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Development of E-Modules Based on Multi-representations in Solid-State Physics Introductory Subject

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Abstract

This study also aims to produce e-modules based on multi-representations in solid-state physics introductory subjects with good validity and practicality. The products produced are in the form of e-modules in the form of 3D flipbooks, including video, animation, sound, flash, and hyperlinks. This study uses the Rowntree development model. This model has three stages, planning, development, and evaluation stage. In the evaluation phase, Tessmer formative evaluation used, which consist of 5 stages, self-evaluation, expert review, one-to-one evaluation, small group evaluation, and field test. In the expert review stage, the average results of evaluations from experts obtained at 4.6 or 92.2% with a very valid category. The one-to-one evaluation stage found that the average result of the student questionnaire's impression on the use of teaching materials was 89%, with the category very practical. At the small group evaluation trial stage, the average score of the students' questionnaire assessment towards the use of teaching materials was 93.48% (very practical category). Based on the assessment that has been done, the e-module (electronic module) based on a multi-representation in solid-state physics introductory subject has been successfully developed with good validity and practicality.

Keywords: Research and development; e-module; multi-representation; introduction of solid-state physics

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INTRODUCTION

Human civilization is in the 4.0 industrial revolution with the mastery of technology as one of the keys to facing this era in this 21st century (Hartini, Misbah, Dewantara, Oktovian, & Aisyah, 2017; Syahputra, 2018). The industrial revolution 4.0 marked by automation and digitalization in various fields. In the field of education characterized by the existence of this learning model does not require lecturers and students to be in the same place (Dewantara, Misbah, & Wati, 2020; Dewantara, Wati, Misbah, Mahtari, & Haryandi, 2020), and increasingly varied choices of learning resources available. This situation exists with the availability of electronic books (e-books),

ease of access to digital applications such as e-libraries, e-forums, e-journals, and so on (Ghofur & Kustijono, 2015).

Meanwhile, there are many other ways to utilize technology as a learning resource, one of which is an e-module (Sugianto, Ade, Siscka, & Yuda, 2013). E-modules can be interpreted as electronic modules, non-printed, and only in the form of files that can be opened with the help of electronic media such as tablets, smartphones, PC, and other electronic media based on operating systems, especially Android (Riyadi & Qamar, 2017). A form of presentation of teaching materials that contain animation, audio, navigation, links, and videos can be called an electronic module (e-module) (Gunawan, 2010). E-modules can be opened and read either through a computer or smartphone with the required application. E-modules created with various features and degrees of complexity electronically should be able to encourage students to achieve learning objectives by loading material, organized methods, and evaluations that arranged systematically (Priyanthi, 2017).

Introductory solid state Physic is one of the compulsory subjects that students must take at one of The Teacher Training Institute. This subject aims to make students able to have a view and master knowledge about crystal structure, diffraction of x-rays by crystals, crystal bonds, free electrons in crystals, energy band theory, and semi-conductor materials and can apply them as to the development of science and technology. In presenting their preliminary concepts, the solid-state in Physics can be expressed using more than one representation (Aulia, Ismet, & Zulherman, 2016). Waldrip, Prain, & Carolan (2010) stated that representation represents, illustrates, or symbolizes objects and processes.

Previous research on teaching materials in the form of electronic modules on the quantum physics theme has been conducted by Hidayat, Suyatna, & Suana (2017). Hill, Sharma, & Johnston (2015) also stated that learning with online modules can improve students' understanding of concepts. The use of e-modules can improve students' learning independence (Hapsari & Suyanto, 2016), learning outcome (Herawati & Muhtadi, 2018; Imansari & Sunaryantiningsih, 2017), critical thinking skills (Suarsana, 2013) and problem-solve (Utami, Nugroho, Dwijayanti, & Sukarno, 2018). The use of e-modules in the learning process will foster creativity and productive thinking habits and create active, innovative, and enjoyable conditions in the learning process (Budiarti, Nuswowati, & Cahyono, 2016). Digital teaching materials will be needed to support student lecturing activities, and teaching materials are not yet available. With electronic teaching materials, students will be more interested in independent learning (Ramadhan, Dewa, P.N., & Agus, 2014).

Therefore, researchers try to develop teaching material in the form of e-modules based on multi-representation. This study also aims to produce e-modules based on multi-representations in solid state physics introductory subject with good validity and practicality.

METHOD

This study is a research and development which produces E-Modules Based on Multi-representations in Solid State Physics Introductory Subject. This e-module used by students Physics Education Study Program covering crystal structure-based multi-representation. The research and development model adapts the Rowntree development model (Prawiradilaga, 2015). The flow of research can be seen in Figure 1.

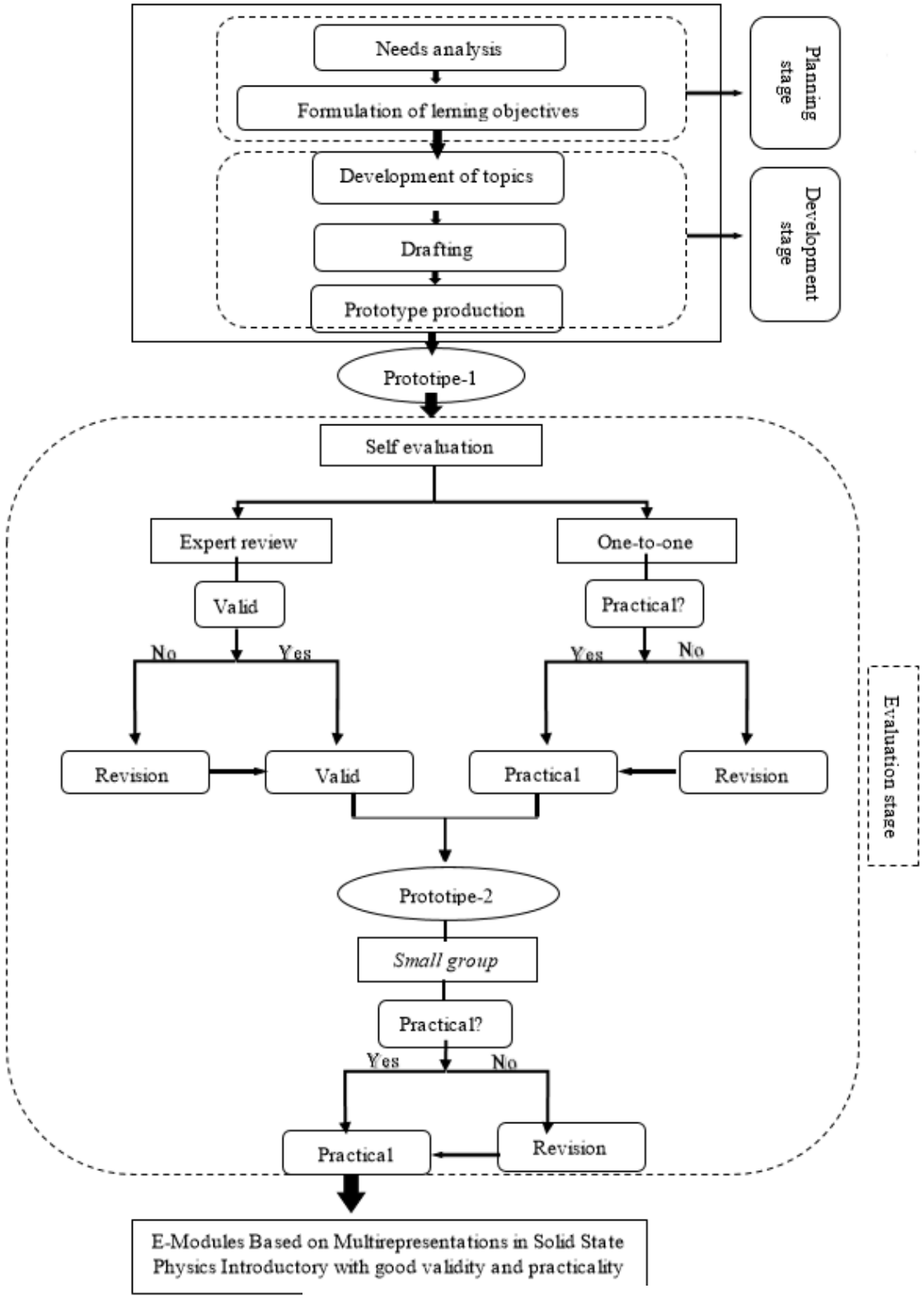

Figure 1 The flow of research

Figure 1. The flow of research

The results of the validation from the pre expert are then analyzed and calculated as a percentage. Then the results are grouped according to categories as shown in Table 1.

Table 1 Final Score Categories based on Expert Validation

Percentage (%)	Category
86 ≤ EVR ≤ 100	Very Valid
70 ≤ EVR ≤ 86	Valid
56 ≤ EVR ≤ 70	Less Valid
0 ≤ EVR≤ 56	Invalid

EVR : Expert Validation Result

(Wiyono, 2015)

The questionnaire used to determine students' opinions about the practicality of the product and improve the quality of products produced in the previous stage. The use of the questionnaire carried out during one-on-one evaluation trials and small group evaluations. The data obtained is calculated as a percentage, then grouped according to the categories shown in Table 2.

Table 2 Categories of Practical Values

Percentage (%)	Category
86 ≤ HEOS ≤ 100	Very Practical
70 ≤ HEOS < 86	Practical
56 ≤ HEOS < 70	Less Practical
0 ≤ HEOS < 56	Not Practical

HEOS : One To One And Small Group Evaluation Results

(Wiyono, 2015)

RESULTS AND DISCUSSION

This research resulted in e-modules based on multi-representation for solid-state physics introductory subject in the theme of crystal structure for physics education students. E-module contains crystal structure material that is packaged as attractive as possible and equipped with video, audio, simulation, hyperlinks, and interactive questions.

The development method carried out by adjusting the Rowntree product development model using Tessmer's formative evaluation technique, which consists of self-evaluation, expert review, one-to-one evaluation, small group evaluation, and field tests. However, because the purpose of the study is only to get teaching materials that are valid and practical so that it does not reach the stage of the field test. Products that have been developed can be seen in Figure 2.

Figure 2 Cover e-module developed

Planning Stage

Based on the needs analysis, it found that e-modules based on multi-representations in solid-state physics introductory course needed to be developed. Based on (1) the solid-state Physics introductory subject based on multi-representation teaching materials in electronic form, this is not yet available. (2) Students are still experiencing difficulties in

understanding the concepts in the solid-state physics introductory subject because their microscopic and abstract studies require simulations and videos to help students. (3) along with the development of the industrial revolution era 4.0, it needed to teach materials that can adjust to the development of more advanced and all-electronic technology.

Development Stage

Based on the syllabus and materials that have been determined, then developed a topic by outlining the content of teaching materials in the form of material structure in the chapter of the crystal structure. The teaching materials consist of the general crystal concept, such as the definition of crystal, crystal lattice geometry; the atomic packing fraction of the crystal; examples of simple crystals in everyday life.

Furthermore, drafting also was done by determining the points to be elaborated in the material, such as a preface, table of contents, study instructions, the structure of the material, introduction, standard content, sample questions, summary, practice, and reference reading, video, audio, and hyperlink.

Evaluation Stage

Prototype-1 which has been developed then get in the self-evaluation stage by the researcher and is consulted with experts so that it gets some suggestions for improvement, namely; (1) some buttons that do not work correctly; (2) use of sentences in the introduction; (3) development of the image of the arrangement of atoms in the crystal; (4) consistency in the use of pictures in representing crystal defects; 5) add information on some of the most popular solid-state producing areas currently which is known as agate. Prototype-1 and evaluation tools that have been declared good and approved by experts. Then the researchers conducted an expert review stage. the results of the evaluation by experts can be seen in Figure 3.

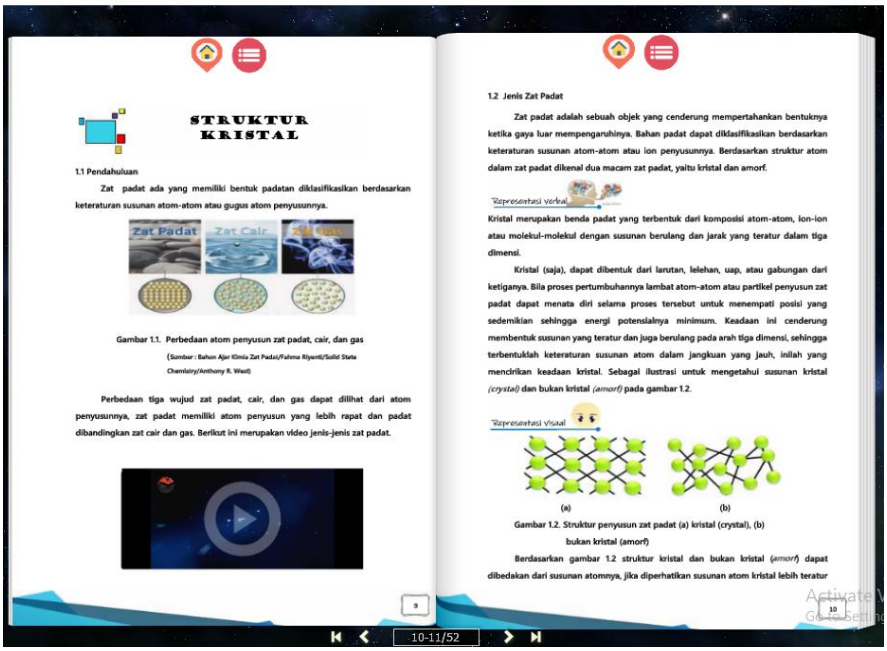

Figure 3 E-module layout based multi-representation

At this stage, prototype-1 is evaluated and validated by experts to determine the design validity of the e-modules that have been developed. The results of the validation of the design aspects that have been done are 92.2%. These results indicate that e-modules are declared to be very valid for general e-module criteria, which include the order of presentation, completeness of information, use of fonts, layouts, illustrations, drawings, simulations, and display designs. The results and some suggestions from the validator can be seen in Table 3 and Table 4.

Table 3 Expert comments and suggestions on prototype-1

Expert review	**Aspects**	**Comments and suggestions**
Validator	Design	1. The title of the cover is fixed in accordace with the contents of the material. 2. Improve the competency term with learning outcomes. 3. Make the image display can be enlarged. 4. Correct the order after practice questions, answer keys then formative tests. 5. Tests should be made to be able to give feedback.

Table 4 Presentation of expert validation results

No	**Indicator**	**Percentage**
1	The order of presentation	100,0 %
2	Completeness of information	86,0 %
3	Use of fonts	100,0 %
4	Pictures, videos. Audio and website links	80,0 %
5	Lay out	90,0 %
6	Illustrations, images, animations and graphics	100,0 %
7	Display design	90,0 %
	Percentage of total	91,6 %

Table 4 shows that the e-module developed was declared valid. This indicates that the products produced following the theory, focus on aspects of content, the format of learning tools are adequate in the design of the display, packaging, use of fonts and product components with each other consistently related to each other. This is similar to what Haviz (2014) states that learning products concluded to be valid if they are developed based on adequate theoretical aspects, appearance aspects, and format aspects. The validator's conclusion states that prototype-1 is worth testing.

E-module has been developed according to curriculum demands. Besides, that e-module can motivate students in lectures. Because e-modules developed, they have been adapted to the level of technological development and are equipped with multiple representations to help students understand the crystal structure's concept.

Furthermore, the researcher also conducted a one-to-one stage with three students. The aim is to see the practicality of prototype-1 from the user's perspective through a questionnaire of student responses to the use of prototype-1. Overall, all three students gave positive responses with an average rating of 89% in the very practical category. Comments and

suggestions about one-to-one results were then corrected to get prototype-2 teaching materials. The practical category here means that the E-modules developed are easy to use by users both by lecturers and students in understanding the material and geometric shapes of crystal structures.

Prototype-2 was then tested in the small group evaluation stage with nine students from the 2016 Physics Education Study Program. They were divided into three groups to follow the learning process using prototype-2. At the end of the learning process, students will fill out their questionnaire about the product. The average value of student responses is 93.48%, with a very practical category.

The results of one-to-one and small group evaluations can be seen in Table 5.

Table 5 One-to-one and small group results

No	Indicator	Percentage	
		One-to-one	***Small group***
1	Benefits to add insight	100%	95%
2	Completeness of information	93%	91%
3	Providing motivation	93%	93%
4	Effective and clear use of language	80%	93%
5	Clarity of instructions for using multi-representation based e-modules	86%	95%
6	Use of fonts: types and sizes	93%	93%
7	Lay Out	90%	94%
8	Video and link	80%	95%
9	Display design	90%	91%
	Percentage of total	89%	93%

Table 5 shows that the developed e-module is practical. E-module developed can be useful because the percentage of student response questionnaire results are at intervals $86 \leq HEOS \leq 100$. Furthermore, e-modules developed are practical because they provide benefits to students. Some of them are a) e-modules used can foster student enthusiasm in studying crystal structures because students given a visual display of crystals, b) e-modules help students understand the concept of crystal structure because it equipped with multiple representations, video simulations, and interactive questions c) e-modules are practical and easy to use because they have been adapted to technological developments. E-modules can be used as an alternative learning resource integrated with various electronic advantages in packaging material content (combined with images, animations, videos, and simulations). They can be accessed anytime and anywhere with the internet network (JH, 2018). The existence of e-modules is beneficial in the learning process, e-modules make students more enthusiastic in learning videography and make it easier for students to understand the material more quickly and effectively in lessons (Priatna, Putrama, & Divayana, 2017). Electronic modules make students active and independent in the learning process (Asmiyunda, Guspatni, & Azra, 2018; Putra, Wirawan, & Pradnyana, 2017). Based on the explanation and analysis of the research results, it was found that the e-module developed product was valid and practical.

CONCLUSION

In this study, it can be concluded that it has been successfully developed an e-module based multi-representation of solid-state physics introductory subject with valid and practical. This e-module can be an alternative to the solid-state physics introductory subject in Physics Education Study Program at the Sriwijaya University. It can be implemented in the field trial phase to determine its effectiveness.

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