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Development of an Enrichment Book with Hematite as a Battery Electrode in Renewable Energy Learning

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Abstract. Learning innovation is needed to maximize interaction between teachers and students so that learning is much more effective and efficient, one of which is through enrichment books so that students learn not only theory but also its application. Enrichment books were developed to enrich students' knowledge. In this research, an enrichment book will be created using hematite as a battery electrode in renewable energy learning. The aim of this research is to determine the development and feasibility of enrichment books using hematite as battery electrodes in renewable energy learning. Enrichment books are an innovation in education that was developed to enrich information that is not obtained from textbooks. The method used in this research is R&D. The research was carried out using the ADDIE model, but this research was limited to the development *stage*. The enrichment book was developed using the Canva application. The data collection technique was carried out using a *purposive sampling technique*. The enrichment book that has been created is validated by distributing questionnaires to expert validators and practitioner validators. The research was conducted at three schools in the Greater Solo area, namely S MA N Kebakkramat, MA Al Madinah Nogosari, and SMK Batik 2 Surakarta. The results obtained show that the enrichment book with hematite as a battery electrode can be applied in physics learning on renewable energy materials with a validation score of 68.41 or perfect criteria. This research can be the basis for developing enrichment books using hematite as battery electrodes in Renewable Energy learning.

Keywords: Battery; enrichment book; hematite; renewable energy

INTRODUCTION

Learning in schools must be connected to learning media. Learning media helps maximize interaction between teachers and students so that learning is much more effective and efficient. There are various learning media available, but the learning process usually only uses textbooks. The impression that textbooks are too contextual and need to provide examples of applications of the material presented causes students to have difficulty processing the learning material. As a learning innovation, the use of textbooks in the classroom can be supplemented with non-textbooks.

Non-text books are books that do not directly explore one subject area. There are various non-text books, such as reference books, guide books, and enrichment books. Enrichment books contain information to enrich and improve the knowledge and technology of students, educators, education managers, and other communities (Rofiah et al., 2015). The characteristics of enrichment books are that the material presented is accurate, the material is developed based on science, and various knowledge is developed, such as factual, conceptual, procedural, and metacognitive knowledge (Khoiriah et al., 2018).

Enrichment material is usually given to students who have achieved minimum completeness according to the provisions of each school. Enrichment material contains expansion or deepening of the competencies studied (Khoiriah et al., 2018). In this research, the enrichment book developed is an expansion or deepening of renewable energy material. In renewable energy materials, there are many applications that can be applied in making enrichment books, one of which is the energy conversion sub-material related to batteries.

Batteries have been widely used in portable devices, such as cell phones, tablets, and laptops. Not only that, batteries have also been developed and used in electric vehicles (Liu et al., 2018). Batteries are an energy reserve in the form of electrochemical cells that can convert chemical energy into electrical energy. Many types of batteries are available depending on the material, one of which is the lithium-ion battery (Cho et al., 2015). Of all the metals available for battery materials, lithium is considered the most promising material.

Lithium has advantages as a battery-building material. Apart from being a widely available material, lithium is also non-toxic, very light, and electropositive. Another benefit is that lithium batteries have a higher energy storage potential than batteries made from other chemicals. Even though it has many advantages, lithium is very reactive, so in making batteries, we do not use metallic lithium; instead, we use compounds that are able to donate lithium ions (Li^{+}). Various studies have been carried out to obtain good Li-ion battery performance. One factor that influences battery performance is the quality of the electrodes.

Battery quality is determined from the optimal electrode material to prevent damage to the battery that occurs due to various factors such as dissolution, structural degradation, and particle isolation. Currently, a lot of research has been carried out to develop electrode materials for making Li-ion batteries, such as *lithium cobalt oxide* (LCO), *lithium manganese oxide* (LMO), *lithium iron phosphate* (LFP), *lithium nickel cobalt aluminum oxide* (NCA) and *lithium nickel manganese cobalt oxide* (NMC) (Zubi et al., 2018). Not only that, electrodes for Li-ion batteries were also developed from iron oxide material (Fe_2O_3).

There are three types of iron oxide available in nature, namely *magnetite* (Fe_3O_4), *hematite* (α-Fe_3O_4), and *maghemite* (γ-Fe_3O_4). Of the three types of iron oxide available, hematite is the most stable polymorph under ambient conditions, environmentally friendly and a versatile material. Hematite has been used as a red pigment, catalyst, electrode, gas sensor, magnetic material, and anti-corrosion protective paint (Davar et al., 2016). Hematite can be used as a battery electrode material through various methods. The methods that have been used for the hematite synthesis process are sol-gel, microemulsion, forced hydrolysis, precipitation, polymerization, direct oxide, thermal decomposition, sonochemistry, hydrothermal, solvothermal, electrochemistry, solution combustion, and pyrolysis (Bagheri et al., 2013).

Of the various methods available, the sol-gel method is considered more promising for the hematite synthesis process. There are technological variations in the sol-gel method that allow the manufacture of materials in the form of sol, powder, film, and ceramic. Synthesis using the sol-gel method can also maintain uniformity of size and crystallinity, which is essential for its application in battery electrode materials (Rasheed et al., 2018). Moreover, compared with other synthesis methods, the sol-gel synthesis method is more advantageous due to its low cost, suitable homogeneity, and high purity (Takai et al., 2019). This method also makes it possible to synthesize materials with any oxide composition, even new organic and inorganic materials that do not exist naturally (Pierre, 2020). Based on the description above, hematite has potential as a battery electrode material through synthesis using the sol-gel method, but it still needs to be developed and researched further.

In this research, an enrichment book was developed using hematite as a battery electrode in renewable energy materials. This material was chosen because no enrichment book on renewable energy material has been created. In research conducted by Rofiah et al. (2015), an enrichment book was developed on optical material; apart from that, Hanum (2015) also developed an enrichment book on temperature and heat material. This enrichment book is designed so that students can enrich their knowledge and know about alternatives for making Li-ion batteries other than those sold on the market, namely hematite batteries.

METHOD

The research method used is R&D research with the ADDIE model. ADDIE is a development model that consists of five stages, namely *Analyze* (analysis), *design* (planning), *Develop* (development), *Implement* (implementation), and *Evaluate* (evaluation) (Branch, 2009). However, this research is limited to the *develop stage*. The needs analysis stage is carried out by collecting information through literature studies, the planning stage is carried out by preparing an enrichment book, and finally, the development stage is carried out with the results of the enrichment book that has been developed and product validation is carried out through questionnaires. The selection of research subjects was carried out using a *non-probability sampling technique (non-random sample* with *purposive* sampling type. This technique was carried out by selecting certain people or events as research subjects based on considerations about which samples were the most useful or *representative* of certain criteria (Firmansyah & Dede, 2022). The research was carried out in three schools, namely SMA N Kebakkramat, MA Al Madinah Nogosari, and SMK Batik 2 Surakarta.

Data collection was carried out through questionnaire techniques. Questionnaires are needed to obtain validation from expert validators and practitioner validation. This questionnaire aims to find out whether the enrichment book developed is suitable for application in renewable energy learning or not.

The validation questionnaire assessment uses a Likert scale consisting of four alternative answer choices, as shown in Table 1.

Table 1. Scoring Terms

Category	Score
S.B. (Very Good)	4
B (Good)	3
C.B. (Pretty Good)	2
T.B. (Not Good)	1

The aspects used in the questionnaire consist of *self-instruction, self-contained, stand-alone, adaptive,* and *user-friendly* (Dewayani, 2018; Septora, 2017). The feasibility of the questionnaire is processed using assessment criteria calculations to determine the feasibility of the enrichment book that has been developed, as in Table 2.

Table 2. Assessment criteria

Score Intervals	Criteria
$X \geq Mi + 1. Sbi$	Very good
$Mi + 1. Sbi > X \geq Mi$	Good
$Mi > X \geq Mi - 1. Sbi$	Not enough
$X < Mi - 1. Sbi$	Very less

RESULT AND DISCUSSION

RESULTS

This research consists of three stages, namely the analysis, design, *and* development *stages*. At this stage, the analysis was carried out by collecting information from literature studies regarding the possibility that hematite batteries could be applied in physics learning on renewable energy materials. Literature studies show that hematite material has the characteristics of a battery electrode. Information about hematite batteries is used as material in making enrichment books to determine further their suitability for application in physics learning on renewable energy materials.

In renewable energy materials, there are many applications that can be used as enrichment books, one of which is the energy conversion sub-material. Batteries are an example of energy conversion that can convert chemical energy into electrical energy. Therefore, the enrichment book developed in this research discusses batteries with the title "Hematite Battery Electrodes." This title was chosen as an expansion or deepening of renewable energy material. With this enrichment book, students can learn about batteries and alternatives for making them even though they cannot practice them directly.

At the planning stage, an enrichment book is created, which begins with preparing a framework containing a title page, table of contents, instructions for use, learning activities, evaluation, bibliography, and glossary. After that, prepare all the materials needed. Design selection is carried out by the content of the material presented. The preparation of the enrichment book was carried out using the Canva application. The enrichment book on renewable energy material that has been developed is designed in A4 size and in the form of a .pdf file, which can be accessed *online* or *offline*. If you want to access it *offline*, users can download it first. This enrichment book can also be printed to become a physical book. The enrichment book display can be seen at Figure 1.

Figure 1. Enrichment Book Appearance (a) Cover Page (b) Table of Contents (c) Learning Activities (d) Evaluation

The results of the enrichment book that has been prepared are then validated through a questionnaire by expert validators and practitioners. Expert validators consist of two people, while practitioner validators consist of three people. If the validation results are still not feasible, then revisions will be made first according to the comments and suggestions given. The results of the experts' validation can be shown in Table 3.

Table 3. Expert Validation Results

Characteristics	Average Score
Self-instruction	27.00
Self-contained	6.50
Stand alone	3.00
Adaptive	12.00
User friendly	20.00
Total	**68.50**

Based on the results of expert validation, the total average score for the enrichment book developed was 68.50, which is an excellent criterion. Of the five characteristics of the expert questionnaire results, the most prominent is *adaptive*, meaning that enrichment books are developed by developments in science. The results of validation by practitioners can be shown in Table 4.

Table 4. Practitioner Validation Results

Characteristics	Average Score
Self-instruction	26.70
Self-contained	7.33
Stand alone	3.00
Adaptive	10.30
User friendly	21.00
Total	**68.33**

Practitioner validation results show that the enrichment book developed has a score of 68.33 or perfect criteria. This enrichment book means it can be applied to learning at school. Of the five characteristics of the practitioners' questionnaire results, the most prominent is *user-friendly*, meaning that the enrichment book developed can be easily accessed by users.

From the results of the expert validation and practitioner validation questionnaires, the overall results of the enrichment book questionnaire can be obtained, as shown in Table 5.

Table 5. Questionnaire Results

Validator	Average score	Criteria
Expert	68.50	Very good
Practitioner	68.33	Very good
Average	**68.41**	**Very good**

Based on the validation results, the enrichment book has an average score of 68.41, or very good criteria. These results state that the enrichment book on dynamic electricity material entitled "Hematite Battery Electrodes" is suitable for application in physics learning in high school or equivalent.

DISCUSSION

In this research, an enrichment book was developed using hematite as a battery electrode in renewable energy learning. The enrichment book developed aims to enrich students' knowledge. Enrichment books do not act as the primary teaching material in learning but as a support for learning. This book can be given to students who have met competency in renewable energy materials. Therefore, the content or material presented is an expansion or deepening of renewable energy material.

In renewable energy materials, there is an energy conversion sub-material, one example of which is batteries as electrochemical cells that can convert chemical energy into electrical energy. There are various types of batteries; one of the most promising is the lithium-ion battery because it has a higher energy storage potential than batteries made from other chemicals. Lithium-ion batteries can be composed of various types of electrode materials, one of which is iron oxide in the form of hematite (α-Fe_2O_3). In this study, hematite was chosen as the lithium-ion battery electrode because hematite is the most stable polymorph under ambient conditions, is environmentally friendly, and is a versatile material (Davar et al., 2016).

With this enrichment book, students can learn about batteries and alternatives for making them even though they cannot practice them directly. The enrichment book developed contains material about batteries, types of batteries, options for making battery electrodes using hematite material, the capacity of batteries produced from hematite material compared to lithium-ion batteries that are available on the market, as well as the application of energy conversion in batteries .

The enrichment book was developed using the Canva application. This application was chosen because it has many advantages, including making it easier for users to design, even for beginners, various kinds of *templates available* that can be used for free or for a fee, a choice of different types of designs that can be adapted to the user's needs, such as power points, posters, books and there are many more that can be selected according to user needs. There is no need to install the application on a computer because it is a web-based application that is easy to access using a laptop or *smartphone*, and the resulting files that have been designed can be downloaded and shared in various formats.

The questionnaire results were obtained through expert validation and practitioner validation. Validation results by expert validators show that the enrichment book has a score of 68.50, or perfect criteria. Of the five characteristics, the most prominent result of the questionnaire by experts is *adaptive*. *Adaptive* means enrichment books that are developed in accordance with developments in science.

The validation results by practitioner validators show that the enrichment book has a score of 68.33 or very good criteria. Of the five characteristics of the questionnaire results from practitioners, the most prominent characteristic is *user friendly*. *User-friendly* means that the enrichment book developed can be easily used and accessed by users.

Overall results of the questionnaire from the enrichment book developed show that the enrichment book on renewable energy material entitled "Battery Electrodes Made from Hematite" is suitable for application in physics learning in high school or equivalent with a score of 68.41 or perfect criteria.

There are advantages and disadvantages to the development of enrichment books. The advantage of an enrichment book using hematite as a battery electrode is that it contains a deepening or expansion of renewable energy material, can enrich students' knowledge, and has an attractive appearance. Meanwhile, the disadvantages of the enrichment book being developed are that it cannot be used as the primary teaching material, the material studied is considered too complicated, and it can only be given to students who have met competency in renewable energy material.

CONCLUSION

Based on the research that has been carried out, the enrichment book with hematite as a battery electrode can be applied in learning renewable energy with a validation score of 68.41 or perfect criteria.

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