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Development of STEM-Based Digital Handouts for Nuclear Physics Introduction Courses During the Covid-19 Pandemic

Murniati[1]*, Apit Fathurrohman[1], Yurindah Letari[1]

[1] Physical education, Universitas Sriwijaya, Indralaya, Palembang, Indonesia

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Abstract: The Covid-19 pandemic has caused changes in the world educational system. The pandemic caused a rapid transition from face-to-face lectures to online lectures. The times of the Covid-19 pandemic or what is often called "the New Normal", are still ongoing today. Online lectures are expected not to reduce the Program Studi's Graduate Learning Outcomes (GLO) of a course or not to reduce competencies that must be mastered by students. Lecturers as course supervisors must try to facilitate the student learning process with valid, and easy-to-use teaching materials. To meet the needs of these students, first, we must know the student's responses to the teaching materials, so that it can facilitate independent learning in students during these pandemic times. This research is developmental research that aims to produce digital handouts that can be accessed via cellphones or laptops and can be accessed both online and offline situations. The development model chosen in this research is the Rowntree model with Tessmer formative evaluation. The data was obtained through online questionnaires created in the google form and given to lecturers or students. The results showed that 100% of students had difficulties in learning nuclear physics introduction materials independently and 86% of them requested that the teaching materials should be provided with pictures, animations, and videos. Based on the needs analysis above, we develop a valid and practical STEM-based digital handout teaching materials about nuclear physics introduction.

Keywords: Development; Digital handouts; Introduction to Nuclear Physics

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Introduction

Lectures that were originally carried out in face-to-face manners on campus were changed to online lectures/e-learning to prevent the spread of Covid-19 (Harahap et al., 2021). Online learning is carried out without involving face-to-face directly in class, but by using media and infrastructure available on each campus (Sijabat et al., 2020). By utilizing existing technology, online learning is a flexible method of learning, it is a method that can be done anywhere and anytime by utilizing an adequate internet network. The media or platforms commonly used by lecturers in online learning are e-learning, Zoom, Google Meet, Google Classroom, Telegram, Youtube, and so on (Winangun, 2020).

Teaching materials can be interpreted as an arrangement that is made systematically of materials that have been collected from various learning resources (Prastowo, 2012). Teaching materials must contain the criteria. Knowledge. In the learning process knowledge includes: (1) Facts, it means everything that is in the form of reality and truth, including the names of objects, historical events, symbols, places name, names of people, names of parts or components of an object and so on; (2) Concepts, it means everything in the form of new meanings that can arise as a result of thinking, including definitions, meanings, special characteristics, essence, core or content and so on; (3) Principles, are the main, basic, and have the most important positions, including theorems, formulas, adages, postulates, paradigms, theorems, and relationships between

* Corresponding Author: murniati_mukhtar@yahoo.co.id

concepts that describe causal implications; (4) Procedures are systematic or sequential steps in doing an activity and the chronology of a system.

Handouts are teaching materials that contain important concepts and are used to help students during the learning process. Handouts that can be accessed through digital media, such as handouts that can be accessed through cellphones and laptops are called digital handouts (Humaira et al., 2019). Handouts are said to be valid if they are designed based on the state-of-the-art knowledge and content components that are interrelated with each other (Cahyanto et al., 2016).

STEM is an integrated learning approach to science, technology, engineering, and mathematics. Study shows that this integrated approach can increase learning interest in science and technology lessons. Many benefits have been associated with STEM education, such as providing opportunities for more student-centered, meaningful, engaging, and less fragmented learning experiences involving higher-level thinking and problem-solving skills (Stohlmann et al., 2012). Experience in STEM learning can prepare students for the global economy of the 21st century (Cachaper et al., 2008). Students need solid STEM knowledge to become ready for employment (Becker & Park, 2011). STEM country of origin, United States, the application of STEM in the field of education is being held intensively. As the President's Council of Advisors on Scientific and Technology (PCAST) recommended forming the "STEM Master Teachers Corps" that assess and reward 5% of the best STEM teachers in America (President's Council of Advisors on Science and Technology (PCAST), 2010). PCAST is also planning in the next decade to recruit 100.000 teachers to teach by using the STEM approach (President's Council of Advisors on Science and Technology (PCAST), 2010). Introduction nuclear physics materials require deep mathematical and physical skills to be understood and it has many applications in sciences and technologies, such as accelerator and reactor.

Thus, the STEM approach is very suitable to be implemented in the introduction of nuclear physics materials. A lack of commercial materials forces teachers to fall back on their resources and designing their teaching materials can enable them to make the best use of the resources available in their teaching context (Howard & Major, 2004). Developing teaching materials by educators can be a solution to the lack of teaching materials. Studies that provide teaching materials have been done, one of them is done by (Kurniasari et al., 2014) and (Riandry et al., 2017). Based on this, it is important to produce teaching materials on introduction to nuclear physics materials which contain also an explanation about physics and technology application materials, so the students can get meaningful learning and the objectives of learning can be achieved. Similar to that study, the researcher tried to develop teaching materials in the form of a handout on distribution function materials based on STEM for Physics Education of Sriwijaya University.

STEM (Science, Technology, Engineering, and Mathematics). STEM (Science, Technology, Engineering, and Mathematics) education is one of the science learning methods that can help develop a generation that can overcome the hardships of the challenging 21st century. According to Anggraini & Huzaifah (2017) STEM is an approach that integrates and also links several STEM subjects to create problems based learning. So that by applicating the STEM approach, students will exercise how to apply the knowledge that they learned in class to real-life situations and everyday problems that happen in the real world

One of the development research models that can be used as a basis according to Gustafson and Branch 1997 in Riandry et al. (2017) is the Rowntree model. This model is a learning design model to produce a product such as learning videos, learning multimedia, books, teaching materials, and teaching aids

Method

This research is developmental, this research aims to produce a STEM-based digital handout. The research and development model used in this research is the Rowntree model, which consists of three stages, namely: (1) the Planning stage, which is the stage where we analyze the needs and formulate the learning objectives; (2) the Development Phase, is the stage where we developing and preparing the topic, draft preparation, and produce a prototype of a product that will be used for learning; (3) Evaluation stage, is the stage where we try the product prototype, evaluate, and make improvements based on previously obtained evaluations (Prawiradilaga, 2009).

The evaluation method used in this research is Tessmer's formative evaluation. This evaluation method is used to determine the validity and practicality of the developed product. Tessmer suggests that formative evaluation consists of five stages as shown the following in Figure 1 chart:

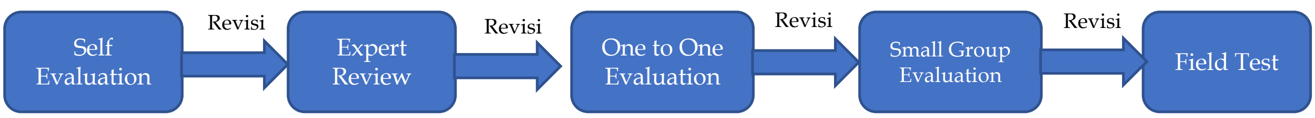

Figure 1. Tessmer Evaluation Stage

The walkthrough is a validation method that involves several experts to evaluate the product prototype, to produce a valid product. The data collection tool used in this method is the validation sheet given to the experts. The validation sheet contains a list of questions used to collect data in the form of responses, suggestions, or comments as a basis for revising the initial product (prototype 1). At this stage, expert validation includes content, language, and design validation. The validation indicator of prototype 1 modifies Teaching Materials Development Guide by the Ministry of National Education (2008).

The results obtained through walkthrough validation will be used as the basis for revising the product. The validation sheet given to the validator is made on a Likert scale in the form of a checklist with five categories of answers.

Table 1. Criteria for Scoring Validation and Questionnaire (Sugiyono, 2013)

Answer category	Score of question
Very Good	5
Good	4
Doubtful	3
Not good	2
Very Not Good	1

The validation results from the validator are presented in table 1, after finding the average score

$$\bar{x} = \frac{\sum x_i}{n} \quad (1)$$

With Xi = the number of scores obtained, n = the number of validators then discussed in Table 1. Validity category

Table 2. Category of validity (Ketang, 2015; Destiani, 2017)

Average Score	Category
4 ≤AVS ≤5	Very Valid
3 ≤AVS <4	Valid
2 ≤AVS <3	Less Valid
1 ≤AVS <2	Invalid

Note: AVS = Average Validity Score

Results and Discussion

Practical Data Collection Techniques

Practicality is a form of evaluation method to determine the practicality of the product developed by giving a Likert scale to several students who have taken the nuclear physics introduction course at the one-to-one evaluation and small group evaluation stages.

Product Development Results

Table 3. Expert review stage result.

Indicator	Conversion result
Complete information	5.0
Order of serving	5.0
Use of fonts	5.0
Illustration, pictures, audio, video, and website links	5.0
Display design	5.0
Legibility	4.7
Information clarity	5.0
Conformity with good and correct Indonesian rules	4.5
Use language effectively and efficiently	4.5
Science	4.8
Technology	5.0
Engineering	4.5
Mathematics	5.0
The suitability of the material with basic competencies and learning indicators	4.0
The truth of the substance of the learning material	4.0
Compatibility with student needs	4.0
Compatibility with digital handout needs	5.0
Benefits to increase knowledge insight	5.0

Table 4. Average Results of Walkthrough

Component	Average Score	Category
Design	5.00	Very valid
Language	4.67	Very valid
Contents	4.58	Very valid

Table 5. Validator suggestions/comments

Validator	Comments/ Suggestions	Repair
Language	The cover has not shown the identity of the study program and institution	Already repaired
	Instructions for using "Handout" do not need to use capital letters except at the beginning of the sentence	Already repaired
	Page 3: a hypothesis is not a hypothesis	It's been replaced
	Spacing between sentences in paragraphs is not uniform, example page 33 uses 1 space	Already repaired
	Replace the 2.2 images even though it's been enlarged it's still not clear	It's been replaced
	Pages 60 and 62: tidy up the writing of the formula so that it is easy to read and attractive to look at	It's been tidied up
	Figure 3.1 is still not clear even though it has been clarified	Already repaired
	Describe the section on the handout according to each STEM component.	Already equipped
Desain	The image on the right cover is not symmetrical in the cross-	Revised

Validator	Comments/ Suggestions	Repair
	section, please fix it. And only pictures of people sleeping on the headcover are shown. try not to have the body, just crop it	
	All references: pictures, videos, and simulations on the module must come from clear sources and primary sources	Already equipped
Contents	There needs to be an emphasis on technology and engineering	Already added
	The radioactive Discovery Technique is not engineering, try to find something else	It's been replaced

One-to-One Evaluation Results

The co-test stage will be tested on 3 students of Physics Education years 2018 In class, who are taking a nuclear Physics introduction course. This test is intended to make it easier for them to learn the contents of the digital handout so that they can provide positive evaluations. This evaluation aims to determine the practicality of teaching materials in terms of users, identify and reduce errors in material content, writing, language used in the handout, layout, and overall display design of the handout. Students were asked to study the contents of the handout as a whole, then asked to fill out a questionnaire to find out their responses. The results of the assessment questionnaire responses from three students are presented in Table 6.

Table 6. Results of the One-to-One Evaluation Stage

Component	Average score	Categories
Science	4.00	Practical
Technology	4.30	Very Practical
Engineering	4.00	Practical
Mathematics	3.67	Practical
Use of fonts	4.30	Very Practical
Illustrations, pictures, audio, video, and website links	4.67	Very Practical

Small-Group Evaluation Results

After the co-test was tested on 3 students, and we have some of their responses and suggestions, improvements and perfection were made and tested again on 9 students with good and average ability in the Small Group Evaluation stage. The results of this evaluation can be seen in Table 7.

Table 7. Results of the Small Group Evaluation Stage

Component	Average	Category
Science	4.89	Very Practical
Technology	5.00	Very Practical
Engineering	4.78	Very Practical
Mathematics	4.67	Very Practical
Use of fonts	4.83	Very Practical
Illustrations, pictures, audio, video, and website links	4.56	Very Practical

The development research model that can be used is the Rowntree model according to Gustafson and Branch 1997 in Riandry et al. (2017).

Planning Stage, the planning stage of developing a STEM-based Nuclear Physics digital handout has been carried out according to the Rowntree product development model procedure (Prawiradilaga, 2009), which begins with conducting needs analysis by distributing questionnaires to several students of physics education years 2018. The results of this needs analysis become reasons to create a development plan that can support academic success (Stohlmann et al., 2012). Based on the analysis of the material contained in the Semester Program Plan Rencana Program Semester (RPS) for the Nuclear Physics course. The material presented in the digital handout will focus on the chapter on the structure of the atomic nucleus, nuclear models, radioactivity, and nuclear reactions.

1) Development Stage

Based on the procedure of Rowntree's product development model, the development stage is carried out by developing topics, drafting, and producing prototypes (Prawiradilaga, 2009). In developing the research topic, Garis Besar Isi Handout Digital (GBIHD), or the content outlines of the digital handout will be compiled according to the sub-topics determined which are the structure of the atomic nucleus, nuclear model, radioactivity, and nuclear reactions. Furthermore, the researchers organize the prototype according to a predetermined draft. In the process of making this prototype, we used the flip pdf professional application because it was considered effective and easy to use (Sriwahyuni et al., 2019). All stages are carried out systematically to produce a STEM-based Nuclear Physics digital handout as a prototype-1.

2) Evaluation Stage.

The evaluation stage in this study was carried out based on the Tessmer formative evaluation stage (Tessmer, 1993). First, prototype 1 which has been developed is validated by the supervisor and myself (self-evaluation). Furthermore, it was validated by an expert lecturer (expert review) which aims to find out aspects of the content, design, and valid Digital Handout language. The average score obtained at the expert review stage is very valid with each average conversion value for the design aspect (5), content (4.58), and language (4.67). and language, namely 4.92, 4.46, and 4.5 (Mawarni & Muhtadi, 2017; Riandry et al., 2017). Furthermore, the product was revised and then tested at the one-to-one evaluation stage. The results of the one-to-one evaluation stage show that this prototype met the very practical category with the overall results of the assessment questionnaire responses that have been given to the three students being 4.35. From the suggestions and comments at the one-to-one evaluation stage, the product was revised and then entered the small group evaluation stage and the overall results of the assessment questionnaire responses from the nine students were 4.74, this means the prototype has met the very practical category.

The developed STEM-based Nuclear Physics Introduction Digital handout has the following strong and weak points. The strong point is: (1) Innovation, presenting printed teaching materials in digital form. So that it can display videos, 3D images, hyperlinks, and other supporting things that cannot be displayed in printed form (Priyanthi et al., 2017); (2) This digital handout is more efficient because it can be carried anywhere and can be stored in external memory, drives, or clouds, so that it can be reviewed anytime and anywhere. The Weakness and effectiveness of this product have not been observed because it has not been tested extensively (field test).

Conclusion

Based on the results of development research using the Rowntree development model and Tessmer formative evaluation that has been done, it can be concluded that it has successfully been developed a valid and practical handout of introduction to nuclear physics materials based on STEM. Expert review evaluation results stage for design, content, and linguistic aspects of the product shows that the developed product is a very valid teaching material. With an average conversion value for each design aspect of 5, content of 4.67, and language of 4.58, the expert review evaluation stage for design, content, and linguistic aspects of the product shows that the developed product is a very valid teaching material. With an average conversion value for each design aspect of 5, the content of 4.67, and language of 4.58. Based on this research results, STEM-based Nuclear Physics Introduction Digital Handouts course in the Physics Education, Study Program, Universitas Sriwijaya, we suggest the need for further research mainly using the field test stage to determine its effectiveness, by measuring their use and student learning outcomes

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