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Development of Interactive E-Modules Based on POGIL (Process Oriented Guided Inquiry Learning) on Stoichiometry Material in Senior High School

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Abstract: This research aims to produce a POGIL-based interactive chemistry e-module for chemistry learning in chapter stoichiometry or chemical calculation. This type of research is Research and Development (RnD) and the Borg and Gall development model. The subjects of this research were XI grade high school students. Product validation was carried out by material and language and media experts. The application used is Flip PDF Professional. The product trial was conducted at SMAN 71 Jakarta. The results showed that: (1) Expert assessment related to material aspects amounted to 85% with good interpretation, language aspects 85.83% good interpretation, and media aspects 82.21% good interpretation. (2) Assessment by teachers on a small and large scale as a whole increased, namely 94.91% on a small scale and 99.22% on a large scale with very good interpretation, and assessment by students as a whole also increased, namely 82% on a small scale and 83.50% on a large scale with good interpretation. It can be concluded that the e-module developed is very good and feasible to use as teaching material in the classroom and the students' independent learning process.

Keywords: Chemistry electronic module; Flip Book; Interactive; Stoichiometry; Critical Thinking

Introduction

The teaching and learning process generally relies on textbooks from schools (Hardiansyah & Mulyadi, 2022; Roemintoyo & Budiarto, 2021). However, on the other hand, teachers and students also expect supporting teaching materials, especially technology-based ones. The learning process using module including in electronic form can increase students' interest in learning, learning outcomes, and critical thinking (Pigai & Yulianto, 2024). In addition, the use of e-module, especially on materials that are considered difficult by students, is needed for the learning process. Stoichiometric material in chemistry includes calculations, concepts, laws, and formulas that are considered difficult by most students but need to be mastered in the chemistry learning process (Diana et al., 2016; Gulacar et al., 2013).

This is because, if there are difficulties that are not resolved in understanding stoichiometry material, it has the potential to hinder understanding in learning other chemical materials (Anwar et al., 2023). Efforts to facilitate an independent and learner-centered learning process continue to be developed so that the teaching materials used are in accordance with curriculum demands and consider needs. 21st century learning which also leads to innovation and optimal utilization of technology, especially with the existence of electronic module that can support learning to make it more interesting, reduce dependence on teachers, and provide

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convenience in learning every competency that must be (Sugianto et al., 2017; Susanti et al., 2022).

The presence of learning with e-module is also expected to be an effort to facilitate meaningful learning processes and improve critical thinking skills, which is one of the 4 21st century learning competencies (Kirana, 2023; Sari & Sugiyarto, 2015). This is due to the interesting visualization in the e-module that can help students understand the material more easily (Adawiyah et al., 2021; Enawaty, 2023; Uz et al., 2019).

Preliminary and needs analysis conducted at SMAN 71 Jakarta and SMA Muhammadiyah 11 Jakarta involving 73 student respondents by filling out questionnaires and interviews with chemistry teachers, found that: 1) Most students have difficulty in understanding chemistry materials, one of which is stoichiometry because learning often only uses textbooks from schools and teacher presentation displays. 2) The causes of difficulties in the chemistry learning process are concepts that are difficult to understand, the material needs to be memorized, the material is too much, and the existing learning resources are less interesting. 3) The textbooks provided are not easy to understand. 4) The textbooks used are not available in digital form and are easily accessible. 5) Learners feel happy if there are teaching materials or learning resources that are interesting, can be accessed digitally, and support the learning process independently anywhere. 5) 43 out of 73 students think that stoichiometry material is material that is difficult to understand quickly.

Based on this background, the researcher developed an interactive e-module in the form of a flip book on stoichiometry material. It is hoped that the implementation of this product can improve critical thinking skills and become an attractive and innovative alternative teaching material for the learning process (Purnamasari et al., 2024; Seruni et al., 2020). The advantage of e-module as teaching materials to be developed is the presentation of a systematic summary of the material. In addition, the presentation in the e-module is also equipped with images and pop ups, and practicum videos and practice questions that are expected to help students understand chemical material well through audio visual.

The selection of effective learning methods can be used as an alternative solution in an effort to solve the above problems. Effective learning methods according to experts are learning methods that emphasize the process of gaining knowledge (learning based on constructivism) and linking knowledge with real experiences in everyday life (Hanson, 2006).

One of the learning methods based on constructivism that Moog has developed is the *Process Oriented Guided Inquiry Learning* (POGIL) method. The process-oriented guided inquiry method emphasizes cooperative learning, students working in teams, designing activities to build cognitive abilities (conceptual understanding), and developing skills during the learning process such as the process of science, thinking skills, problem solving, communication skills, management, building positive social attitudes and self-assessment skills that can develop metacognitive knowledge (Hanson, 2006).

Based on the references and problems obtained during observation, the author believes that it is necessary to conduct development research with the title "Development of interactive e-module based on POGIL *(*Process Oriented Guided Inquiry Learning*)* in improving students' critical thinking skills on stoichiometry material in high school.

Method

This research is a *Research and Development* (R&D), which is a process used to develop and validate products used in learning, using the Borg and Gall model development method (Borg & Gall, 2007). The development research conducted consists of several stages starting with conducting a needs analysis, continuing with the development process, and ending with a trial.

The product to be produced is a POGIL (*Process Oriented Guided Inquiry Learning*) based chemistry e-module in the form of a flipbook. Flipbook is a digital book display with a series of images that vary gradually from one page to the next, so that when the page changes quickly, images appear to animate by simulating movement or some other changes. The main type of software used to create this e-module is Flip Professional.

The trial phase was conducted at SMAN 71 Jakarta. The results of the validation questionnaire are in the form of a percentage of feasibility obtained based on a Likert scale. Electronic module teaching materials are said to be feasible if the results of the validation value provide a percentage ≥ 61%.

The rating scale used in this research instrument is adopted from Puskurbuk (Center for Curriculum and Bookkeeping) using 10 levels, as in Table 1.

Table 1. Descriptive Interpretation with Rating Scale

Score	Interpretation
1	Very Poor
2	Very Poor
3	Less
4	Less
5	Less
6	Good

Score	Interpretation
7	Good
8	Good
9	Very Good
10	Very Good

The collected data is processed by summing, comparing with the expected amount and obtaining a feasibility percentage (Sugiyono, 2019) with the Formula 1.

$$\% = \frac{(\Sigma \text{ score obtained})}{(\Sigma \text{ maximum score})} X\ 100\% \quad (1)$$

The results of the calculation of the percentage of feasibility are categorized according to the interpretation using a rating scale as in Table 2.

Table 2. Descriptive Interpretation of Quality with Rating Scale

Percentage %	Interpretation
0-29	Very poor
30-59	Less good
60-89	Good
90-100	Very good

The development of this e-module is made using the Flip Professional application through the following flow.

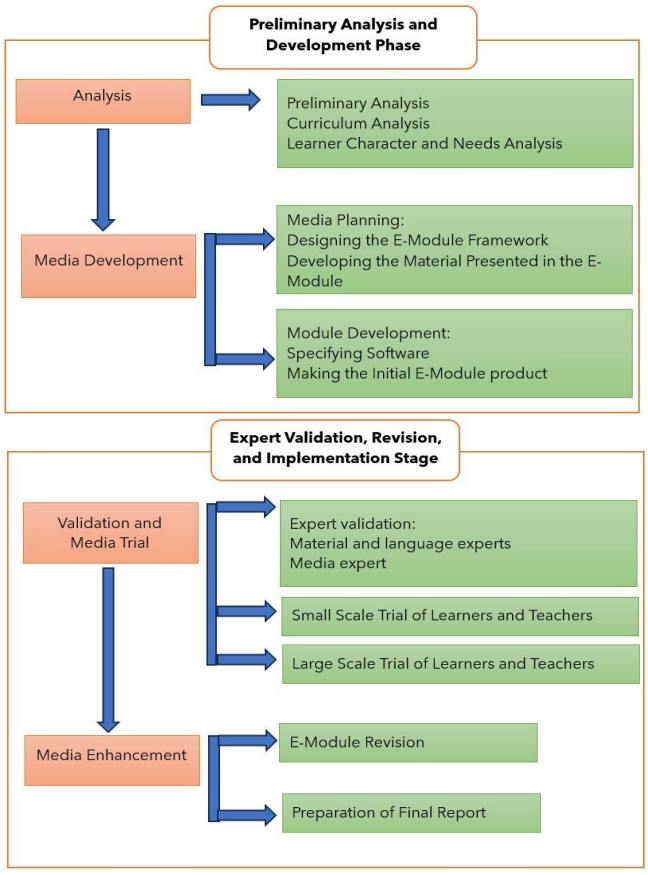


Figure 1. Flow of e-Module Development

Result and Discussion

The Flip Professional application has the advantages of a very attractive appearance, complete navigation, the effect of flipping digital module is more real, and the video display is clearer (Setianingrum et al., 2022). The following are some page views on the POGIL-based chemistry e-module.

Needs Analysis

The needs analysis was conducted at SMA Negeri 71 Jakarta and SMA Swasta Muhammadiyah 11 Jakarta. The needs analysis stage was carried out by distributing questionnaires to teachers and students of class XI IPA. From the results of the needs analysis (need assessment) of students obtained data as much as 89% of 73 students need teaching materials that are innovative, easy to understand, and facilitate the learning style of students. Then, 80.8% of students are interested in the use of learning module, and 93.2% need digital module or e-module that are practical by containing text, images, audio, and supporting videos, and 82.2% of students need e-module in supporting the process of learning chemistry independently.

As for the results of interviews with chemistry teachers at these schools, information was obtained that so far teachers have mostly used textbooks provided by schools as teaching materials in learning, rarely using module, especially interactive e-module, while stoichiometry material is one of the topics that is not easily accepted by students just like that and teachers feel they need alternative teaching materials that can be used in delivering learning. Therefore, it is necessary to develop teaching materials such as interactive e-module so that they can make it easier for students to undergo the learning process for the learning process, support students to learn independently, and improve current learning skills including critical thinking skills (Alya & Dwiningsih, 2024; Rahmatsyah & Dwiningsih, 2021).

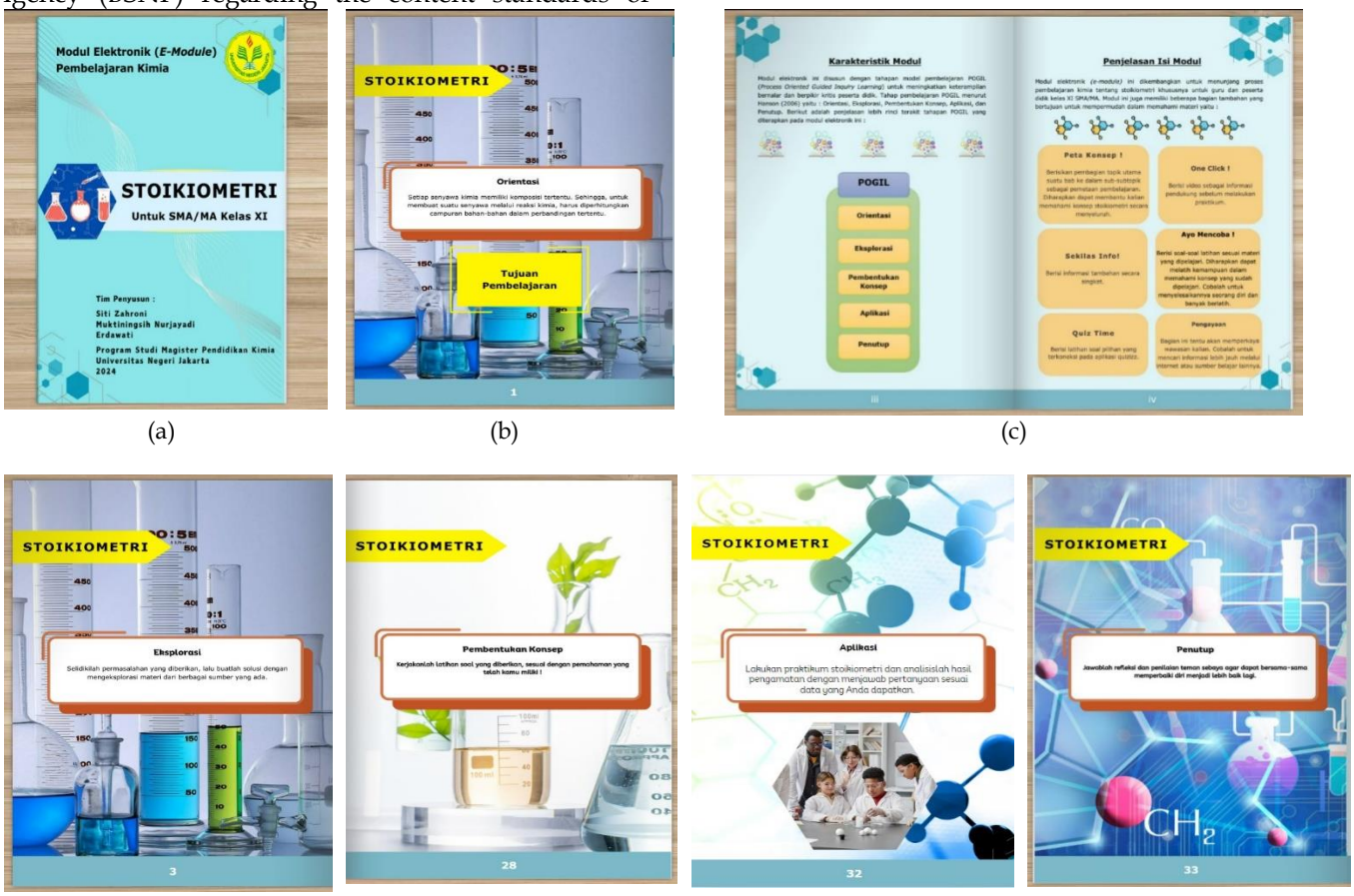
Analysis of Teaching Material Development

Before developing the product, researchers analyzed the curriculum and material of stoichiometry. This aims to determine the content of the material in the teaching materials to be developed in the module. The curriculum to be developed is the Merdeka Curriculum.

This Merdeka Curriculum in Phase F - Class XI students are expected to be able to apply mathematical operations in chemical calculations which are then derived in several learning objectives, namely explaining the meaning of stoichiometry, equalizing reaction equations, using the concept of moles in calculations, determining molecular formulas and empirical formulas, determining limiting reagents, calculating the percent yield of a chemical reaction,

understanding stoichiometry in everyday life (Amalia et al., 2025).

The content of the e-module is adjusted to the provisions of the National Education Standardization Agency (BSNP) regarding the content standards of teaching materials in terms of material, presentation techniques, completeness of presentation and language, and is equipped with interactive multimedia such as pop up images, quizzes, animations, and learning videos.



(a) (b) (c)

(d) (e) (f) (g)

Figure 2. Display of e-module: (a) cover page; (b) orientation stage page; (c) content characteristics and POGIL steps on the e-module; (d) Exploration stage page; (e) Concept formation stage page; (f) Application stage page; (g) the closing stage page

Teaching Material Trial Analysis

This stage consists of the initial product trial stage and the field trial stage. The teaching material trial aims to obtain an assessment of the electronic module teaching material products produced. There are three teams that are the subjects of the development research product trials, namely a team of material, language, and media experts as well as students and teachers both on a small and large scale.

Material Trial

Indicators of material aspects consist of material coverage, material accuracy, skills, suitability for students. The results of validation of material aspects from experts on electronic learning module (e-module) are presented in Table 3.

Table 3. Results of Material Aspect Validation on Electronic Module

Indicators	Percentage (%)	Interpretation
Coverage of the material	85.0	Good
The accuracy of the material	90.0	Very good
Skill in presenting the material	82.5	Good
Suitability with students	82.5	Good
Average Percentage	85.0	Good

Judging from the percentage above, it shows that the results of the trial of teaching materials based on the validation of a team of material experts based on 4 indicators, namely material coverage, material accuracy,

skills in presenting material, and suitability for students have shown a good interpretation with an average of 85%.

Language Trial

Indicators of language aspects consist of communicative, motivating ability, straightforwardness, coherence and conciseness, conformity with language, use of terms with symbols. The results of the validation of language aspects from experts on electronic learning module (e-module) are presented in Table 4.

Table 4. Results of Language Aspect Validation on Electronic Module

Indicators	Percentage (%)	Interpretation
Communicative	85.00	Good
Motivating ability	85.00	Very good
Directness	85.00	Good
Coherence and order	90.00	Very Good
Conformity with language	85.00	Good
Use of terms with symbols/signs	85.00	Good
Average Percentage	85.83	Good

Judging from the percentage above, it shows that the results of the trial of teaching materials based on the validation of a team of linguists based on 6 indicators, namely communicativeness, motivating ability, straightforwardness, coherence and conciseness, compatibility with language, use of terms with symbols or symbols have shown a good interpretation of 85.83%.

Media Trial

The assessment of the media expert team was carried out to test the feasibility and obtain an assessment and input from the e-module in two main aspects. First, the cover aspect, namely the cover layout (design), cover typography (the letters used are attractive and easy to read, simple), and cover illustration aspects (content). Second, the design aspect is the layout of the e-module content (consistent, placement and appearance of elements, accelerating understanding), typography content (simple, easy to read, facilitates and clarifies understanding, and creates attractiveness) used in e-module teaching materials.

The results of the analysis of the trial or validation of the e-module media obtained from the expert expert team are shown in Table 5.

Table 5. Results of Media Aspect Validation of E-Module

Indicators	Percentage 1 (%)	Interpretation 1	Percentage 2 (%)	Interpretation2
Cover design	82.50	Good	81.25	Good
Cover typography	80.00	Good	88.30	Good
Cover illustration	80.00	Good	80.00	Good
Content layout	80.00	Good	86.00	Good
Content typography	79.40	Good	84.70	Good
Average Percentage	82.21	Good	84.05	Good

Judging from the percentage in Table 3, it shows that the results of the trial of teaching materials based on the validation of a team of media experts based on 5 indicators, namely design, typography, and cover illustrations as well as layout and typography of content have shown a good interpretation, namely the average interpretation 1 and 2 of 82.21%.

Teacher Trial

Teacher trials were conducted in two stages, namely small-scale and large-scale teacher trials. The teacher trial aims to obtain an assessment of the teaching materials in the form of electronic module (e-module) produced. This is because teachers are users as well as facilitators of teaching materials. The results of the small-scale trial analysis became the evaluation material for the product revision or improvement process before proceeding to the large-scale trial stage. The results are presented in Table 6.

Table 6. Results of Module Test Analysis for Teachers

Indicators	Small Scale %	Interpretation	Large Scale %	Interpretation
The suitability of the substantive content with the competencies that must be achieved by students.	100	Very Good	100	Very Good
Clarity of information	92.8	Very Good	96.4	Very Good
Language	95.8	Very Good	100	Very Good
Audio and visual display	93.8	Very Good	100	Very Good
The usefulness of	91.7	Very Good	95.8	Very Good
Relevance of material substance with POGIL base - Orientation	100	Very Good	100	Very Good
Relevance of material substance with POGIL base - Exploration	87.5	Good	100	Very Good
Relevance of material substance with POGIL base - Concept Discovery	100	Very Good	100	Very Good
Relevance of material substance with POGIL base - Application	100	Very Good	100	Very Good
Relevance of material substance with POGIL base - Closing	87.5	Good	100	Very Good
Average Percentage	94.91	Very Good	99.22	Very Good

The results of the analysis of the module trials on teachers on all indicators in the small-scale trial showed a very good interpretation with an average of 94.91%, although some indicators did not get a perfect percentage due to some input. However, after making revisions or improvements, the percentage results on the large-scale trial on various indicators have shown a very good interpretation with a higher percentage, namely an average of 99.22%.

Learner Trial

Student trials are conducted because they are students who will use teaching material products in the learning process. This stage is divided into two stages, namely small-scale and large-scale student trials. The results of the module trial on students are listed in Table 7.

Table 7. Results of Module Trial Analysis for Students

Indicators	Small Scale %	Interpretation	Large Scale %	Interpretation
Quality of materials, experiments, and questions	84.01	Good	84.53	Good
Language	82.26	Good	84.66	Good
Audio and visual display	82.46	Good	82.95	Good
Implementability and software engineering	81.45	Good	84.47	Good
Usability	81.79	Good	84.31	Good
Relevance of material substance with POGIL base - Orientation	82.26	Good	82.20	Good
Relevance of material substance with POGIL base - Exploration	82.26	Good	82.95	Good
Relevance of material substance with POGIL base - Concept Discovery	81.45	Good	82.95	Good
Relevance of material substance with POGIL base - Application	80.64	Good	83.33	Good
Relevance of material substance with POGIL base - Closing	81.45	Good	82.70	Good
Average Percentage	82.00	Good	83.50	Good

The results of the field trial results on students both small and large scale show that the electronic module teaching material product (e-module) has received a good assessment with an average of 82.00% on a small scale and 83.50% for a large scale.

Based on the results of the analysis of trials that have been conducted on material, language, and media experts, as well as teachers and students, it can be concluded that the Process Oriented Guided Inquiry Learning (POGIL)-based e-module teaching materials on grade XI stoichiometry material developed in this study are said to be good. This is indicated by the results of the trial with a percentage of more than 70% in each instrument indicator. Thus the purpose of this study to produce and test the feasibility of e-module electronic teaching materials on grade XI stoichiometry material has been achieved.

Conclusion

The research on the development of stoichiometric electronic module (e-module) that refer to the Merdeka Curriculum has gone through several stages of research, namely the needs analysis stage, the teaching material development stage, and the teaching material trial stage to a team of material, language, media experts, and field tests to teachers and students. The process of developing this teaching material uses Canva-Pro and Flip PDF Professional software. Canva-Pro for the e-module design process and Flip PDF Professional for making e-module into interactive flip books. The developed learning module contains module characteristics, explanation of module content, instructions for using learning outcomes concept map learning objectives 7 learning activities of stoichiometry sub-materials, case study enrichment summaries, exercise questions, quizizzes, learning reflections, bibliography, glossary, author profile, and also equipped with pop up images and learning videos. The results of the teaching material trial based on the validation of the material expert team have shown a good interpretation of 85%, teaching material have shown a good interpretation of 85.83%, team of media experts, have shown a good interpretation, namely the average interpretation 1 and 2 of 82.21%, the field trial results on teachers on both small and large scales have received very good assessments with an average of 94.91% on a small scale and 99.22% for a large scale, and also the field trial results on students had received a good assessment with an average of 82.00% on a small scale and 83.50% for a large scale. The results of the product trial stated that the stroichiometry electronic module (*e-module*) produced was suitable for use in the learning process.

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This research article was collaboratively authored by Siti Zahroni, first author, Erdawati, second author, and Muktiningsih Nurjayadi, corresponding author. The authors contributed to creating interactive electronic module (e-module) of stoichiometry, conducting research, analyzing data, and writing the article. All authors thoroughly reviewed the findings and approved the final manuscript.

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Conflicts of Interest
The authors declare that they have no conflict of interest.

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