

Phenomena of Digital-Based Learning Media in the Indonesian Educational Curriculum (*Kurikulum Merdeka*) Regarding Chemical Bonding Materials: A Literature Review

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Abstract: Chemistry is a subject with complex, abstract, and microscopic concepts, so the quality of education must continue to be improved in line with developments in existing science. One of the realizations of this is the Indonesian Independent Curriculum (*Kurikulum Merdeka*). This curriculum aims to form a quick and responsive generation in understanding the material by being actively collaborative and communicative with various learning sources. One example of a material that requires explicit delivery is chemical bonds, so the solution is to pay attention to supporting materials in learning, such as learning media. This study aims to describe the phenomenon of digital learning media in the Indonesian Independent Curriculum (*Kurikulum Merdeka*) on the chemical bonding concept. The method used in this research is a systematic literature review for data collection. In this research, there are 12 literature indexed by Sinta on the topic of the development and implementation of digital media in teaching the concept of chemical bonds. The research articles obtained were then examined to connect the aims, methods, and results of the research. Based on the literature review, it was found that there was a positive response from students and teachers in using digital learning media for the concept of chemical bonds.

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INTRODUCTION

In the 21st century, technology is rapidly developing and has a major impact on all sectors, including education. Technology plays a crucial role in classroom learning, creating better productivity and efficiency. The use of technology in learning is inseparable from modern education (Singh, 2021). Internet-connected technology provides convenient facilities for activities such as communication, work, study, and other interactions. Today's children and adolescents grow up in a digital world, spending much of their time online. Therefore, it is necessary to pay attention to this phenomenon in the implementation of learning (Ott & Tiozzo, 2022).

Touchscreen mobile devices (e.g., smartphones and tablets) have become ubiquitous for young children. Interactive applications or "apps" that are considered "educational" for young children are also growing in popularity and are increasingly being integrated into early childhood classrooms as learning tools due to their perceived benefits for child engagement and active learning. The integration of interactive application technologies into children's lives at home and school has outpaced the research necessary to inform comprehensive recommendations for their use. Recommendations so far have focused on preventing excessive screen use rather than opportunities to maximize learning. Research into whether young children can learn from interactive applications, academic, cognitive, or social-emotional skill domains that may be best supported by interactive applications, and the conditions

under which this learning can be maximized still appears (Damiati et al., 2024).

A new learning method that aligns with students' life patterns rather than imposing demands, digital learning media has its way of adapting to students' learning styles. Effective use of learning media involves a combination of 'hands-on' creative production and critical reflection, thereby enhancing students' enjoyment and experience of the media (Buckingham, 2007). It is related to the complex concept of chemical bonds in microscopic aspects, such as defining ionic bonds, covalent bonds, and polar covalent bonds, which are generally found in the process of bond formation (Meltafina et al., 2019). Therefore, this digital learning media exists to help students construct and visualize how chemical bonds occur.

Improving the quality of education continues to be a priority because education is the foundation for the development of a country and educates human resources to compete in a complex and dynamic era of progress. This is exemplified by the introduction of an independent curriculum by the Indonesian Minister of Education, Nadiem Makarim. The main concept of this curriculum is to empower students in their learning. The curriculum aims to form a generation that is quick and responsive in understanding material because in practice as students are required to be active, collaborative, and communicative and interact directly with various learning resources (Indarta et al., 2022). The main elements of the Independent Curriculum include student-centered learning, where students have the freedom to choose the lessons they are interested in without feeling burdened by the term "Freedom to Learn," and a curriculum that is developed by the school itself according to the needs and characteristics of the school. In developing the Independent Curriculum, you must understand the characteristics of the educational unit, develop the vision, mission, and objectives of the educational unit, plan and map learning, establish mentoring systems, conduct evaluations, and provide professional development (Cholilah et al., 2023).

Chemistry is one of the compulsory subjects in high school. Chemistry is a science that is complex, abstract, and studies material on a micro-scale (Nugraha, Dian Anita, 2013) Learning about chemical bonds involves understanding how atoms interact with each other to form molecules and chemical compounds. Studying chemical bonds will understand the physical and chemical properties of a substance, as well as how reactions occur. To understand the concept of chemical bonds, alternative concepts are provided, such as analogical models and the relationship between symbolic, macroscopic, and microscopic levels (Ünal et al., 2006). The use of digital learning media can provide an increase in conceptual understanding, learning motivation, and learning outcomes in the chemical bonding concept (Ilyasa & Dwiningsih, 2020).

Digital learning media are developed in various forms, such as comics and bulletins uploaded to social media, games, software, and videos (Puspitasari et al., 2024). Appropriate learning media can increase students' understanding of the material to be studied. Besides being useful for students, choosing the right learning media can help and facilitate teachers in conveying material to students. The use of learning media also needs to pay attention to existing developments. Digital technology, over time, the faster it develops. Many people, especially the Z generation, cannot be separated from their digital names. This phenomenon needs to be utilized to use digital-based learning media to increase learning motivation and students' understanding of chemical material. Limitations in the use of digital learning media include inadequate facilities and infrastructure, such as unstable electricity and signals. Additionally, there is digital literacy among teachers, as well as limited knowledge and skills in using technology to support the learning process (Rahma et al., 2023).

METHOD

The method used in preparing this article was to conduct a systematic literature review for data collection. The review focused on the phenomenon of digital-based learning media in the Indonesian education curriculum (*Kurikulum Merdeka*) on chemical bonding materials and included scientific literature in both English and Indonesian from national and international sources during the period 2021 – 2023.

The search was carried out on digital academic databases, including ERIC, Google Scholar, and

Scimago, as well as national literature indexed by Sprott, such as chemistry education literature, science education literature, and science education research literature. The search was then expanded to international literature, such as the International Journal of Instruction, the International Journal of Mobile and Blended Learning (IJMBL), and others.

The first step involved searching for national and international literature using a combination of the following keywords: digital learning media, ICT, chemical bonds, and independent curriculum. The criteria for scientific literature used were limited to recency, with the inclusion of articles published only in the last 3 years (2021-2023), and excluding articles published in proceedings.

The 12 collected literature was reviewed to determine the aims, methods, and results of the literature. This review then linked digital learning media with the curriculum in Indonesia.

RESULT AND DISCUSSION

Based on the results of the review analysis, related to the analysis of digital-based learning methods, there are 2 articles and phenomena regarding digital-based learning media in the Indonesian Education curriculum, there are 10 articles.

3.1 Analysis of Digital-Based Education Methods

The curriculum is a set of subjects in an educational institution that directs the learning and teaching process so that it runs well and is directed. Curriculum is the core of the educational process, whether education is good or bad is determined by the curriculum. Curriculum changes are still often made in education in Indonesia; this is done so that education in Indonesia is in accordance with the needs of students and adjusts to the times. Teachers, as implementers of curriculum development, must carry out their roles properly. The development of the current curriculum, namely the independent curriculum, provides freedom for educational institutions, teachers, and students to innovate, be creative, and independent in the learning process. This provides an opportunity to develop media according to the needs of the era.

3.2 Innovation of Learning Methods in the Advancement of Educational Media in Indonesia

The discovery of various kinds of digital in the community is one manifestation of the existence of major innovations at this time. In addition, technology can be accessed freely and easily. This massive transformation can be felt in all areas of life, one of which is in the field of education. Various innovations have been developed to support the smooth running of the learning process, one of which is the use of learning media. Several researchers have developed digital-based learning media. This digital-based learning media innovation was developed to provide a new style of learning and provide a new atmosphere for students in carrying out learning activities. Chemistry is one of the subjects that students find difficult to understand because there are levels of representation, namely macroscopic, sub-microscopic, and symbolic, where an approach is needed that is able to integrate the three chemical level representations to form a comprehensive understanding. The ability of students is still relatively weak which is caused by several factors due to the lack of chemical representation in macroscopic and submicroscopic forms in visual form and can be caused by a lack of motivation and interest in learning from the students themselves. Several researchers have analyzed digital-based learning media in increasing students' motivation and interest in learning, including the following:

Table 1. Analysis of Digital-Based Learning Methods

No.	Author, Years	Research purposes	Research methods	Research result
1.	Widarti et al., 2022	To analyze the profile of digital literacy needs based on interactive	Qualitative descriptive research method	The results of the study stated that teachers need learning media that can

learning media on the concept of elemental chemistry in high school students

help explain abstract material to be more communicative and interactive, which is expected to increase students' understanding and interest in the material presented.

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| 2. | Rokhim et al., 2022 | To find out the effectiveness of the application of Instagram media on the learning interests of group I and II students in material analysis. | Methods of data collection using qualitative analysis with a descriptive approach. H | The results showed that the Instagram application could effectively increase students' interest in learning group I and II analysis material which was considered problematic. |
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From some of the research analyses above, it can be seen that teachers, as educators and as implementers of this independent curriculum development, are required to have innovations in carrying out the learning and teaching process. Based on research by Widarti et al., 2022 it was revealed that teachers need learning media that can help explain abstract material to be more communicative and interactive, so it is expected to increase students' understanding and interest in the material presented.

3.3 Utilization of Technology as Learning Media in Chemical Bonding Material

Learning media functions in overcoming the limitations of student experience and the limitations of classroom space, thus enabling students to learn flexibly. In addition, learning media will also make it easier for educators to deliver learning material. This convenience is obtained through the use of technology that has experienced development in the present, one of which is learning media in the field of chemistry.

The development of chemistry learning media aims to make it easier for students to receive material about chemical bonds conveyed by educators. In addition, the development of chemistry learning media will also make it easier for educators to process material that will be conveyed to students with media that can make it easier for students to understand the learning.

The impact that is felt from the development of learning media, especially for understanding chemical bonding material, is that the percentage of students who understand chemical bonding material increases, which results from material that can be accessed repeatedly, from anywhere, and at any time (Flexible). The development of learning media itself has been researched and developed by researchers to increase students' interest in learning chemical bonding material, resulting in an increase in student success in understanding chemical bonding material.

Table 2. Digital-Based Learning Media

No.	Author, Year	Title	Research purposes	Research methods	Research result
1.	Awanda et al., 2020	The Implementation of Mind Mapping on Chemical Bond Learning Assisted by Information	To find out the effect of applying mind mapping on chemical bonding learning	This study was a quasi-experimental design with a non-randomized posttest control group	There are differences in student learning outcomes using IT- assisted mind mapping

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| | Technology towards the Students' Learning Outcomes in Class X MIA 1 at SMA Negeri 1 Sindue | assisted by information technology on student learning outcomes in Information Technology Assisted Chemical Bonding subjects | Sampling | learning on chemical bonding material. This can be seen from the posttest average score of each class, namely in the experimental class = 77.12, and in the control class = 67.6. | |
| 2. | Kherul Jefri et al., 2021 | The Effectiveness of 3-D Molecular Visualization Augmented Reality (V- Max) on Students' Achievement and Visualization Proficiency in the Topic of Chemical Bonds | To help students improve the visualization of the topic of chemical bonding through the use of digital technology in 3-D Molecular Visualization Augmented Reality (V-MAX) games. | Using the V-MAX game that uses Game-Based Learning (PBP) has been used in Teaching and Facilitation (PdPc). This study is a quantitative Kemmis and McTaggart's two-cycle action study. The instrument used is a set of Pre-Test and Post-Test questions, Chemistry Bond assignment questions, and student feedback questionnaires. Quantitative data analysis is descriptive in the form of percentages. | Augmented Reality (AR) integrated games that use methods Game-Based Learning (PBP) has had a positive effect on the level of visualization students to the molecules found in the topic of chemical bonds and achievement of marks V-MAX quiz by students. Students also obtained good marks through the assignments given |
| 3. | Wegwerth et al., 2021 | From Abstract to Manipulatable: The Hybridization Explorer, A Digital Interactive for Studying Orbitals | With the increasing use of digital educational media, there is an opportunity to develop new methods to present abstract ideas to provide a more meaningful learning | The author uses interactive software development methods. | The Hybridization Explorer has been designed to make abstract, in this case orbitals, manipulable. From the usage study, it is clear that students |

			experience.		accept the visualization presented in the explorer and find it helpful
4.	Lingga & Pasar Maulim Silitonga, 2022	Application of E-Booklet Media in Learning Chemical Bonds in High School	Aims to measure the learning outcomes of class X SMA PAB 8 Saentis Percut Sei Tuan which is taught between e-booklet media and PPT.	Deep sample This research was done by random sampling technique by lottery. Type The research used is a quasi-experimental design . The data collection technique begins with the preparation stage and the implementation stage.	Based on the results of processing student learning outcomes data, the average value of students' chemistry learning outcomes in experimental class 1 using e-booklet media in the learning process is higher than the value average chemistry learning outcomes of students in experimental class 2 using PPT media in the learning process.
5.	Sundari & Pasar Maulim Silitonga, 2022	Application of Articulate Storyline Interactive Media in Learning Chemical Bonds in High School	Aims to find out whether the learning outcomes of students who are taught by applying interactive media Articulate Storyline are higher than the learning outcomes of students who are taught with the application of PowerPoint media.	Research design The design used is the pretest-posttest design control group design. Which instrument used is a test instrument in the form of multiple choices related to chemical bonding material. Hypothesis testing was carried out using the right-sided T-test for one sample group and	The results obtained in this study indicate that the average learning outcomes of students who are taught by interactive media Articulate Storyline is higher than the completeness criteria minimum. Furthermore, it was found that

			two groups sample.	student learning outcomes were taught with interactive media articulate storyline is higher than student learning outcomes that are taught with PowerPoint media.	
6.	Sitepu & Herlinawati, 2022	Development of Google Sites Web-Based Learning Media on Ionic and Covalent Bond Material for Class X SMA	In a transitional period like now, technology is needed in the learning process, teacher must be able to use learning media by utilizing existing technology that makes it easier for students to learn. learning, the purpose of this research is to analyze google sites web-based learning media developed in chemistry subjects, and the feasibility of google sites web-based learning media developed.	The Google Sites web-based learning media research and development model uses ADDIE learning model. This study uses non-test instruments, instruments non-test in the form of a validation sheet that meets the BSNP standards, namely aspects of content feasibility, presentation, language and graphics by the four-category scale validator.	The feasibility validation results show that the development of google sites learning media on ionic bonding material and covalently in the appropriate category and does not need to be revised with the acquisition of an average value of content feasibility of 3.63; language feasibility of 3.85; presentation feasibility of 3.87; and eligibility graph of 3.74.
7.	Nababan et al., 2023	The Effect of Computational Chemistry-Based Learning Media Using the STAD Type Cooperative Learning Model on Learning Motivation	This study aims to determine whether there is an influence of media use computational chemistry-based learning using the STAD type cooperative learning model on learning motivation on the subject of chemical bonds.	The study used a non-test instrument in the form of a questionnaire consisting of 30 statement. Test the hypothesis using the right-hand T-test, if $t_{count} > t_{table}$ means that H_a is accepted and H_0 is rejected, which means there is an influence on the use of learning media	From the results obtained, namely $t_{count} > t_{table}$ ($3.12 > 1.666$) with this, H_a is accepted and H_0 is rejected, there is an effect of using the media computational chemistry-based learning using cooperative learning models STAD type on student motivation

	in the Subject of Chemical Bonds		based on on the subject of computational chemical bonding chemistry using the STAD type cooperative learning model on student learning motivation.		
8.	Samosir & Nainggolan, 2022	The Effect of Applying NHT Cooperative Learning Type-Based Chemical E-Modules on Class X High School Chemistry Learning	This research aims to: (1) find out whether the increase in student learning outcomes cooperative type NHT-based chemistry e-modules are higher than those of NHT learning accompanied by student reference teaching materials. (2) to find out whether there is an effect of the application of chemical e-modules based on cooperative type NHT on learning outcomes student.	This research is a type of experimental research using a model learning cooperative learning type Numbered Head Together (NHT) through the approach Quantitative analysis was processed statistically in the Microsoft Excel 2010 application. The research used was a quasi-experimental design, which involved experimental and control classes, to determine whether there was an effect of something imposed on the subject studied.	In the hypothesis test, namely the one-sided (right-hand) T-test at a significance level of 0.05 obtained $t_{count} > t_{table}$ ie $3.004 > 2.002$ then H_a is accepted and H_o is rejected. With the cooperative type NHT-based chemistry e-module to students' chemistry learning outcomes in chemical bonding material.
9.	Frailich et al., 2009	Enhancing students' understanding of the concept of chemical bonding by using activities provided on an interactive	To investigate the effectiveness of a web-based learning environment in increasing high school class X students' understanding of the concept of chemical bonding.	This study combines quantitative and qualitative research. The quantitative study consisted of achievement questionnaires administered to the experimental and comparison groups. In contrast, qualitative research includes observation and interviews with students and teachers.	The results obtained from this study are that web-based learning activities that integrate visualization tools with active and cooperative learning strategies provide opportunities for students to build their knowledge of the concept of chemical bonding.

10.	Kuit & Osman, 2021	CHEMBOND3 D e-module effectiveness in enhancing students' knowledge of chemical bonding concepts and visual-spatial skills	This study investigates the effectiveness of the CHEMBOND3D e-module, which integrates a web-based visualization tool, Molview, on chemical bonding concept knowledge and visual-spatial skills between the treatment and control groups.	Pretest-posttest non-equivalent control group with a quasi-quantitative experimental design. A pilot study was conducted to verify the validity and reliability of the CHEMBOND3D Chemical Bond Knowledge Test and the Revised Purdue Visualization Rotation Test. A total of 112 pre-university students from 10 schools in Sabah were selected based on the sampling method.	The results showed a significant increase in chemical bonding concept knowledge and visual-spatial skills for treatment group students who used the CHEMBOND3D e-module compared to control group students who used conventional methods. This provides new evidence of the potential of web-based applications in studying microscopic chemical concepts in chemical bonding.
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From the several studies above, it was found that there were differences in student learning outcomes in chemical bonding material supported by various innovative learning media used. The innovation given aims to provide a new atmosphere for students and provide a separate meaning of learning to students. Existing technological advances are used by teachers as interactive and communicative learning media. Technology that continues to develop has a positive impact on the world of education and helps students and educators in the learning and teaching process.

One of the factors that often causes learning in the classroom to be less effective is the lack of variation applied by the teacher in delivering the material. When the learning process does not go well, this can hinder students' progress in achieving the learning goals that have been set. Therefore, to ensure success in achieving learning goals, it is necessary to use a variety of learning approaches. This includes the application of various appropriate learning models, the use of innovative learning strategies, the introduction of interesting learning methods, and the use of various learning media that are relevant and attract attention (Sundari & Pasar Maulim Silitonga, 2022).

To make learning more effective, it is necessary to pay attention to learning principles such as attention and motivation, activeness, direct involvement, repetition, challenges, and individual differences in interactions between educators and students. The principles of learning for educators can be observed in their behavior in managing and implementing learning, choosing relevant methods and learning media, understanding the characteristics of students, giving assignments and exercises, and assessing and showing the results to students (Damiati et al., 2024).

Several types of effective digital learning media, such as molecular software. Specialized software used in chemistry, such as molecular visualization software, can help students understand molecular structure and chemical bonds in more depth. They can manipulate molecules virtually and visualize chemical bonds from multiple perspectives. Another type of digital learning media, such as interactive websites, can provide in-depth information about the different types of chemical bonds, including examples and applications in everyday life. The website may also offer interactive exercises or quizzes to test student understanding. The development of Google Sites web-based learning media on ionic and covalent bond materials is an example of successful media use in increasing students'

knowledge.

A common problem in studying chemical bonds is difficulty in visualizing the structure of molecules in three dimensions, which interferes with tasks such as describing a molecule and determining molecular geometry. To overcome this problem, digital learning media, such as 3D Molecular Visualization Augmented Reality (V-MAX) and CHEMBOND3D, were used. In the t-statistical test, differences were found between the use of CHEMBOND3D and V-MAX. The use of media has been effective in overcoming learning problems, but there needs to be follow-ups, such as more study guidance and ongoing evaluation.

The application of Virtual Reality (VR) technology in learning media can provide a very interesting and immersive experience in studying chemical bonding materials. Here is how VR works in learning media for chemical bonding materials. In 3D Molecular Simulation, students can “enter” a virtual world where they can see molecules directly in three dimensions. They can interact with these molecules, rotating, enlarging, or shrinking them as desired. For example, they can study the structure of chemical bonds in a particular molecule by looking at it from different angles. Students can also participate in virtual molecular modeling to build molecules from their constituent atoms. They can see how atoms interact and form chemical bonds and how the structure of a molecule affects its chemical properties.

Various digital-based chemistry learning media have been developed and researched for their effect on students. The media was developed by researchers to make it easier to teach material to students, especially chemical bonding material, which is considered difficult for students to understand (Frailich et al., 2009). Interactive learning media is an independent study aimed at achieving certain learning goals, carried out in the field of education. It is presented in digital form using audio, video, animation, and navigation and is designed to help users relate to and support events. Learning media provides a series of online solutions that include four sections: Scientific Conditions, Methods, Objects, and Personalities. Electronic devices can display text, images, animations, and short videos from electronic devices such as computers and telephones. The presence of interactive learning media aims to provide valuable new learning opportunities for students and can further improve understanding of concepts and learning outcomes. Therefore the introduction of electronic modules is accepted and improves student learning. In addition, the electronic module format has been changed with multimedia support, giving students the freedom to choose, integrate, and develop the knowledge they want to learn (Adillah et al., 2023).

Learning media align with the *Kurikulum Merdeka*, where students are required to learn in various ways. The relationship between the *Kurikulum Merdeka* and digital learning media is harmonious, such as the flexibility to study at any time according to their needs, the accessibility of digital learning, which supports the principle of inclusivity in the independent curriculum, the diversity of learning resources, and collaboration and student involvement in learning.

The *Kurikulum Merdeka*, as a new curriculum, requires readiness, including technological adaptation for teachers and students. Teachers must have digital literacy, including mastering the four pillars of digital literacy, to become superior teachers. Digital literacy can no longer be separated from learning. By having sufficient digital literacy, teachers can learn a lot to prepare themselves to implement the *Kurikulum Merdeka* (Ayu Rizki Septiana & Moh. Hanafi, 2022). The use of digital learning media is very dependent on developing technology and the digital literacy of educational actors. *The Kurikulum Merdeka* emerged not because of a change in ministers but rather as an effort to improve the learning system so that students become more able to adapt to current developments. Curriculum changes are very important to ensure that the education provided remains relevant to the demands of the times (Rani et al., 2023).

CONCLUSION

The use of digital-based learning media in the *Kurikulum Merdeka* provides many benefits and receives positive responses from students. Various innovations are outlined in developing learning media to positively impact educators and students, especially on chemical bonding material. The benefits that many students feel based on the results of several studies include increasing student

understanding, increasing student learning interest and motivation, and providing an interactive and fun learning experience. Overall, the use of digital-based learning media on Chemical Bonds material in the Indonesian *Kurikulum Merdeka* can be an effective solution in increasing learning effectiveness as long as it is appropriately implemented and gets adequate support from the school and the government.

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