Circuit: Jurnal Ilmiah Pendidikan Teknik Elektro
Volume 11 No. 1, September 2026 - February 2027
ISSN: 2549-3698; E-ISSN: 2549-3701
DOI: 10.22373/crc.v11i1.33878

Development of AC to DC Current Converter Demonstration Tools in the Electrical Circuits Course

Gina Saria Putri[a*], Hari Anna Lastya[a]

[a]Universitas Islam Negeri Ar-Raniry Banda Aceh, Indonesia

E - mail : 220211002@student.ar-raniry.ac.id

*Corresponding author

Submitted: 22-01-2026 Accepted: 18-06-2026 Published: 30-10-2026

Abstract

Instruction in the Electric Circuits course requires media capable of making abstract concepts more concrete, particularly regarding the conversion of AC to DC current. This study aims to develop and test the feasibility of an AC-to-DC conversion demonstration tool as a learning aid. The research employs the Research and Development (R&D) methodology, specifically the 4D model, which consists of four stages: define, design, develop, and disseminate. Data were collected through validation by two subject matter experts and two media experts, as well as via a response questionnaire administered to 12 students during a limited-scale trial. The results indicate that the developed demonstration tool is highly feasible, with validation scores of 88% from subject matter experts and 91% from media experts. Student feedback yielded an 80% approval rating, categorized as "good." These findings demonstrate that the tool effectively helps students grasp the AC-to-DC conversion process in a more concrete manner and supports independent learning, making it a suitable supplementary learning resource for the Electric Circuits course.

Keywords: *Teaching Aid, Electric Circuits, AC to DC Converter, 4D model*

Abstrak

Pembelajaran mata kuliah Rangkaian Listrik memerlukan media yang mampu mengonkretkan konsep abstrak, khususnya pada materi pengubahan arus AC ke DC. Penelitian ini bertujuan untuk mengembangkan dan menguji kelayakan alat peraga pengubah arus AC ke DC sebagai media pembelajaran. Metode penelitian yang digunakan adalah *Research and Development* (R&D) dengan model 4D yang meliputi tahap *define, design, develop,* dan *disseminate*. Data diperoleh melalui validasi dua orang dosen ahli materi dan dua orang dosen ahli media, serta angket respon dari 12 mahasiswa semester ganjil pada uji coba terbatas. Hasil penelitian menunjukkan bahwa alat peraga yang dikembangkan dinyatakan sangat layak, dengan persentase validasi ahli materi sebesar 88% dan ahli media sebesar 91%. Respon mahasiswa memperoleh persentase 80% dengan kategori baik. Berdasarkan hasil penelitian, menunjukkan bahwa alat peraga ini efektif membantu mahasiswa memahami proses konversi arus AC ke DC secara lebih konkret dan mendukung pembelajaran mandiri, sehingga layak digunakan sebagai media pembelajaran pendukung pada mata kuliah Rangkaian Listrik.

Keywords: Alat Peraga, Rangkaian Listrik, Pengubah arus AC ke DC, Model 4D

Introduction

Education is a vital component of human life because it is the medium for transmitting values, principles, scientific knowledge, and technological know-how. Furthermore, the strategic integration of technologies in educational frameworks plays a pivotal role in fostering students problem-solving skills, enhancing adaptive learning environments, and preparing them for the demands of a global knowledge-driven economy[1]. Education encompasses all learning experiences that occur throughout a person's life and everywhere. Education is defined as a process consisting of specific methods to enable individuals to acquire knowledge, understanding, and behaviors appropriate to their needs. The learning process takes place in the classroom and requires individual student responsibility to ensure that learning is active and not solely dependent on educators [2].

In learning at university, especially in the Electrical Circuits course, students often experience difficulties in understanding basic electrical concepts, such as the introduction of electrical components and the working principles of circuits. In the learning process, media are needed that are able to visualize concepts so that they are easier for students to understand [3]. Media is essentially one component of the learning system, with the rapid advancement of digital technologies, modern learning media not only bridges geographical gaps but also supports personalized learning [4]. As a component, learning media should be an integral part and must be in accordance with the overall learning process. The end result of media selection is the use of the media in learning activities, so that students can interact with the selected media [5].

Teaching aids are one of the learning media that have an important role in the learning process, namely as an aid for the learning process. Considering the importance of learning media, in improving the quality of education, educators must be able to use teaching aids that are appropriate to the concepts being discussed or taught [6]. Proper selection and utilization of these instructional materials help bridge abstract ideas with visual representations, thereby strengthening students' conceptual comprehension, active engagement, and overall learning performance [7].

Cicilia Retnaningsih's research proved that the use of teaching aids in science learning can improve student activity and learning outcomes. The application of teaching aids encourages active student involvement through experimental activities and discussions, and helps to concretize abstract science concepts so that learning becomes more effective and meaningful [8]. In addition, Tri Murdiyanto's research showed that the use of teaching aids in the learning process has a positive impact on students' interest and motivation in learning. The results of the study revealed that teaching aids are able to concretize abstract learning concepts, make learning more interesting and interactive, and encourage active student involvement in learning activities, so that the learning process becomes more effective [9].

Research by Putri Sion Tobing et al revealed that the development of teaching aids for musical scales made from used materials on sound resonance material is effective in improving students' cognitive knowledge, as indicated by the N-Gain value of 0.78 in the high category [10]. Previous research shows that the use of teaching aids is effective in concretizing learning concepts and improving students' understanding

and learning outcomes, as shown by the research of Cicilia Retnaningsih, Tri Murdiyanto, and Putri Sion Tobing et al. However, most of these studies still focus on elementary and secondary education levels and have not specifically developed teaching aids in engineering courses in universities, especially on the material of converting AC to DC current. Therefore, this research has a novelty by developing a teaching aid for converting AC to DC current designed for Electrical Circuit courses in universities.

Based on the description, it is necessary to develop learning media in the form of a teaching aid for converting AC to DC current that is in accordance with the characteristics of the Electrical Circuits course. Therefore, this study aims to design and validate a teaching aid for converting AC to DC current as a learning medium in the Electrical Circuits course to support the learning process and help students understand the concept of converting electric current more concretely [11].

Method

This study uses the *Research and Development* (R&D) method with the 4D model (*Define, Design, Develop, Disseminate*) [12]. The R&D method is used because this study not only aims to determine the effect of a treatment, but also to produce and test the feasibility of learning products. The 4D model was chosen because it has systematic and easy-to-apply stages in developing learning tools, starting from the needs analysis stage to product validation. Each stage is interrelated and aims to produce valid, practical, and effective products for use in the learning process [13].

Define stage is conducted to analyze learning needs, student characteristics, and the material on converting AC to DC current based on the learning outcomes of the Electrical Circuits course. The *design stage* aims to design teaching aids, including circuit design, component selection, and the arrangement of the display of the teaching aids to suit the concept to be conveyed. The *develop stage* is the stage of development and assembly of teaching aids followed by a validation process by material experts and media experts and revisions based on validator input..

The research flow steps for the AC to DC current converter demonstration tool can be seen in Figure 1. The description of the research stages in Figure 1 is as follows:

1. Start
   The initial stage of research which marks the start of a series of activities for developing a demonstration tool for converting AC to DC current.
2. Analysis of Curriculum and Learning Materials
   At this stage, an analysis of the Electrical Circuits course curriculum, learning outcomes, and competencies required for students was conducted. The analysis also included a review of the AC-to-DC conversion material to determine the key concepts to be presented through the visual aids.
3. Design of a Demonstration Tool for Converting AC to DC Current
   This stage includes designing the teaching aids, constructing the electrical circuit, and selecting the components used. The design was carried out by considering safety, ease of use, and the suitability of the teaching aids to the

needs of project-based learning. The tools and materials used in designing these teaching aids are shown in Table 1.

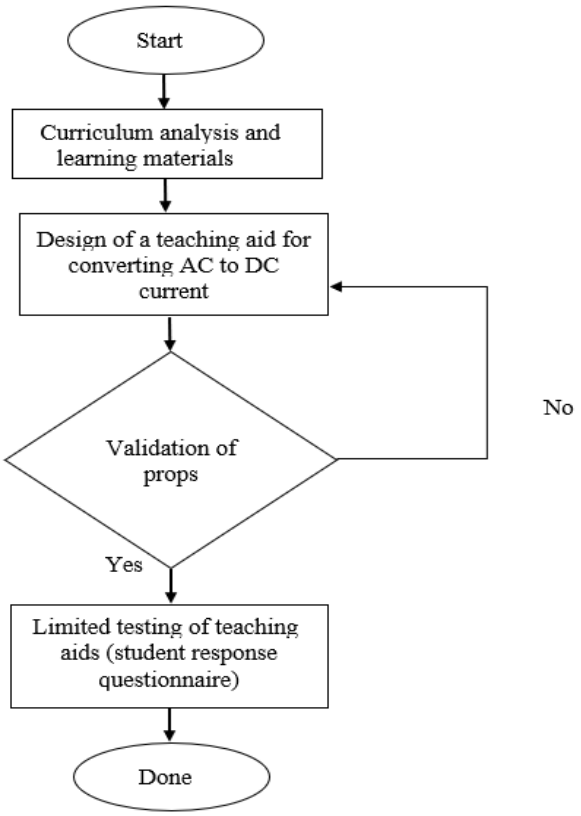


Figure 1. Research flow for AC to DC current converter demonstration device

Table 1. Tools And Materials For Designing Teaching Aids

No.	Material	Amount	Tool
1.	1A Transformer	1 piece	solder
2.	100uF electrolytic capacitor	2 pieces	tin
3.	2200uF Elco capacitor	2 pieces	screwdriver
4.	MKP/ceramic capacitor 100nF	4 pieces	cutter
5.	Regulator 7812 & 7912	2 pieces	multimeter
6.	LED lights	1 piece	-
7.	Resistor	1 piece	-
8.	Cables and plugs	enough	-
9.	Jumper cables	enough	-
10.	1n4007 diode	4 pieces	-
11.	Breadboard	1 piece	-

4. Validation of Teaching Aids

   At this stage, the teaching aids are assembled according to the predetermined design. They are then validated by subject matter and media experts to assess their functional feasibility, conceptual accuracy, and appearance. The validation results are used as a basis for making improvements and refinements to the teaching aids.

5. Limited Trial of Teaching Aids (Student Response Questionnaire)
   The revised teaching aids were piloted on a limited scale with students. The pilot aimed to determine student responses to the use of the teaching aids, including ease of use, clarity of function, and the usefulness of the teaching aids in aiding understanding of the material. Data were obtained through a student response questionnaire.
6. Finish
   The final stage that marks the end of the entire research process for developing a teaching aid for converting AC to DC current.

Data collection in this study was conducted through a validation process and limited trials of the AC to DC current converter teaching aid developed. Validation was conducted using a validation sheet given to expert validators, consisting of 2 material expert lecturers and 2 media expert lecturers from the Electrical Engineering Education Study Program and a lecturer from the Physics Education Study Program of UIN Ar-Raniry Banda Aceh. The material expert validation sheet consisted of 16 statement items, while the media expert validation sheet consisted of 20 statement items. which is used to assess the suitability of the material, appearance, practicality, and suitability of the teaching aids as learning media. Validation is carried out after the teaching aids have been designed and developed to assess the suitability of the teaching aids as learning media in the Electrical Circuits course [14].

The developed teaching aid is an AC to DC current converter teaching aid designed to demonstrate the working principles of transformers, diode rectifiers, and the process of changing electric current from AC to DC. The teaching aid is used as a supporting learning medium so that students can observe and understand the concept of converting electric current directly [15]. Consequently, hands-on interaction with these educational modules, significantly boosting student confidence in electrical engineering laboratories [16]. In addition to validation by experts, data collection was also carried out through limited trials on students of the Electrical Engineering Education Study Program. Respondents in this limited trial were 12 odd semester students. At this stage, teaching aids were used in learning activities, then students were asked to fill out a student response questionnaire that was distributed online. The student response questionnaire consisted of 16 statements used to determine the level of practicality, ease of use, and benefits of the teaching aids in helping to understand the material on AC to DC current converters [17].

The data analysis technique used in this study was quantitative data analysis. Quantitative data were obtained from the assessment results of material expert and media expert validators through validation sheets, as well as from the results of student response questionnaires during the limited trial stage. Data analysis was carried out by calculating the scores obtained from each assessment indicator [18].

The ideal score is used to determine the feasibility level of the developed learning aids, which is obtained from the multiplication of the number of statement items, the highest score for each statement, and the number of respondents. The feasibility percentage of the AC to DC current converter teaching aid is calculated using the

following equation, The percentage of suitability of teaching aids can be seen using equation (1).

$$persentase = \frac{jumlah\ skor\ yang\ diperoleh}{skor\ ideal} \times 100\% \quad \text{.....(1)}$$

Information :
P = Percentage of scores obtained
F = Total score obtained
N = Maximum score

The feasibility percentage results obtained are then interpreted based on the feasibility criteria. The feasibility criteria for learning aids are presented in Table 2.

Table 2. Eligibility criteria

Eligibility Category	Percentage (%)
Very worthy	81-100
Worthy	61-80
Quite decent	41-60
Not worthy	21-40
Not feasible	0-20

Results and Discussion

a. Results of Teaching Aids Development

The result of this research is a demonstration device for converting AC to DC current, developed as a learning tool for the Electrical Circuits course. The demonstration device was designed based on learning outcomes, material indicators, and the characteristics of students in the Electrical Engineering Education Study Program. The development of the demonstration device aims to help students understand the working principles of electric current converter circuits more concretely through direct observation and practice.

The AC-to-DC current converter demonstration tool is designed to demonstrate the process of converting electric current from an AC voltage source, transformer, and diode rectifier to a DC output. Students can directly observe each stage of the current conversion process and make measurements using electrical measuring instruments. The AC-to-DC current converter demonstration tool is shown in Figure 2 .

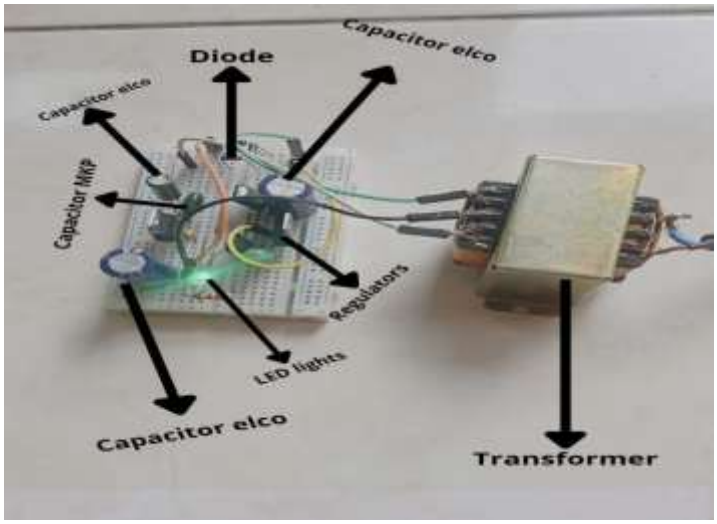


Figure 2. Display of the AC to DC Current Converter Demonstration Tool

This teaching aid serves as a learning aid that helps students understand the concept of converting AC to DC. Students are actively involved through observation and analysis of the teaching aid's working principles based on demonstration videos and explanations. Thus, the teaching aid serves not only as a demonstration tool but also as a means to train students' analytical and problem-solving skills in understanding the concept of converting AC to DC.

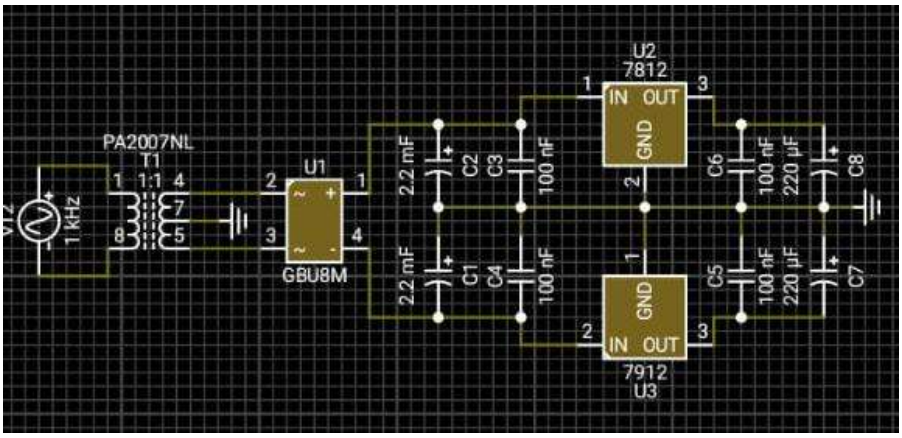


Figure 3. Circuit Diagram Of A Demonstration Device For Converting AC To DC Current

To provide a clearer understanding of the working principle of the developed teaching aid, the circuit diagram of the AC to DC current converter is shown in Figure 3. The circuit consists of a transformer, a bridge rectifier (GBU8M), a filter capacitor, and IC regulators 7812 and 7912. The transformer functions to reduce the AC voltage from the PLN electricity source, while the bridge rectifier converts the AC voltage to DC voltage. The filter capacitor is used to smooth the rectified voltage, while the regulator IC functions to produce a stable output voltage.

The device was tested using a multimeter to determine the performance of the circuit. The measurement results showed that the AC-to-DC converter model was capable of converting a 220 VAC input voltage to a stable DC output voltage of approximately ±12 VDC. These results indicate that the developed circuit functions well and can be used to demonstrate the AC-to-DC conversion process in Electrical Circuits courses.

b. Media Testing Results

The learning media testing was conducted through a validation process by material experts and media experts, as well as limited trials with students. This validation was conducted by two lecturers from the Electrical Engineering Education Study Program and a lecturer from the Physics Education Study Program, where 2 lecturers validated the material and 2 lecturers validated the media experts. The material expert validation aimed to assess the suitability of the material with the learning outcomes and curriculum of the Electrical Circuits course. Meanwhile, this validation was also conducted to ensure the completeness of the material, the clarity of the presentation of concepts, and the relationship between the material and the desired learning objectives. Meanwhile, the media expert validation aimed to assess the suitability of the teaching aids in terms of presentation, language, visual appearance, ease of use, tool safety, and their usefulness in supporting the learning process. The validation results obtained from material experts and media experts were then analyzed quantitatively to determine the

feasibility level of the AC to DC current converter teaching aid. The assessment results from material experts covering aspects of content feasibility and suitability of the material to learning needs in the Electrical Circuits course are presented in Table 3.

Table 3. Results of Material Expert Validation

No.	Statement	Total
	A. CPMK Compliance	
1.	With this AC to DC current converter demonstration tool, users can understand the basic concept of changing electric current.	100%
2.	This AC to DC current converter demonstration tool helps improve users' understanding of the current rectification process.	80%
3.	The use of this AC to DC current converter demonstration tool can help improve user skills in practicing electrical circuits.	80%
	B. Sub-CPMK Compliance	
4.	The material presented in the AC to DC current converter demonstration tool is in accordance with the concept that is to be displayed.	100%
5.	The presentation of material on the AC to DC current converter demonstration tool can help students understand the process of changing AC to DC current.	80%
6.	The material on the AC to DC current converter teaching aid supports students in understanding how circuits work.	100%
	C. Suitability of Learning Materials	
7.	The material on the AC to DC current converter teaching aid is in accordance with the material being studied by the user.	80%
8.	The material on the AC to DC current converter teaching aid is easy for users to understand.	80%
9.	The material is presented sequentially starting from AC current to DC current.	90%
	D. Suitability of assessment indicators	
10.	The assessment indicators are in accordance with the material on the AC to DC current converter teaching aid.	90%
11.	The assessment indicator can measure the user's understanding of the AC to DC current converter demonstration tool.	90%
12.	Assessment indicators are in accordance with the abilities to be achieved through the use of teaching aids.	80%
	E. Suitability of Learning Forms, Learning Methods, Student Assignments, Time Allocation	
13.	The use of AC to DC current converter teaching aids is in accordance with the form of learning activities carried out.	90%
14.	The method used supports the use of AC to DC current converter teaching aids.	90%
15.	The assignment given to students is in accordance with the use of the AC to DC current converter demonstration tool.	90%
16.	The time allocation used is in accordance with the use of the AC to DC current converter demonstration tool.	90%
Overall Percentage (%)		**88**

Based on the validation results carried out by two material experts, it shows that the AC to DC current converter teaching aid has met the eligibility in terms of material completeness and suitability to the learning needs of the Electrical Circuits course. This validation was carried out to ensure the suitability of the material content, learning objectives, and the accuracy of the AC to DC current conversion concept with the learning outcomes of the course, so that the teaching aid can be used as a learning support medium for students.

Table 4. Media Expert Validation Results

No.	Statement	Total
	A. Media Forms	
1.	The components in the AC to DC current converter demonstration tool can be clearly shown.	90%
2.	The AC to DC current converter demonstration tool used is easy for students to understand.	90%
3.	This teaching aid has the main components of a rectifier (diode/bridge, rectifier), transformer, and filter.	100%
4.	This AC to DC current converter demonstration tool can be a learning medium for students in learning activities.	100%
5.	The displayed teaching aids can present the concept of the theory of AC to DC rectification material.	90%
	B. General Appearance	
6.	The design of this teaching aid can attract students' attention.	90%
7.	The layout of the components on the teaching aids is neat and precise so that it is attractive to students.	100%
8.	The appearance of this demonstration tool is simple so that students can understand the process of changing AC current to DC.	80%
9.	Students can understand the differences in the characteristics of AC current and DC current through this teaching aid.	90%
	C. Practical	
10.	The tools and materials used in this teaching aid are easy to obtain.	90%
11.	This teaching aid has a relatively affordable manufacturing cost.	100%
12.	The tools and materials used in this teaching aid are simple.	90%
13.	The tools and materials used are easy for students to understand their function.	90%
	D. Technical	
14.	This prop has good durability for long term use.	90%
15.	The tools and materials in this teaching aid are suitable and safe for use.	80%
16.	The AC to DC current converter can function properly	100%
17.	The operation of this teaching aid has a working procedure that is easy to understand.	90%
	E. Media Quality	
18.	Operation of this teaching aid can be done manually safely.	80%
19.	This teaching aid has high utility value in learning.	80%
20.	The maintenance costs of this teaching aid are relatively low.	90%
Overall Percentage (%)		**91**

Based on the validation results conducted by two subject matter experts, the AC to DC current converter teaching aid was assessed to have a very high level of feasibility with a percentage of 88%. This result was obtained from a comparison between the obtained score and the ideal score on the validation sheet. The subject matter expert validation aims to ensure that the concept of AC to DC current rectification, component functions, and material presentation in the teaching aid are in accordance with the learning outcomes of the Electrical Circuits course and are easily understood by students. Meanwhile, validation results by media experts showed a 91% feasibility rating. This assessment covered aspects of the visual aid's appearance, clarity of presentation, ease of use, and the media's usefulness in supporting the learning process. The AC-to-DC current converter was deemed practical, safe to use, and able to help students understand the current conversion process more concretely, even though learning was conducted online.

Thus, based on the validation results from material experts and media experts, the AC-to-DC current converter teaching aid is declared very suitable for use as a supporting learning medium in the Electrical Circuits course. This teaching aid can be used as a means of independent learning through demonstration videos and online explanations, especially in learning conditions that do not allow for face-to-face learning. Student responses to the use of the AC to DC current converter teaching aid were obtained through a questionnaire. The assessment criteria for student responses were determined based on the percentage of scores obtained and classified into several categories as presented in Table 5.

Table 5. Assessment Categories

Assessment Categories	Percentage (%)
Very good	81-100
Good	61-80
Pretty good	41-60
Not good	≤ 40

Next, the results of student responses are presented in table 6.

Table 6. Student response results

No.	Statement	Total
	A. Understanding the Material	
1.	Ease of understanding AC to DC circuit material through the use of teaching aids.	80%
2.	Understanding the function of diodes in rectifier circuits through teaching aids.	81%
3.	Understanding the concept of changing AC current to DC through teaching aids.	81%
	B. Clarity of Tools and Language	
4.	Clarity of explanation on teaching aids.	75%
5.	Ease of understanding the language used in the teaching aids.	59%
6.	The display of the demonstration tools makes it easier to recognize the circuit components.	83%

7.	The suitability of the level of difficulty of the teaching aids to the students' abilities.	55%
	C. Ease and Independence of Learning	
8.	Ease of use of teaching aids in learning.	80%
9.	Support for teaching aids for independent learning outside of lecture hours.	80%
10.	Ease of understanding how the teaching aids work.	59%
	D. Benefits of using teaching aids	
11.	Benefits of teaching aids in learning electrical circuits.	88%
12.	The role of teaching aids as supporting media for learning.	90%
13.	Positive learning experiences through the use of teaching aids.	80%
	E. Impact on Skills	
14.	Improving skills in analyzing electrical circuits through teaching aids.	80%
15.	Improving understanding of AC to DC circuit practicals through demonstration tools.	83%
16.	Teaching aids increase confidence in understanding electrical circuit material.	85%
Overall Percentage		**80%**

Based on the results of student responses to the use of the AC to DC current converter teaching aid in the Electrical Circuits course, the total positive response reached 80% with a Good category. These results indicate that the teaching aid is considered easy to use, clear in presenting concepts, and useful in helping to understand the material in the Electrical Circuits course. Thus, the use of AC to DC current converter teaching aids is declared feasible and effective as a supporting medium for learning in the Electrical Circuits course.

Based on the research results, the AC to DC current converter teaching aid for the Electrical Circuits course has been validated by media and material experts. The validation results indicate that the developed teaching aid is categorized as very feasible with a percentage of 88% and 91%, respectively, in terms of both material and media aspects. Based on the results of media expert validation, the AC to DC current converter teaching aid was assessed as having a clear appearance and systematic presentation of the material, so that it was able to support student interaction and involvement in learning the Electrical Circuits course. This finding is in line with research by Arya Aulia et al., which states that the use of teaching aids as learning media can increase student activity and understanding because abstract concepts are presented in a more concrete manner [19]. Meanwhile, the results of validation by material experts indicate that the material on converting AC to DC current presented in teaching aids is in accordance with learning outcomes, contains complete concepts, and is arranged systematically so that it is easy for students to understand.

In addition to expert validation, student questionnaire results showed that the AC-to-DC current converter demonstration tool received an excellent rating of 80%. Students assessed the tool as easy to use, helpful in understanding the material, and

supportive of independent learning. This result is in line with research by Deva Untari et al., which concluded that teaching aids can help students understand concepts through direct learning experiences and project-based activities, thus having a positive impact on conceptual understanding [20].

Although the results of this study are in line with previous studies, this study has differences and novelties. Previous studies generally used teaching aids as learning aids or were applied at elementary and secondary levels of education [21]. Meanwhile, this study places AC to DC current converter teaching aids as the main learning media used in an integrated manner in the learning process of Electrical Circuits courses in higher education. Students not only understand the concept theoretically but also through direct practical experience. Furthermore, integrating functional hardware training kits into core engineering curricula equips students with essential hands-on competencies and measurement skills [22].

In addition, this study emphasizes student learning independence, where the AC to DC current converter demonstration tool can be used independently as a means of practice, observation, and material consolidation, both inside and outside of classroom learning activities. This is in line with research which states that the implementation of learning by utilizing teaching aids is able to increase learning motivation, active involvement, and understanding of student concepts [23]. The results of other studies also state that teaching aids validated by material and media experts are declared suitable for use in learning [24]. It also shows that the use of teaching aids receives a very good response from students because it is able to increase understanding and learning motivation [25]. Thus, this research provides a new contribution in the application of learning using teaching aids, especially in the Electrical Circuits course which requires an integrated understanding of concepts and practices.

Conclusion

Based on the results of the research and discussion, it can be concluded that the developed learning aids for the Electrical Circuits course are declared suitable for use in the learning process. The validation results by material experts and media experts indicate that the learning aids have met the feasibility aspects in terms of suitability of the material, appearance, and function as learning media. In addition, the results of limited trials through student response questionnaires showed a good response to the use of the learning aids, which indicates that the learning aids are easy to use and help students understand the material and increase learning motivation. Thus, this learning aid can be used as an alternative effective learning media for the Electrical Circuits course in higher education and is expected to be a reference for the development of learning aids and media in other engineering courses.

In addition to obtaining excellent validation results from material experts, media experts, and students, the developed teaching aid is also capable of converting 220 V AC input voltage to an output voltage of approximately ±12 V DC. This shows that the teaching aid is not only suitable for use as a learning medium, but also functions according to its development objectives in demonstrating the process of converting AC to DC current.

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