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Enhancing Students' Conceptual Understanding and Learning Independence in Chemical Equilibrium using E-Module Based Guided Discovery Learning

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Abstract

Chemical equilibrium is considered abstract so it requires visualization by analogy through electronic modules combined with interactive multimedia teaching materials. This study aims to examine the influence of a guided discovery learning-based e-module on chemical equilibrium on the development of conceptual understanding and self-directed learning among 11th grade science students enrolled in the control and experimental groups. The research framework employed in this study follows a research and development (R&D) model. The participants were selected using the cluster random sampling technique. The e-module, developed based on GDL principles, was administered to 72 science 11th grade students through a quasi-experimental design involving a posttest-only control group. The research employed conceptual understanding test of chemical equilibrium and a self-directed learning questionnaire as data collection instruments. The disparities in conceptual understanding and self-directed learning between the control and experimental groups were assessed using the MANOVA (Hotteling's trace) test. There is a significant difference in both the overall and individual abilities of conceptual understanding and learning independence between students who used electronic modules based on GDL and those who did not, as indicated by simultaneous significance levels of 0.001 and individual significance levels of 0.009 and 0.004, all of which are smaller than 0.05.

Keywords: conceptual understanding, e-module, guided discovery learning, learning independent

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1. Introduction

Chemistry education plays a crucial role in equipping students with the necessary knowledge and skills to understand and navigate the complex world of chemical phenomena (Ristiyani & Bahriah, 2016). Among the challenging topics within chemistry, chemical equilibrium stands out due to its abstract nature and the requirement for students to comprehend concepts at various levels, including the macroscopic, microscopic, and symbolic. Achieving a deep understanding of chemical equilibrium is essential for students to grasp the fundamental principles, laws, and theories that govern chemical reactions (Rakhmawan et al., 2018).

Traditionally, the teaching and learning of chemical equilibrium have relied on conventional methods that may not effectively cater to the diverse learning needs and preferences of students. Some teachers have changed their teaching methods by implementing technology in the classroom as well as the demands of 21st century skills. The use of technology in the classroom has a positive impact on retaining, improving, and engaging students thereby making learning student-centered. However, advancements in educational technology have opened up new avenues for enhancing the teaching and learning process (Luthfiani & Yerimadesi, 2022; Yerimadesi, et al., 2023; Wahyuni, et al., 2022). The integration of technology, particularly guided discovery learning (GDL) and electronic modules (e-modules) holds great potential in improving conceptual understanding and fostering self-directed learning in chemistry education (Handayani et al., 2021).

Conceptual understanding is a fundamental aspect of chemistry education, enabling students to explain and apply scientific concepts accurately. The development of the GDL-based e-module recognizes the importance of conceptual understanding and aims to address the challenges students face in comprehending chemical equilibrium (Wulandari et al., 2018). By adopting a guided discovery approach, students are encouraged to actively explore and discover concepts through hands-on experimentation, problem-solving, and critical thinking. This learner-centered approach empowers students to construct their knowledge, facilitating a deeper and more meaningful understanding of chemical equilibrium.

In addition to enhancing conceptual understanding, the development of the GDL-based e-module also emphasizes the promotion of self-directed learning (Abidin, 2019). Self-directed learning is an essential skill for students to cultivate as it enables them to take ownership of their learning journey, regulate their learning process, and develop lifelong learning skills (Wahyuni, et al., 2022). The interactive and flexible nature of e-modules provides students with opportunities to engage in independent exploration, inquiry, and reflection. By offering a platform that supports self-directed learning, the GDL-based e-module aims to foster students' abilities to actively seek information, analyze data, and develop critical thinking and problem-solving skills (Utami et al., 2022).

The utilization of technology in education has been increasingly recognized for its potential to transform and enhance the learning experience. E-modules, as innovative instructional materials, offer a range of advantages over traditional learning resources. They provide comprehensive coverage of the subject matter, allowing students to access information from multiple sources and engage with interactive multimedia elements. E-modules also offer navigational features, evaluation components, and the integration of supporting software, enabling students to delve deeper into the content and monitor their progress (Asmiyunda et al., 2018; Ikram et al., 2018; Siregar & Harahap, 2020).

The significance of technology in the learning process is further exemplified by the global COVID-19 pandemic, which has necessitated the adoption of remote and online learning approaches. Educational institutions worldwide have faced the challenge of providing quality education while ensuring the safety and well-being of students. The development of the GDL-based e-module aligns with this shift towards digital interventions in education. It recognizes the potential of technology in mitigating the limitations imposed by the pandemic, enabling students to access educational resources and engage in meaningful learning experiences regardless of physical classroom constraints (Razzaq et al., 2018). Self-regulated is a learning activity that takes place more driven by the individual's own will, choice, and responsibility in learning. Students who have good learning independence can regulate their learning style, are active in seeking information, and look for ways to solve obstacles, and they will be more responsible. Students learning independence is still minimal, shown by low learning outcomes because students still learn a lot if they have help from other people (Siagian et al, 2020). The habit of participants who only depend on educators in the learning process results in low students thinking abilities in understanding lessons and low levels of independence that a student has (Sugianto et al, 2020).

Teaching materials in the form of modules can be combined with interactive multimedia teaching materials in the form of electronic modules (e-modules). Based on research, the development of electronic modules has several advantages, including material coverage that encourages users to seek as much information as possible from various sources, is innovative, includes navigation, and evaluation, and is equipped with supporting software (Suarsana & Mahayukti, 2013). Example of developing an electronic chemistry magazine module with the help of a flipbook maker application on reaction rate material (Ramadhan & Linda, 2020). One way for students to understand concepts is by integrating understanding of concepts at three representative levels through the use of technology (Iswara et al, 2017). So, efforts that can be made to make learning more effective are by using interesting teaching materials in the form of innovative modules to increase understanding of concepts and self-regulated.

By developing a GDL-based e-module on chemical equilibrium, this research seeks to contribute to the advancement of chemistry education and the effective integration of technology in enhancing conceptual understanding and promoting self-directed learning. The outcomes of this study will provide valuable insights into the design and implementation of technology-enhanced instructional materials, facilitating more effective and engaging learning experiences for students in the realm of chemistry education.

2. Research Method

This research model is research and development. The product produced in this research is an electronic module based on guided discovery learning. This development research aims to develop an electronic module based on guided discovery learning on chemical equilibrium material that can increase conceptual understanding and the level of learning independence of students at the senior high school level. In line with this approach, a quasi-experimental method was employed, specifically utilizing a posttest-only control group design. This design allowed for a comparison of learning outcomes between an experimental group exposed to the guided discovery learning-based e-module on chemical equilibrium and a control group that did not receive the intervention. The variations in the learning activities implemented in the experimental and control groups can be seen in Table 1.

Table 1. Learning Stages in the Experimental and Control Groups

Learning Stages	Experimental Group	Control Group
Initial Stage	Opening, an apperception is presented with images or videos in the module, and motivation is given.	Opening, an apperception is presented with images or videos in a PowerPoint, and motivation is given.
Main Stage	Utilizing an electronic module integrated with the stages of the guided discovery learning model (stimulus, problem statement, data collection, data processing, and verification).	Without electronic modules, learning is carried out through the implementation of the scientific approach aided by PowerPoint, worksheets, and printed books.
Final Stage	Engaging in the process of reviewing the learning, drawing conclusions, conducting assessments, and assigning tasks.	Seeking clarification on unfamiliar subject matter, conducting assessments, and assigning tasks.

The methods and implementation design employed in this study can be seen in Table 2.

Table 2. Quasi Experiment Method with Post Test Only Control Group Design

Groups	Treatment	Post-test
Experimental	X_1	O_1O_2
Control	X_2	O_1O_2

Description :

X_1 : Learning using electronic modules based on guided discovery learning.

X_2 : Conventional learning with the scientific 5M approach (aided by PowerPoint, worksheets, and printed books).

O_1 : A questionnaire on learning independence.

O_2 : Concept comprehension questions.

The study took place at SMAN 1 Kalasan during the months of November and December 2021, specifically in the 11th grade of the academic year 2021/2022. SMAN 1 Kalasan was chosen as the research site due to the implementation of the 2013 curriculum and the availability of smartphones for both students and teachers to operate the e-modules.

As for the test subjects at the implementation stage, they were selected by appointing a school and selecting two classes randomly using the cluster random sampling technique at the school. Cluster random sampling is a regional sampling technique used to determine samples if the object to be studied is very large. The target population of this study was all students of 11th grade natural science in Yogyakarta who had the same characteristics as students of 11th grade natural science SMAN 1 Kalasan. The research sample consisted of two 11th grade at SMAN 1 Kalasan, they natural science four class as the experimental group (learning using electronic modules based on guided discovery learning) and the natural science 2 class as the control group (conventional learning with the scientific 5M approach aided by PowerPoint, worksheets, and printed books).

The first activity involved gathering information through interviews conducted with chemistry educators in of 11th grade mathematics and natural science at SMAN 1 Kalasan. Subsequently, the experimental and control sample learning classes were selected, syllabi were developed, and lesson plans (RPP) were created for both the experimental and control classes. Concept comprehension questions and a questionnaire on learning independence were also prepared. The concept comprehension question indicators were developed based on the aspects of concept comprehension outlined by Schwedler & Kaldewey (2020), Swedeer et al. (2019), Andaman & Tan (2018), Kiryak & Calik (2018), Yaman et al. (2019), Anderson & Lorin (2010), and Kilpatrick et al. (2003), resulting in indicators for concept comprehension, which is identification, comparison, and generalization.

Furthermore, the questionnaire on learning independence was designed by developing indicators of learning independence based on the aspects of learning independence as described by Cukurova et al. (2018), Hockings et al. (2018), Martin & Evans (2018), and Shah et al. (2020). This process resulted in indicators for learning independence, which are autonomy, motivation, self-confidence, and responsibility. The obtained data were subsequently analyzed descriptively and quantitatively, presenting the assessments in the form of percentages.

During the classroom research phase, learning was conducted according to the prepared lesson plans (RPP) in the selected classes for the study, they are class of 11th grade natural science four was the experimental group, and mathematics natural science two was the control group. The learning process consisted of four sessions and concluded with a post-test. Throughout the learning activities, student engagement was observed through Zoom and WhatsApp groups.

Learning independence was assessed through a questionnaire completed by the students, providing quantitative data. The questionnaire consisted of 40 questions that were theoretically tested beforehand. The self-regulated questionnaire can be seen in Table 3. The Likert scale is a scale presented in several groups of items, which is favorable (positive) items and unfavorable (negative) items. Favorable items are items that contain behavioral concepts that support the attribute to be measured, while unfavorable items are items whose contents contradict or do not support the behavioral characteristics desired by the learning independence indicator.

Table 3. Self-regulated Questionnaire

No	Indicator	Number	
		(+)	(-)
1.	Discipline in carrying out tasks	8,13,35	18,23,28
2.	Study time management	5,20	17,34
3.	Self-evaluation	33,37,40	16,39
4.	Interest in learning	6,25,38	21,3
5.	Trying to get information	12,29	36
6.	Responsible for carrying out tasks	22,27,31	4,9,14
7.	Learning goals	26	19
8.	Self-confident	1	11,24,32
9.	Don't depend on other people	10	2,7,15,30

In this research, the hypothesis was evaluated using the MANOVA statistical analysis technique. Before conducting the hypothesis testing, it was necessary to verify the prerequisite conditions for the hypothesis. The study aimed to assess the disparities in concept comprehension and learning independence capabilities between the control and experimental groups. These differences were quantified using the MANOVA method, specifically employing Hotteling's trace as the statistical measure.

In this research there are two hypotheses tested. The first is H0, there is no significant difference in concept comprehension and learning independence, both collectively and individually, among students who use electronic modules based on guided discovery learning on chemical equilibrium compared to those who do not.

The second is H1, there is a significant difference in concept comprehension and learning independence, both collectively and individually, among students who use electronic modules based on guided discovery learning on chemical equilibrium compared to those who do not.

The data analysis for the MANOVA test involved assessing the significance level with a threshold of < 0.05. If the significance value is less than 0.05, the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted. This indicates a significant difference in concept comprehension and learning independence between students who utilize electronic modules based on guided discovery learning and those who do not use electronic modules based on guided discovery learning.

3. Result and Discussion

This research was conducted in both the control group and the experimental group. In the control group, no electronic modules based on guided discovery learning for chemical equilibrium were distributed. Following the completion of the learning sessions in both the control and experimental groups, a concept comprehension test was administered as the final step. Subsequently, a learning independence questionnaire was administered in the subsequent meetings. The visual representation of the electronic module based on guided discovery learning for chemical equilibrium can be seen in Figure 1.


04 Kegiatan Belajar: Penerapan Kesetimbangan Kimia dalam Industri

4.1 *Stimulus*

Gambar 2. Proses Pemupukan

Pupuk urea ($CO(NH_2)_2$) merupakan bahan kimia yang terbentuk melalui reaksi NH_3 dengan CO_2. Amonia digunakan dalam pembuatan bermacam-macam monomer yang mengandung nitrogen untuk industri nilon, polimer-polimer akrilat, dan busa poliutretan. Amonia juga digunakan dalam industri farmasi, macam-macam bahan organik, anorganik, detergen dan larutan pembersih, pupuk, dan bahan peledak (TNT atau trinitrotoluena).

Dasar teori dari reaksi sintesis amonia dan uji laboratorisnya merupakan penelitian **Fritz Haber** (1908). Usaha pengembangan proses Haber menjadi proses besar-besaran. Usaha tersebut merupakan tantangan bagi insinyurinsinyur kimia pada saat itu. Hal ini karena metode tersebut mensyaratkan reaksi kimia dalam fasa gas pada suhu dan tekanan tinggi dengan katalis yang sesuai. Pekerjaan ini dipimpin oleh Carl Bosch di Badishe Anilin and Soda Fabrik (BASF). Pada tahun 1913, pabrik beroperasi dengan produksi 30.000 kg NH_3 per hari. Pabrik amonia modern saat ini mempunyai kapasitas 50 kali lebih besar.

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Figure 1. Module Electronic Content

A summary of the descriptive analysis results for concept understanding and learning independence scores in the control group presented in Figure 2 and experimental group is presented in Figure 3. In terms of mathematical procedural skills, students taught using the electronic module based on guided discovery learning for chemical equilibrium exhibited higher performance compared to those taught using the conventional model. Thus, descriptively, it can be concluded that the electronic module based on guided discovery learning in the teaching of chemical equilibrium has a positive impact on concept comprehension and learning independence.

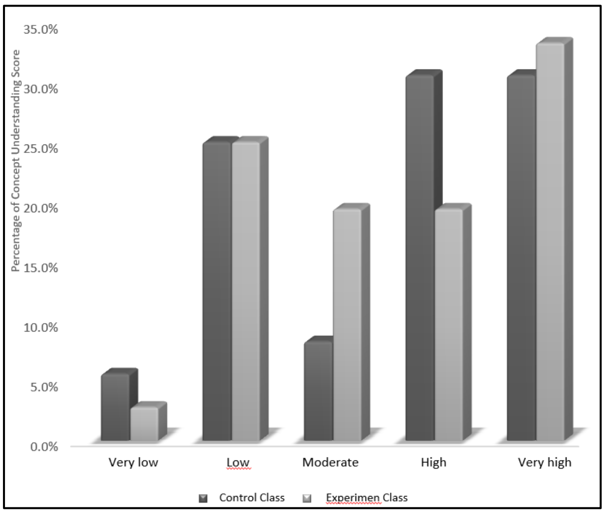

Figure 2. Distribution of Categories of Concept

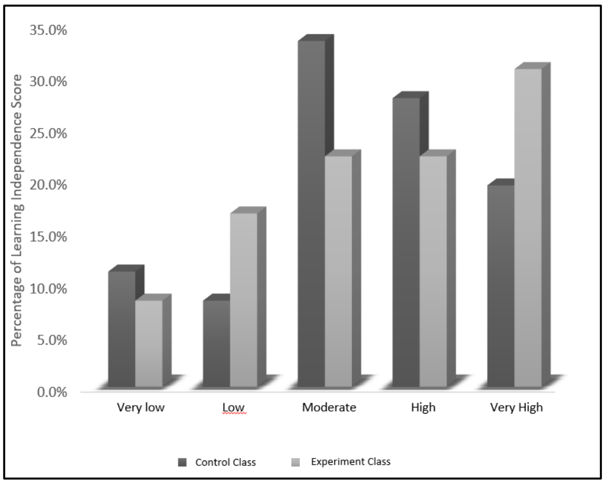

Figure 3. Distribution of Independent Learning

The data analysis employed in this study was MANOVA analysis. Before conducting the MANOVA analysis, several assumptions needed to be satisfied, which are the assumptions of normality, homogeneity, and correlation among the dependent variables. The normality of data distribution was tested using the Shapiro-Wilk test at a significance level of 5% (α = 0.05). The results of the normality test are presented in Table 4.

Table 4. The Result of Normality Test

Variables	Groups	Shapiro-Wilk		
		Statistic	df	Sig.
Concept understanding	Control	0.952	36	0.117
	Experimental	0.953	36	0.128
Independent learning	Control	0.956	36	0.164
	Experimental	0.958	36	0.183

The homogeneity of covariance matrices in this study was tested using Box's M test. The variables tested for homogeneity were concept understanding questions and the learning independence questionnaire. The obtained Box's M value was 3.551, with an associated F value of 1.147 and a significant value of 0.328. Since the significance value is greater than 0.05, the data can be considered homogeneous.

There is a linear relationship between each pair of dependent variables for each independent variable. This can be observed in Figure 4, which displays scatter plots indicating the linearity between the dependent variables.

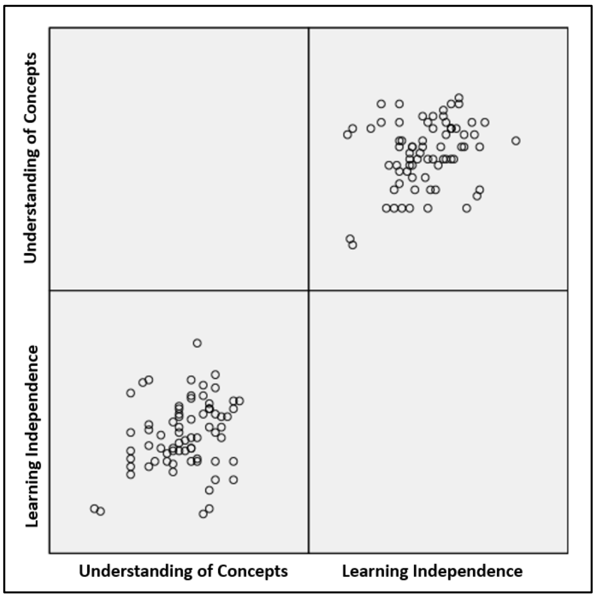

Figure 4. Scatterplot of the Dependent Variable's Linear Relationship

There is a linear relationship between each pair of dependent variables with the groups of independent variables. Based on the test of linearity, with a value of 0.143, it can be concluded that there is a linear relationship in each dependent variable because the significance value is greater than 0.05 (0.143 > 0.05). In this study, Pearson correlation was used for the correlation analysis. The results of the correlation analysis can be seen in Table 5.

Table 5. The Result of Correlation Test

		C_U	I_L
C_U	Pearson Correlation	1	0.416
	Sig.(2-tailed)		0.000
	N	72	72
I_L	Pearson Correlation	0.416	1
	Sig.(2-tailed)	0.000	
	N	72	72

The result obtained from the correlation analysis is a Pearson correlation value of 0.416. This indicates a moderate relationship between concept understanding and learning independence. The significance value obtained is 0.000, which is smaller than 0.05. This indicates a positive relationship between concept understanding and learning independence among the students. The results of the MANOVA test for this hypothesis can be seen in the following Table 6.

Table 6. The Result of Manova Test

Effect		Value	Sig.	Partial Eta Square
Intercept	*Pillai's Trace*	0.994	0.000	0.994
	Wilks's Lambda	0.006	0.000	0.994
	Hotteling's Trace	162.786	0.000	0.994
	Roy's Largest Root	162.786	0.000	0.994
Groups	*Pillai's Trace*	0.197	0.001	0.197
	Wilks's Lambda	0.803	0.001	0.197
	Hotteling's Trace	0.246	0.001	0.197
	Roy's Largest Root	0.246	0.001	0.197

Based on the results of the MANOVA test in Table 6, a significance value of 0.001 was obtained. The significance value of the MANOVA test is smaller than the significance level of 0.05 (0.001 < 0.05), and Hotelling's trace value is 0.246. This indicates that the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted, suggesting a simultaneous difference in concept comprehension and level of learning independence among students who use guided discovery learning-based electronic modules compared to those who do not use such modules in the topic of chemical equilibrium. The difference in concept comprehension and learning independence between the control and experimental groups is influenced, in part, by the learning resources used. The control group solely utilized a chemistry textbook as the learning resource, while the experimental group used guided discovery learning-based electronic modules.

The electronic module based on guided discovery learning has differences from existing modules, which the GDL learning module, especially on the stimulus stages for each chemical equilibrium material is presented in varied forms in the form of videos, two-dimensional images, and examples of chemical equilibrium. Participant Students can study chemical equilibrium practical material through video demonstrations presented on electronic modules during the pandemic. The presentation layout and the display of electronic modules on each page increase students' interest in the learning process using electronic modules. Chemical equilibrium electronic module based on guided discovery learning has user-friendly characteristics as indicated by instructions and explanations. Information to assist users in the use of electronic modules includes ease of user response and use of simple language as well as easy to understand.

The implementation of electronic modules based on guided discovery learning can transform passive learning conditions into active and creative ones, shifting from teacher-oriented to student-oriented learning (Kumalasari, 2015). For example, in the guided discovery learning-based electronic modules, problems are presented through videos or animated images that are relevant to daily life in the experimental class.

The differences in concept understanding and level of learning independence obtained indicate that the use of guided discovery learning-based electronic modules influences students' concept understanding and level of learning independence. The magnitude of the influence provided by guided discovery learning-based electronic module instruction, as indicated by the partial eta squared value, is 0.197. This value corresponds to a high category, or it can be concluded that the use of guided discovery learning-based electronic modules has a significant impact on students' concept understanding and level of learning independence, accounting for 19.7% of the variance.

This is relevant to research conducted by Shahrul & Muladi (2018), where students who used electronic modules showed a learning independence score of 82.04% because they were able to understand information and problems presented in videos, audio, and images. Android-based learning media, such as interactive online modules, assist students due to the repeated access to learning materials provided by electronic modules. Students are also provided with group discussion exercises, which can enhance their concept comprehension more effectively (Metz et al., 2020). Furthermore, electronic modules that incorporate stimuli from everyday phenomena can improve students' concept comprehension and serve as a self-learning activity (Al Mamun et al., 2020).

The results of the univariate analysis of students' concept understanding can be seen in Table 7.

Table 7. The Result of the Univariate Test of Students' Concept Understanding

Variable	Sig.	*Eta Square*	Description
Concept Understanding	0.009	0.093	There is a difference

Based on the hypothesis testing results presented in Table 7, a significance value of 0.009 was obtained. This significance value is smaller than the significance level of 0.05 (0.009 < 0.05). Consequently, the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted. The analysis indicates that there is a simultaneous difference in concept comprehension abilities between students who used electronic modules based on guided discovery learning and those who did not, in the context of chemical equilibrium.

The difference is attributed to the use of electronic modules based on guided discovery learning, which encourages students to actively seek various learning resources to solve problems. This active engagement leads to an increase in concept comprehension as students acquire and absorb a wealth of knowledge. In contrast, in the control group, where only textbook materials were used, the learning experience became more monotonous as students solely relied on the instructional materials provided by the teacher without exploring other sources. The implementation of electronic modules based on guided discovery learning, which emphasizes student participation, has been found to enhance concept comprehension. This finding is consistent with the research conducted by Herawati & and Muhtadi (2018), which showed a significant difference in concept comprehension before and after using interactive electronic modules. The electronic modules incorporate multimedia elements such as videos, hyperlinks, text, images, tables, and animations, which increase students' enthusiasm for learning. The use of technology in online learning clarifies concept delivery, enhances motivation, and promotes interaction among students and between students and teachers. Clear concept explanations help avoid misinterpretation (Singh & Turman, 2019). Students responded positively during the product trial, expressing that the electronic modules were engaging and helpful in understanding concepts, with an overall response rate of 84.48%. Consequently, students were able to comprehend the material, gather information, and analyze problems (Handayani et al., 2021). The results of the univariate test for student learning independence can be seen in Table 8.

Table 8. The Results of the Univariate Test

Variable	Sig.	*Eta Square*	Description
Independent Learning	0.014	0.084	There is a difference

Based on the results of the test of the between-subject effect in Table 8, a significance value of 0.014 < 0.05 was obtained, indicating a difference in the level of learning independence among students in classes that used electronic modules based on guided discovery learning compared to those that did not. The significance value indicates that the use or non-use of electronic modules based on guided discovery learning has a different effect on the level of learning independence among students.

This finding is consistent with the research conducted by Lu'luilmaknun & and Wutsqa (2018), which found that students using e-learning media with the guided discovery method achieved higher average scores in learning independence compared to students who only received instruction using the guided discovery method. This indicates that e-learning with the guided discovery method is effective in promoting students' learning independence. Cho et al. (2017) reported that self-directed learners have a stronger conceptual understanding and achieve positive affective outcomes. The use of electronic modules can stimulate students' learning independence because learning with e-modules can be conducted anytime and anywhere (Rifa'i, 2019).

4. Conclusion

There is a significant difference in both the overall and individual abilities of conceptual understanding and learning independence between students who used electronic modules based on guided discovery learning and those who did not, as indicated by simultaneous significance levels of 0.001 and individual significance levels of 0.009 and 0.004, all of which are smaller than 0.05. The effective contribution percentages of the electronic modules based on guided discovery learning in chemical equilibrium towards the overall conceptual understanding and learning independence are 19.7%, and individually, 9.3% and 8.4% respectively.

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