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GUIDED DISCOVERY LEARNING-BASED CHEMISTRY E-MODULE AND ITS EFFECT ON STUDENTS' HIGHER-ORDER THINKING SKILLS

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ABSTRACT

This study aims to analyze the effectiveness of guided discovery learning-based e-modules in improving senior high school students' higher-order thinking skills. It belongs to quasi-experimental research with a nonrandomized control-group pretest-posttest design. Three schools in Padang, Indonesia, were chosen as the samples through a purposive sampling technique, and experimental and control classes in each school were assigned based on the homogeneity of their previous academic score. Research instruments were a higher-order thinking cognitive test using multiple-choice questions and worksheets in the guided discovery learning-based e-module made for salt hydrolysis, electrolyte and nonelectrolyte solutions, and chemical elements. Students' test scores were analyzed using the N-gain test and independent sample t-test. The results show that students' higher-order thinking skills in the experimental classes were significantly higher than in the control classes. Most students could fill in the worksheets in the e-modules whose problems were made according to higher-order thinking skills criteria. Multiple representations integrated with learning materials in the e-modules helped students understand chemistry concepts. The ordered stages of guided discovery learning integrated with complete and interactive multimedia in the e-modules facilitated students to engage in learning, investigating, and evaluating information to conclude; the attempts to train higher-order thinking skills. Therefore, it can be concluded that guided discovery learning-based chemistry e-module can effectively improve senior high school students' higher-order thinking skills.

Keywords: chemistry e-module; guided discovery learning; higher-order thinking skills

INTRODUCTION

Higher-order thinking skills are one of the important aspects demanded by the national curriculum. The skills can be defined as a transfer of knowledge and skills, critical thinking, and problem-solving (Brookhart, 2010). When students can apply the knowledge and skills they have acquired during learning to a new setting, transfer learning occurs (Anderson & Krathwohl, 2001). Twelve dispositions and eighteen abilities comprise critical thinking, which is reasonable reflective thinking centered on deciding what to believe or do (Ennis, 2015). Problem-solving is cognitive processing to achieve specific goals when no solution method is obvious (Mayer, 1992). Higher-order thinking skills can be taught to students during learning (Yen & Halili, 2015). Learning science, for example, is relevant in improving students' higher-order thinking skills (Roberts & Bybee, 2014; Dragos & Mih, 2015). Developing higher-order thinking is one of the goals of science education (Sriarunrasmee, 2015; Forawi, 2016).

Learning science, including chemistry, is yet challenging for students. Students struggle to understand chemistry concepts such as solubility, electrolysis, reduction-oxidation reactions, chemical equilibrium, and volumetric analysis (Alabi & Nureni, 2016; David, 2019). In addition to generic factors (The textbooks' inaccurate rep-

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resentations, students' prior knowledge, everyday experiences, and confusion regarding scientific and everyday terminology), learning difficulties come from the nature of chemistry and chemical knowledge that involves an understanding of particulate nature and multiple representations (Tumay, 2016). Therefore, students need help from teachers. They require complete and structured assistance to understand chemistry, perform meaningful learning and foster higher-order thinking skills.

Higher-order thinking skills can be developed during learning processes structured through stages in the so-called learning model. Guided discovery learning is one model that can help students develop higher-order thinking skills (Jalmo, 2020). Syntaxes in the guided discovery learning model help students develop higher-order thinking skills like critical and creative thinking. Students are encouraged to be able to respond to the teacher's open-ended and specific questions using this learning model (Kauchak & Eggen, 2012). It expects students to find and plan their ideas by gaining direction from the educator (Janssen et al., 2014). Undoubtedly, guided discovery learning can impact the average students' cognitive values (Lyu & Wang, 2018), increase students' conceptual understanding (Makoolati et al., 2021), and increase learning interests and learning outcomes of the students.

In addition to the model, learning involves the use of teaching materials. One of the complete and structured materials is e-modules. E-modules are more effective than printed books (Aufa et al., 2021). E-modules are practical and user-friendly, letting students learn independently and making learning more interactive (Loibl & Rummel, 2014). E-modules improve students' conceptual understanding and independent learning processes (Kong et al., 2014), critical thinking skills (Garba et al., 2015; Seruni et al., 2020), self-directed learning abilities (Kuhlthau et al., 2015), and learning outcomes (Rahman et al., 2023). Using e-modules that are based on guided discovery learning can improve students' problem-solving and critical thinking (Garba et al., 2015).

Guided discovery learning-based e-modules were developed by researchers on chemical elements (Khaira & Yerimadesi, 2021), salt hydrolysis (Rosanna et al., 2021), chemical equilibrium (Febrila & Yerimadesi, 2021), atomic structure (Putri & Yerimadesi, 2022), acids and bases (Afrilianti & Yerimadesi, 2021), electrolyte and nonelectrolyte solutions (Wildayati & Yerimadesi., 2021). These studies were in the stages of testing the validity and practicality of the e-modules, but the effectiveness testing has not. Empirical findings about the effectiveness of guided discovery learning e-modules in chemistry are essential. By studying the use of e-modules in chemistry learning, we can clarify discipline-specific constraints in chemistry concepts and learning, an attempt to develop practical instructional approaches and make them realistic and meaningful (Tumay, 2016).

This research used guided discovery learning based on e-modules in chemistry learning. The guided discovery learning model syntaxes were adapted from Yerimadesi (2018), consisting of motivation and problem statement, data collection, data processing, verification, and closure. The topics studied in this research were electrolyte and nonelectrolyte solutions, elemental chemistry, and salt hydrolysis. These topics are studied because they have many contexts and applications in our daily lives. To comprehensively understand the topics needs learning activities that involve critical observation in the macroscopic and submicroscopic representations (salt hydrolysis and electrolyte and nonelectrolyte solution) and critical thinking in concluding information in the topic with long and condensed material (elemental chemistry). The aims of the study are 1) to reveal the effect of guided-discovery learning-based e-module on students' higher-order thinking skills and 2) to reveal the activities of students in using these e-modules. The findings of this research are hoped to contribute to the study of effective instructional strategies in chemistry learning.

METHODS

This research is quasi-experimental with a nonrandomized control-group pretest-posttest design (Wilson et al., 2012; Ravid, 2019). This design used a group of research subjects from a population that was not randomly selected (Boslaugh & Watters, 2008; Cohen et al., 2017). The research was conducted in a few senior high schools in Padang, West Sumatra, Indonesia. The sample for this research was selected using a purposive sampling technique using criteria such as computer laboratories, internet connection availability, and the competence of students and teachers in IT. Three schools were selected as the samples. Students in each school's experimental and control classes were selected with cluster sampling, and the homogeneity of students' academic competence in the two classes was assured.

Students in experimental and control classes learned the topics through a guided discovery learning model. The stages of learning in the guided discovery model include motivation and problem presentation, data collection, data processing, verification, and closure. In the motivation and problem presentation, students were directed to observe, read, understand problems, and make hypotheses. Then students were asked to explore and collect information from various resources in the syntax of data collection. In the next stage, data processing, students answered questions and solved problems to find the concepts. Next, in the verification stage, students verify whether the hypothesis they made in the first learning stage is correct. At the end of the closure learning stage, students wrote their conclusion of the topic learned.

One hundred and two students in the experimental classes followed learning through guided discovery learning-based e-modules on electrolyte and nonelectrolyte solutions (36 students), elemental chemistry (30 students), and salt hydrolysis (36 students). Meanwhile, 107 students in the control classes did the stages of guided discovery learning with printed books offered by schools (35 students learned electrolyte and nonelectrolyte solutions, 36 students learned elemental chemistry, and 36 students learned salt hydrolysis). Learning materials given to students in the experimental classes were put in a structured manner in the e-modules. Students also did learning activities (such as reading the information and answering the questions) in the e-modules. Because e-modules are technology-based learning materials, they could contain complete chemical multiple representations and attractive and interactive media for learning. Similarly, students in the control classes learned the materials from the schoolbooks in a structured order. However, they did learning activities in their book.

Both the pretest and posttest were given to students in the experimental and control classes. The tests were suited to the learning objectives of the higher-level cognitive process. The tests were developed as multiple-choice questions and made to fulfill the characteristics of higher-order thinking skills questions. At the end of the development, criteria of the good test items (valid, reliable, difficulty index- and discriminatory power-proper) left 20 questions on electrolyte and nonelectrolyte solutions, 20 questions on elemental chemistry, and 18 on salt hydrolysis (Rosanna et al., 2021; Putri & Yerimadesi, 2022). Examples of the questions are presented in Figure 1.

Electrolyte and Nonelectrolyte Solution

1. Hydrochloric acid (HCl) and glucose ($C_6H_{12}O_6$) are covalent compounds. If the two covalent compounds are dissolved in water, the HCl solution can conduct electricity, while the $C_6H_{12}O_6$solution cannot conduct electricity. Based on the statement above, it can be concluded that the causes of the conditions
   A. HCl is dissolved in water, the ions (H^+ and Cl^-) move freely because they are completely ionized so they can conduct electricity, while $C_6H_{12}O_6$ when dissolved in water the ions are bound because they are not ionized.
   B. HCl is dissolved in water, the ions (H^+ and Cl^-) are bound because they are not completely ionized, so they cannot conduct electricity, while $C_6H_{12}O_6$ is dissolved in water, the ions move freely because they are not ionized.
   C. The number of ions in HCl is more than the number of ions in $C_6H_{12}O_6$ so it conducts electricity.
   D. HCl is a strong electrolyte while $C_6H_{12}O_6$ is a non-electrolyte
   E. All the answers from a, c and d are correct

2. In water solvents, the solute can act as a strong electrolyte, a weak electrolyte, and a nonelectrolyte. The following are solutions of compounds with a concentration of 0.1 M each in water.
   a. C12H22O11(aq)
   b. NaCl(aq)
   c. Na2SO4(aq)
   d. CH3COOH(aq) (Ka = 1.8 x 10-5)
   The order of the electrical conductivity of the four solutions above, starting from the largest is...
   A. (a) > (b) > (c) > (d)
   B. (b) > (c) > (d) > (a)
   C. (c) > (d) > (b) > (a)
   D. (c) > (b) > (d) > (a)
   E. (d) > (b) > (a) > (c)

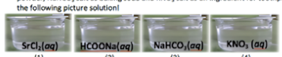
Chemical Elements

1. Consider the following reaction.
   i. Ca(s) + 2H2O(l) → Ca(OH)2(aq) + H2(g)
   ii. 2Ba(s) + O2(g) → 2BaO
   iii. 6K(s) + N2(g) → 2K3N(s)
   iv. 2K(s) + 2H+(aq) → 2K+(aq) + H2(g)
   Based on the above reactions, the correct and appropriate reaction is...
   A. (i) and (ii)
   B. (ii) and (iii)
   C. (i) and (iv)
   D. (iii) and (iv)
   E. (ii) and (iv)

2. A man climbed a mountain. In the middle of the journey, he suddenly felt short of breath and coughed, so he did not decide to continue the journey. Upon further investigation, there were flammable elements that produced gases which could have side effects of shortness of breath and sore throat. Other characteristic of the element is that it oxidizes water into oxygen. What is the element?
   A. Na
   B. Al
   C. Mg
   D. S
   E. ca

Salt Hydrolysis

1. A student doing an experiment on the hydrolysis of salt. She studied four different types of salt with their respective uses. The salts are: $SrCl_2$ salt used to reduce tooth sensitivity, HCOONa salt as a hygroscopic powder, $NaHCO_3$ salt as baking soda and KNO_3 salt as an ingredient for toothpaste. Look at the picture of the following picture solution!



   (1) (2) (3) (4)

   Among the salt solutions above, the salt which when dissolved in water will undergo of anions hydrolysis is....
   A. 1 and 2
   B. B. 1 and 3
   C. 2 and 3
   D. 2 and 4
   E. 3 and 4

2. In one experiment, two bottles labeled A and B contained salt in the form of a white solid. Both contain main group elements and are soluble in water.
   1) Solution A turned blue litmus red
   2) Test on solution B using red and blue litmus showed that the color of the litmus did not change
   3) When solution A was mixed with solution B, a white precipitate occured
   Based on these data, we can conclude that the correct statement about compound A and B is....
   A. Compound A is $(NH_4)_2SO_4$ and compound B is $PbSO_4$
   B. Compound A is $(NH_4)_2CO_3$ and compound B is $Pb(NO_3)_2$
   C. Compound A is $(NH_4)_2SO_4$ and compound B is $BaSO_4$
   D. Compound A is NaF and compound B is $Zn(NO_3)_2$
   E. Compound A is Na_2SO_4 and compound B is $BaSO_4$

Figure 1. Example of Pretest-Posttest Questions on the Topics in This Study

The research data were analyzed using the normalized gain (N-gain) test and the independent sample t-test with the SPSS application. N-gain tests were done to determine the students' concept mastery level. The criteria are high if g is greater than 0.7, moderate if g is less than 0.7 and greater than 0.3, and low if g is less than 0.3 (Hakes, 1999). The independent sample t-tests were done to determine the mean difference between experimental and control classes and the significance of the effect of guided discovery learning-based e-module on students' higher-order thinking skills.

In addition to the test, another instrument in this research was the activity sheet in the e-modules. The e-modules consisted of materials and worksheets. The worksheets were put in the motivation and problem statement stages, data processing, verification, and closure of the guided discovery learning. They were in the form of questions or problems the students must answer. The questions were made accordingly to the materials to achieve learning indicators. Figure 2 displays the appearance of the e-module and the worksheet.

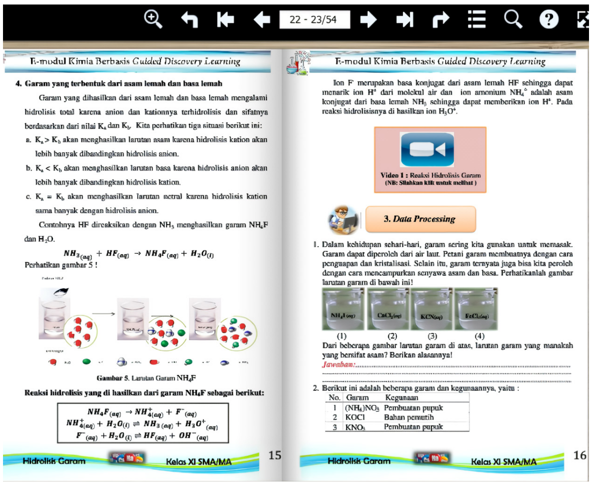


Figure 2. The Module of Salt Hydrolysis and Its Worksheet in the Data Processing Stage

RESULTS AND DISCUSSION

Table 1 presents students' average pretest, posttest, and N-gain scores on the studied topics in the experimental and control classes. The increases in students' learning outcomes are moderate on the three topics in both experimental and control classes.

Table 1. N-gain Description

Topics	Class	Average			
		Pretest	Posttest	N-gain	Category
Electrolyte and nonelectrolyte solutions	Experimental	29.3	73.33	0.61	Moderate
	Control	29.6	67.50	0.53	Moderate
Elemental Chemistry	Experimental	37.36	66.11	0.49	Moderate
	Control	32.43	58.38	0.42	Moderate
Salt Hydrolysis	Experimental	16.98	69.91	0.64	Moderate
	Control	17.29	63.12	0.55	Moderate

Data on students' learning outcomes in the tests were then used in the normality, homogeneity, and hypothesis tests. Firstly, the normality tests were carried out to find out whether the distribution of the data was normal or not. The results of the normality tests are presented in Table 2.

Table 2. Normality Test Description

Topics		Classes	Shapiro-Wilk		
			Statistic	df	Sig.
Electrolyte and nonelectrolyte solution	Pretest	Experimental	.952	36	.086
		Control	.963	35	.258
	Posttest	Experimental	.954	36	.104
		Control	.949	35	.071
Elemental Chemistry	Pretest	Experimental	.522	30	.116
		Control	.613	36	.128
	Posttest	Experimental	.954	30	.194
		Control	.249	36	.098
Salt Hydrolysis	Pretest	Experimental	.452	36	.063
		Control	.713	36	.161
	Posttest	Experimental	.554	36	.121
		Control	.479	36	.055

From Table 2, data from the pretest and posttest in the experimental and control classes on all topics have significance values greater than α level (0.05). Therefore, all of the data are normally distributed. Homogeneity tests were conducted to determine whether the data had the same variance. The results are presented in Table 3.

Table 3. Homogeneity Test Description

Topics	Classes	Levene Statistic	df1	df2	Sig.
Electrolyte and nonelectrolyte solution	Experimental	2.372	1	71	.920
	Control	2.004	1	71	.952
Elemental Chemistry	Experimental	1.272	1	66	.531
	Control	1,504	1	66	.629
Salt Hydrolysis	Experimental	2.283	1	72	.651
	Control	2.544	1	72	.699

As displayed in Table 3, all of the data from experimental and control classes on all topics have significance values greater than α level (0.05). Therefore, they all have homogeneous variances. After normal and homogeneous criteria were met, the hypothesis tests were done through an independent sample t-test on the students' gain scores (difference between pretest and posttest scores) in the experimental and control classes. Table 4 shows the result of the hypothesis tests on the three topics. Table 4 shows significance values smaller than α level (0.05) on the three topics. Therefore, null hypotheses are rejected. The gains of higher-order thinking skills in students in the experimental classes significantly differ from those in the control classes. Students' learning outcomes in the tests of higher-order thinking skills did significantly increase.

Table 4. Results of the Hypothesis Testings

Topics			t-test for Equality of Means			
			Mean difference	t	df	Sig. (2-tailed)
Electrolyte and non-electrolyte solutions	HOTS	Equal variances assumed	-4.15	-1.09	69	.042
		Equal variances not assumed	-4.15	-1.09	69	.034
Elemental chemistry	HOTS	Equal variances assumed	-3.35	-1.38	64	.000
		Equal variances not assumed	-3.35	-1.06	64	.004
Salt hydrolysis	HOTS	Equal variances assumed	-2.65	-2.38	70	.001
		Equal variances not assumed	-2.85	-2.06	70	.000

The activity sheets filled in by the students were graded. Electrolyte and nonelectrolyte solutions have four worksheets. Elemental chemistry has four worksheets, and salt hydrolysis has three worksheets. The scores of students in each worksheet are displayed in Figure 3.

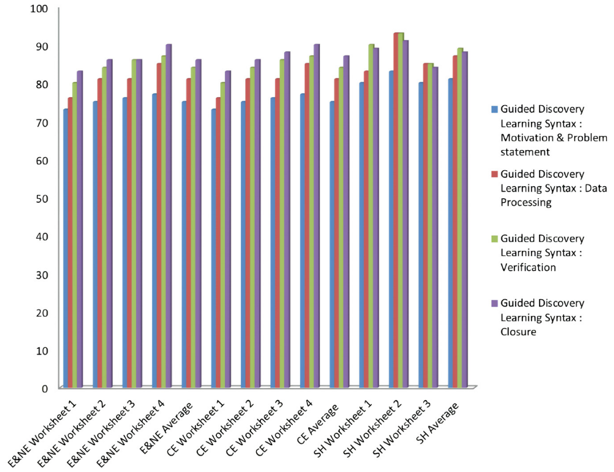


Figure 3. Results of the Analysis of Students' Activity Sheets

On average, for the syntax of motivation and problem statement, students' activities scored 75 on electrolyte and nonelectrolyte solution, 75 on chemical elements, and 81 on salt hydrolysis. For the syntax of data processing, students' activities scored 81 on electrolyte and nonelectrolyte solution, 81 on chemical elements, and 87 on salt hydrolysis. For the syntax of verification, students' activities scored 84 on electrolyte and nonelectrolyte solutions, 84 on elemental chemistry, and 89 on salt hydrolysis. For the syntax of closure, students' activities scored 86 on electrolyte and nonelectrolyte solution, 87 on elemental chemistry, and 88 on salt hydrolysis.

Higher-order thinking skills are needed in the 21st century. With higher-order thinking skills, students understand concepts, apply concepts to different situations, and become more sensitive to problems. Higher-order thinking skills involve specific processes, such as analyzing problems, collecting data, evaluating data, and synthesizing the information to conclude (Chinedu et al., 2015; Zulfiani et al., 2020). These activities align with the stages of the guided discovery learning model used as the basis of e-modules studied in this research. In the guided discovery learning model, teachers provide a stimulus, and students respond by actively engaging in investigations to find the right concept, an attempt to train higher-order thinking skills (Krogman, 2022; Lin et al., 2022).

Students in the experimental and control classes did the stages of guided discovery learning in a structured manner. In the motivation and problem presentation stage, students analyzed arguments, asked questions, answered the questions, and formulated hypotheses based on the information in the e-modules. In the data collection stage, students constructed new concepts or terms by defining terms, considering a definition, and identifying assumptions (Yerimadesi et al., 2019). In the data processing stage, transfer learning happened because students answered and solved problems in a context similar to those previously learned (Anderson &Krathwohl, 2001). In the verification stage, the teacher helped students verify their explanations or conclusions regarding discovering new concepts. In the closure stage, students used strategies to critically evaluate and communicate their answers to their friends. These activities improve basic science skills (Smitha, 2012) and train students' high-order thinking skills during learning (Shieh & Yu, 2016).

As expected, guided discovery-based learning made students in both experimental and control classes increase their scores in higher-order thinking questions in the posttest compared to the pretest. However, the significant difference in students' scores between experimental and control classes shows that it could be caused by the different forms of learning materials given to students in learning. Students in the control classes learned the material from the school textbook. Although complete in the content, the textbooks were lack of chemical representations, structured learning activities, and attractiveness. Students relied on the teachers to progress in the learning process. On the other hand, students in the experimental classes used guided discovery learning-based e-modules that were complete on content and multiple representations, provided organized learning activities, and were attractive and interactive with the students.

As delivered in an electronic form, e-modules could contain more media than what could be put in the printed-out learning materials. For all three topics (electrolyte and nonelectrolyte solutions, chemical elements, salt hydrolysis), contextual examples and static visuals such as pictures and models to represent chemical concepts were attractively, interactively, and comprehensively displayed. Students could zoom in on the visual to make it clear. Animations were added to e-modules to explain chemical concepts at a particular level. This is especially important in understanding abstract concepts (Al-Balushi & Al-Hajri, 2014; Akpinar, 2014), including electrolyte and nonelectrolyte solutions (Wahyuni et al., 2018; Mayresta & Guspatni, 2022) and salt hydrolysis. Videos, mainly of experiments, were included in the e-module of electrolytes and nonelectrolytes. The videos helped students see the macroscopic representations of phenomena (Corredor et al., 2014) that could not always be done in the previous learning, usually due to the limitation of time, tools, and materials to experiment.

Integrating information technology in learning is vital in developing students' thinking skills (DeDonno, 2016). Information technology can advance education. As Al Ruqaishi (2021) stated, it can change students' mindsets to be wiser and more educated. Technology-based learning promotes students' higher-order thinking skills (Edwards, 2016; Ganapathy et al., 2017).

E-modules as technology-based learning materials are beneficial because the modules can contain materials and representations for chemistry concepts that need static and dynamic models to visualize concepts at a particular level and pictures or videos to display phenomena. The so-called multiple representations of macroscopic, submicroscopic, and symbolic representations (Gilbert, 2009) are essential in chemistry learning. Chemical multiple representations guide students' emotions in learning (Pekrun & Loderer, 2020). As seen in the activities and learning processes using e-modules, most students could do the learning independently in all learning stages. In line with Adadan and Ataman (2021), the representations helped students understand the concept. Interactive and complete chemical multiple representations could increase students' curiosity to know more about the concept and continue the learning activities.

The structured teaching materials in the guided discovery learning stages could direct students to discover the concepts and construct their knowledge. Guided discovery learning integrated with the chemical representations in the e-modules increased the critical thinking of the students (Chusni et al., 2022; Kinniburgh, 2022). Additionally, transfer learning, as another term for higher-order thinking skills of the students, also increased based on students' significant gain score in answering higher-order thinking skills questions, which were in the context different from what they learned during learning. In other words, there is a logical reason for how guided discovery learning-based e-modules increase students' learning outcomes in the tests with higher-order thinking skills questions (Ihsan, 2021; Luthfiani & Yerimadesi, 2022).

CONCLUSION

Guided discovery learning-based e-module could improve students' higher-order thinking skills, especially on electrolyte and nonelectrolyte solutions, elemental chemistry, and salt hydrolysis. Students could also do almost all of the learning activities in the e-modules. Teaching chemistry topics with lots of materials and needing multiple representations (especially in the macroscopic and submicroscopic levels) requires multimedia that are complete, interactive, and attractive; those that can be put in technology-based learning materials like e-modules. The structuredness of the guided discovery learning model can be used to engage and direct students in discovering concepts, analyzing information, and making conclusions. These activities facilitate students in enhancing their higher-order thinking skills. Therefore, teachers are expected to combine the completeness of media and the ordered learning structure in learning materials like the guided discovery learning-based e-module.

REFERENCES

Adadan, E., & Ataman, M. M. (2021). Promoting senior primary school students' understanding of particulate nature of matter through inquiry instruction with multiple representations. *Education 3-13*, *49*(3), 317-329.

Afrilianti, N., & Yerimadesi, Y. (2021). Validity and Practicality of Acid-Base E-Module Based on Guided Discovery Learning for Class XI SMA. *International Journal of Progressive Sciences and Technologies (IJPSAT)*, *28*(2), 307–314.

Akpınar, E. (2014). The use of interactive computer animations based on POE as a presentation tool in primary science teaching. *Journal of Science Education and Technology*, *23*, 527-537.

Alabi, T. O., & Nureni, L. (2016). Effects of guided discovery and problem-solving on achievement of secondary school students' in volumetric analysis in Niger State. *ATBU Journal of Science, Technology and Education*, *3*(4), 75-87.

Al-Balushi, S. M., & Al-Hajri, S. H. (2014). Associating animations with concrete models to enhance students' comprehension of different visual representations in organic chemistry. *Chemistry Education Research and Practice*, *15*(1), 47-58.

Al Ruqaishi, S. A. (2021). Factors Influencing Teacher's Engagement. *International Journal of Education, 14* (1), 1-15.

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives* (Complete ed.). New York: Longman.

Aufa, M. N., Rusmansyah, R., Hasbie, M., Jaidie, A., & Yunita, A. (2021). The effect of using e-module model problem-based learning (PBL) based on wetland environment on critical thinking skills and environmental care attitudes. *Jurnal Penelitian Pendidikan IPA*, *7*(3), 401-407.

Boslaugh, S., & Watters, P. A. (2008). *Statistics: A desktop quick reference*. O'Reilly Media, Incorporated.

Brookhart, S. M. (2010). *How to assess higher-order thinking skills in your classroom*. Ascd.

Chinedu, C. C., Olabiyi, O. S., & Kamin, Y. B. (2015). Strategies for improving higher order thinking skills in teaching and learning of design and technology education. *Journal of technical education and training*, *7*(2).

Chusni, M. M., Saputro, S., Suranto, S., & Rahardjo, S. B. (2022). Empowering critical thinking skills on different academic levels through discovery-based multiple representation learning. *Jurnal Cakrawala Pendidikan*, *41*(2), 330-339.

Cohen, L., Manion, L., & Morrison, K. (2017). *Research methods in education*. Routledge.

Corredor, J., Gaydos, M., & Squire, K. (2014). Seeing change in time: Video games to teach about temporal change in scientific phenomena. *Journal of Science Education and Technology*, *23*, 324-343.

David, S. (2019). *Effects of Guided-Discovery and Problem-Solving Teaching Methods on Students' Academic Performance in Financial Accounting in Colleges of Education, North Central, Nigeria* (Doctoral dissertation, Kwara State Univzersity (Nigeria)).

DeDonno, M. A. (2016). The influence of IQ on pure discovery and guided discovery learning of a complex real-world task. *Learning and Individual Differences*, *49*, 11-16.

Dragoş, V., & Mih, V. (2015). Scientific literacy in school. *Procedia-Social and Behavioral Sciences*, *209*, 167-172.

Edwards, L. (2016). Education, Technology and Higher Order Thinking Skills. *Australian Association for Research in Education*.

Ennis, R. H. (2015). Critical thinking: A streamlined conception. In *The Palgrave handbook of critical thinking in higher education* (pp. 31-47). Palgrave Macmillan, New York.

Febrila, P. Z., & Yerimadesi, Y. (2021). Validity and practicality of e-module chemical equilibrium based on guided discovery learning for class XI SMA/MA. *International Journal of Progressive Sciences and Technologies*, *27*(2), 661-666.

Forawi, S. A. (2016). Standard-based science education and critical thinking. *Thinking skills and creativity*, *20*, 52-62.

Ganapathy, M., Singh, M., Kaur, M., Kaur, S., & Kit, L. W. (2017). Promoting Higher Order Thinking Skills via Teaching Practices. *3L: Southeast Asian Journal of English Language Studies*, *23*(1).

Garba, S. A., Byabazaire, Y., & Busthami, A. H. (2015). Toward the Use of 21 st Century Teaching-Learning Approaches: The Trend of Development in Malaysian Schools within the Context of Asia Pacific. *International Journal of Emerging Technologies in Learning*, *10*(4).

Gilbert, J. K. (2009). *Multiple representations in chemical education* (Vol. 4, pp. 1-8). D. F. Treagust (Ed.). Dordrecht: Springer.

Hake, R. (1999). Analyzing change/gain score.

Ihsan A, L. (2021). *Pembuatan E-modul kesetimbangan kimia berbasis android untuk meningkatkan keterampilan berpikir tingkat tinggi siswa kelas XI* (Doctoral dissertation, UIN Sunan Gunung Djati Bandung).

Jalmo, T. (2020). Student Worksheets Based On Discovery Learning Combined With Assessment For Learning Higher Order Thinking Skills (Afl Hots) To Fostering High-Level Thinking Skills Of Students. *The Online Journal of New Horizons in Education*, *10*(1), 69.

Janssen, F. J., Westbroek, H. B., & van Driel, J. H. (2014). How to make guided discovery learning practical for student teachers. *Instructional Science*, *42*(1), 67-90.

Kauchak, D. E., & Eggen, P. D. (2012). *Strategies and models for teachers: Teaching content and thinking skills*. Pearson Higher Ed.

Khaira, U., & Yerimadesi, Y. (2021). Validitas E-Modul Kimia Unsur Berbasis Guided Discovery Learning untuk Kelas XII SMA/MA: Validity of Elemental Chemistry E-Module Based on Guided Discovery Learning for Senior High School. *EPK: Entalpi Pendidikan Kimia*, *2*(1), 47-56.

Kinniburgh, J. C. (2022). *Developing the higher-order thinking skills of middle-school Geography students using Geographic Information Systems (GIS): a study of direct instruction and guided discovery pedagogies and the impact of additional multimedia scaffolding and teacher modelling pedagogies and the impact of additional multimedia scaffolding and teacher modelling.* (Doctoral dissertation, Macquarie University).

Kong, S. C., Chan, T. W., Griffin, P., Hoppe, U., Huang, R., Kinshuk, ... & Yu, S. (2014). E-learning in school education in the coming 10 years for developing 21st-century skills: Critical research issues and policy implications. *Journal of Educational Technology & Society*, *17*(1), 70-78.

Krogman, M. J. (2022). *Social Studies Teachers' Perspectives of Higher-Order Thinking Skills and Their Use in Lessons* (Doctoral dissertation, Northeastern University).

Kuhlthau, C. C., Maniotes, L. K., & Caspari, A. K. (2015). *Guided inquiry: Learning in the 21st century: Learning in the 21st century*. Abc-Clio.

Lin, X. F., Hwang, G. J., Wang, J., Zhou, Y., Li, W., Liu, J., & Liang, Z. M. (2022). Effects of a contextualized reflective mechanism-based augmented reality learning model on students' scientific inquiry learning performances, behavioural patterns, and higher order thinking. *Interactive Learning Environments*, 1-21.

Loibl, K., & Rummel, N. (2014). The impact of guidance during problem-solving prior to instruction on students' inventions and learning outcomes. *Instructional Science*, *42*(3), 305-326.

Luthfiani, A., & Yerimadesi, Y. (2022). Effectiveness of e-module based on guided discovery learning on learning outcomes of high school students. *Jurnal Pijar Mipa*, *17*(6), 770-774.

Lyu, D., & Wang, B. (2018). Effects of the application of computer network technology to guided discovery teaching on learning achievement and outcome. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(7), 3269-3276.

Makoolati, N., Amini, M., Raisi, H., Yazdani, S., & Razeghi, A. (2021). The effectiveness of Guided Discovery Learning on the learning and satisfaction of nursing students. *Hormozgan Medical Journal*, *18*(6), 490-496.

Mayer, R. E. (1992). *Thinking, problem solving, cognition*. WH Freeman/Times Books/Henry Holt & Co.

Mayresta, R., & Guspatni, G. (2022). Effectiveness of Integrated PowerPoint-iSpring Multimedia Prompting Questions on Learning Electrolyte and Nonelectrolyte Solutions Based on Guided Discovery Learning on the Learning Outcomes of Class X High School Students. *Journal of Educational Sciences*, *6*(4), 603-612.

Pekrun, R., & Loderer, K. (2020). Emotions and learning from multiple representations and perspectives. In *Handbook of learning from multiple representations and perspectives* (pp. 373-400). Routledge.

Putri, E. J., & Yerimadesi, Y. (2022). Effectivity of guided discovery learning supported with elemental chemistry e-module on students learning outcomes. *Jurnal Pijar Mipa*, *17*(3), 375-379.

Rahman, L., Silaban, R., & Nurfajriani. (2023, January). The effectiveness of using chemistry e-modules assisted flip pdf professional on improving learning outcomes and motivating students. In *AIP Conference Proceedings* (Vol. 2642, No. 1, p. 090006). AIP Publishing LLC.

Ravid, R. (2019). *Practical statistics for educators*. Rowman & Littlefield Publishers.

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In *Handbook of research on science education, Volume II* (pp. 559-572). Routledge.

Rosanna, D. L., Yerimadesi, Y., Andromeda, A., & Oktavia, B. (2021). Validity and Practicality of Salt Hydrolysis E-Module Based on Guided Discovery Learning for SMA/MA Students. *International Journal of Innovative Science and Research Technology*, *6*(5), 1196-1201.

Seruni, R., Munawaroh, S., Kurniadewi, F., & Nurjayadi, M. (2020, March). Implementation of e-module flip PDF professional to improve students' critical thinking skills through problem based learning. In *Journal of Physics: Conference Series* (Vol. 1521, No. 4, p. 042085). IOP Publishing.

Shieh, C. J., & Yu, L. (2016). A study on information technology integrated guided discovery instruction towards students' learning achievement and learning retention. *EURASIA Journal of Mathematics, Science and Technology Education*, *12*(4), 833-842.

Smitha, V. P. (2012). *Inquiry training model and guided discovery learning for fostering critical thinking and scientific attitude*. Lulu. com.

Sriarunrasmee, J., Suwannatthachote, P., & Dachakupt, P. (2015). Virtual field trips with inquiry learning and critical thinking process: a learning model to enhance students' science learning outcomes. *Procedia-Social and Behavioral Sciences*, *197*, 1721-1726.

Tumay, H. (2016). Reconsidering learning difficulties and misconceptions in chemistry: emergence in chemistry and its implications for chemical education. *Chemistry Education Research and Practice*, *17*(2), 229-245.

Wahyuni, S., Emda, A., & Zakiyah, H. (2018). Pengaruh Penggunaan Media Animasi Pada Materi Larutan Elektrolit Dan Nonelektrolit Terhadap Kemampuan Berfikir Kritis Siswa SMA. *Jurnal IPA & Pembelajaran IPA*, *2*(1), 21-28.

Wildayati, W., & Yerimadesi, Y. (2021). Validitas dan Praktikalitas E-Modul Larutan Elektrolit dan Non Elektrolit Berbasis Guided Discovery Learning untuk Kelas X SMA/MA (Validity and Practicality of E-Module Electrolyte and Non Electrolyte Solutions Based on Guided Discovery Learning for Class X SMA/MA). *EPK: Entalpi Pendidikan Kimia*, *2*(2), 45-54.

Wilson, F. R., Pan, W., & Schumsky, D. A. (2012). Recalculation of the critical values for Lawshe's content validity ratio. *Measurement and evaluation in counseling and development*, *45*(3), 197-210.

Yerimadesi, Y. (2018). *Pengembangan Model Guided Discovery Learning (GDL) untuk Meningkatkan Keterampilan Berpikir Kritis Peserta didik pada*

Pembelajaran Kimia di SMA. Disertasi. Program Studi Ilmu Pendidikan, Pascasarjana Universitas Negeri Padang.

Yerimadesi, Y., Kiram, Y., Lufri, L., Festiyed, F., & Guspatni, G. (2019, October). Validity and practicality of guided discovery learning models for chemistry learning in senior high school. In *Journal of Physics: Conference Series* (Vol. 1317, No. 1, p. 012149). IOP Publishing.

Yen, T. S., & Halili, S. H. (2015). Effective teaching of higher order thinking (HOT) in education. *The Online Journal of Distance Education and e-Learning*, *3*(2), 41-47.

Zulfiani, Z., Suwarna, I. P., & Sumantri, M. F. (2020). Science Adaptive Assessment Tool: Kolb's Learning Style Profile and Student's Higher Order Thinking Skill Level. *Jurnal Pendidikan IPA Indonesia*, *9*(2), 194-207.