital literacy skills have high motivation to learn chemistry concepts and principles through digital platforms so that it significantly influences their learning outcomes. The diversity of students' digital literacy skills is influenced by their background. Family factors, availability of technology, frequency of interaction with technology, experience, and managing the use of technology (Latip et al., 2022). In addition, at Muhammadiyah High School Jayapura, students' learning styles affects students' digital literacy skills and the application of digital literacy has an impact on the chemistry learning outcomes of students (Djarwo, Suaka, Safitri, & Putri, 2024).

Several studies showed a relationship between students' digital literacy skills and students' chemistry learning outcomes at the high school level. A study which had been conducted at SMA Karya Ibu Palembang showed a significant relationship between students' digital literacy skills and learning outcomes of colloid material, namely students' digital literacy skills are directly proportional to students' learning outcomes (Mabubah, Wigati, & Astuti, 2022). Another study of 55 class X students of MAN 1 Nganjuk showed that there is a significant relationship between students' digital literacy skills and students' chemistry learning outcomes (Wahyuni, Firdaus, & Silfianah, 2024). A survey conducted on 89 students of X grade in the 2021/2022 academic year at SMK Negeri 1 Pulo confirmed that digital literacy skills have a significant impact on chemistry learning outcomes (Hadori, 2022).

Learning Models and Media to Enhance Digital Literacy Skills in Chemistry Learning**Table 4.** Learning Models and Media to Enhance Digital Literacy Skills in Chemistry Learning

No	Journal Title	Author	Publication Year	Article Source
1	Analisis Literasi Digital Peserta Didik Melalui Pemanfaatan Media Pembelajaran Berbasis Android <i>Smart App Creator</i> (SAC) dan Instagram dalam Pembelajaran Koloid	Miokti Yessi	2021	Jurnal Riset Pendidikan Kimia
2	Pembelajaran Interaktif Articulate Storyline Berbasis Literasi Digital pada Materi Kimia	Sindi Putri, Kristina Tresia Leto, Sri Astuti Rahman Coa	2024	Seminar Nasional Teknologi, Kearifan Lokal dan Pendidikan Transformatif (SNTEKAD)
3	Pengembangan Modul Digital pada Materi Struktur Atom untuk Menumbuhkan Literasi Digital Siswa	Citra Ayu Dewi, Janista Mia Kusuma, Pahriah, Wilda Syahri	2022	Journal of the Indonesian Society of Integrated Chemistry
4	Using Android-Based E-Module to Improve Students' Digital Literacy on Chemical Bonding	Citra Ayu Dewi, Nurdianti Awaliyah, Nurin Ditriana, Satya Darmayani, Nasrullah, Jan Setiawan, Irwanto	2022	International Journal of Interactive Mobile Technologies
5	Development of Flipped Classroom Based Guided Inquiry Learning System with Digital Literacy Using Discord Application on Thermochemistry	Ezra Delfianza, Mawardi, Okta Suryani	2023	Jurnal Penelitian Pendidikan IPA
6	Improving Students Learning Outcomes and Digital Literacy on Acid-Base Titration Using Titration Screen Experiment Media	Sri Mulyani, Lina Mahardiani, Rakhma Amalia Nurdina	2023	International Journal of Pedagogy and Teacher Education
7	SDBL-Prodeo (Self-Directed Blended Learning-Oriented Prodeo) Design and Validation to Improve Digital Literacy Chemistry Teacher Candidate Students	St Hayatun Nur Abu, Abd. Rasyid Saraha, Fitriani Ibrahim	2022	EduLine: Journal of Education and Learning Innovation

The use of digital media and learning models can attract students' interest in the learning process so that it can enhance students' digital literacy skills in chemistry learning. Some learning media which can be used are the Smart App Creator application, Articulate Storyline, Instagram, Titration Screen Experiment, and electronic modules. Of the several media, some that have been tested to enhance digital literacy in students' chemistry learning are the use of the Smart App Creator application, Articulate Storyline, Instagram, and Titration Screen Experiment. The use of these four learning media shows a significant increase in students' digital literacy. It can be seen from the increase in the percentage between conditions before and after the implementation of digital literacy (Miokti Yessi, 2021; S. Mulyani, Nurdina, & Mahardiani, 2023; S. Putri, Leto, & Coa, 2024). Meanwhile, the use of electronic modules as learning media only reached the validation stage by obtaining a feasibility percentage of 86 good categories and the practical test of using this digital module provide a good response from students. The results show a significant increase in digital literacy scores before and after treatment (Dewi, Awaliyah, et al., 2022; Dewi, Kusuma, Pahriah, & Syahri, 2022). Therefore, the use of this electronic module is a good support for learning activities to be applied in every teaching in order to enhance students' interest in getting to know digital literacy.

In addition to the use of electronic media and modules, there are two learning models which can be used in order to enhance the digital literacy of students and college students that are the Flipped Classroom

model based on Inquiry Learning using the discord application and the SDBL (Self-Directed Blended Learning) learning model oriented to Prodeo (Video Project). Both learning models are only at the development stage which is proved by the validity of the construct and its content including the convincing category. Therefore, this learning model can be used to improve the learning process in order to improve the digital literacy of students and college students (Abu, Saraha, & Ibrahim, 2022; Delfianza, Mawardi, & Suryani, 2023).

In general, the application of innovative digital media and learning models can make a significant contribution to enhance digital literacy and students' interest in chemistry learning. Some media and learning models have reached the trial stage, and others are still in the validation stage, but these media and learning models can still be used to improve students' digital literacy skills in supporting chemistry learning.

CONCLUSION AND SUGGESTION

A. Conclusion

Based on 20 research articles which have been analyzed regarding digital literacy in chemistry of students with the period of 2019 to 2024, information obtained are (1) Digital literacy profile of students, (2) digital literacy profile of college students, (3) the influence of digital literacy on learning outcomes, (4) media and learning models used to improve digital literacy. Therefore, with these four kinds of information, it shows that digital literacy skills in students tend to be used in distance learning in order to manage online learning platforms, while in students they tend to be used to search for information and complete academic assignments. In addition, the level of digital literacy skills in students varies greatly. Digital literacy can have a positive impact on student learning outcomes. There are several learning media which have been developed that are the Smart App Creator application, Articulate Storyline, Instagram, Titration Screen Experiment, and electronic modules, as well as learning models, namely the Flipped Classroom model based on Inquiry Learning using the Discord application and the SDBL (Self-Directed Blended Learning) learning model oriented to Prodeo (Video Project) which can be used in order to enhance digital literacy skills.

B. Suggestion

It is expected to conduct further research on this topic which can provide a significant contribution to enhance the quality of learning through digital literacy mastery among students in order to support the chemistry learning process.

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