Development of an Analog Filter Trainer for Enhancing Practical Skills and Conceptual Understanding in Electrical Engineering Education

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Abstract. Students enrolled in the Electrical Engineering Education program encounter obstacles when attempting to access costly hardware and face the potential for damage during electronics circuit practicums. This research project aims to develop an analog filter trainer as an effective and efficient practicum tool, with the objective of enhancing students' understanding of fundamental concepts and practical skills in electrical engineering. The study employs the Research and Development (R&D) method using the ADDIE model, which comprises five stages: analysis, design, development, implementation, and evaluation. The developed learning media includes a low-pass filter (LPF), a high-pass filter (HPF), a band-pass filter (BPF), and a jobsheet to support practicums in electronics circuits. The analog filter trainer incorporates key components such as an audio frequency generator circuit, an audio filter circuit block, an LCD, and a rotary switch. Test results demonstrate that this trainer meets the specified criteria and received high validation from media experts (87.83%) and content experts (84.16%). Student responses were also very positive, with a rating of 85.67%. The use of the analog filter trainer as a practicum tool has been shown to enhance students' understanding of basic electronics circuit concepts and practical skills. This media also reduces costs and the risk of hardware damage. We hope that this research will contribute to the development of innovative and effective practicum media for electrical engineering education.

Keywords: Analog Filter Trainer, Practical Media, Electrical Engineering Education, ADDIE Development, Electronic Circuits.

1 Introduction

Electronic circuits are an important aspect in the study of electrical engineering [1]. Students in electrical engineering education programs need to understand basic concepts and develop practical skills in designing and analyzing electronic circuits. An electronic circuit practicum is an effective method to help students gain a deep understanding of the basic principles and practical applications in this field.

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However, in electronic circuit practicums, students face several obstacles. One of the main challenges is limited access to the hardware needed to conduct experiments [2]. This hardware is often expensive and difficult for students to obtain, especially in sufficient quantities for everyone in the class. Additionally, the risk of hardware damage during practicums is a common issue.

To overcome these obstacles, the development of an analog filter trainer as a practicum tool for electronic circuits is essential. The analog filter trainer is a device specifically designed to simulate various types of analog filter circuits [3]. By using an analog filter trainer, students can access electronic circuit practicums virtually and conduct experiments without the constraints of expensive hardware access or the risk of hardware damage [4].

The goal of this research is to develop an analog filter trainer as an effective and efficient electronic circuit practice tool for students in the electrical engineering education program. The analog filter trainer will be developed using current simulation technology. It will allow students to access and practice electronic circuits through computers or mobile devices [5].

Based on the above description and the findings of previous research, learning materials that are engaging and easy to understand will encourage active participation by students. When students are provided with hands-on and flexible media, they can more easily grasp the concepts being taught. Therefore, the goal of the researchers is to develop learning media that facilitates the understanding of the working principles of analog filters. These materials will provide an overview, skills, and knowledge to help students meet the required competency standards. The learning media will include low-pass filters (LPF), high-pass filters (HPF), band-pass filters (BPF), along with instructor guides and job sheets to support practical applications in electronic circuits [6], [7].

It is anticipated that the findings of this study will significantly contribute to the development of innovative and effective practicum media for electronic circuits. The use of analog filter trainers is expected to enhance students' understanding of fundamental concepts in electronic circuits and equip them with the practical skills necessary in this field. Additionally, the adoption of analog filter trainers is expected to reduce both the costs and risks associated with electronic circuit practicums.

2 Methods

This study adopted the Research and Development (R&D) method, following the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model (Figure 1) as described by Suratnu (2023) [8]. The primary objective of this research is to develop an effective analog filter trainer and evaluate its feasibility based on assessments from media and material experts. Consequently, this research is expected to produce high-quality and reliable learning media for electronic circuit practicums.

In this study, the product is expected to be developed in the form of learning media designed to assist in teaching the basic competencies of explaining the working principles of analog filters. The learning media aims to provide students with a clear understanding, practical skills, and knowledge, ensuring that these competency standards are met. The learning media includes a Low Pass Filter (LPF), High Pass Filter (HPF), Band Pass Filter (BPF), and supporting jobsheets for practicums.

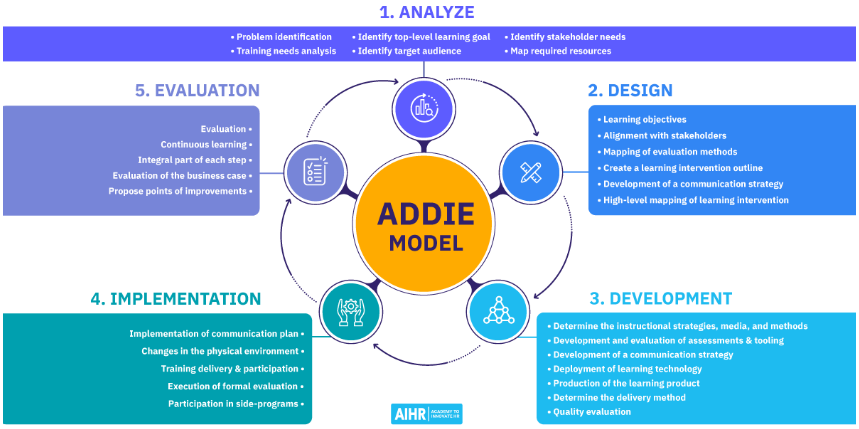


Fig. 1. Product development using the ADDIE model.

2.1 Product Design and Spesification

The design of the developed analog filter trainer is illustrated in Figure 2 and includes the following specifications:

a. The audio frequency generator (AFG) circuit utilizes the XR2206 IC as a sine, triangle, and square wave generator.
b. The Butterworth-type audio filter circuit block uses the Op-Amp LM741.
c. A 16x2 LCD matrix displays information such as frequency values and signal amplitude.
d. A rotary switch allows for the selection of the desired waveform and frequency range.

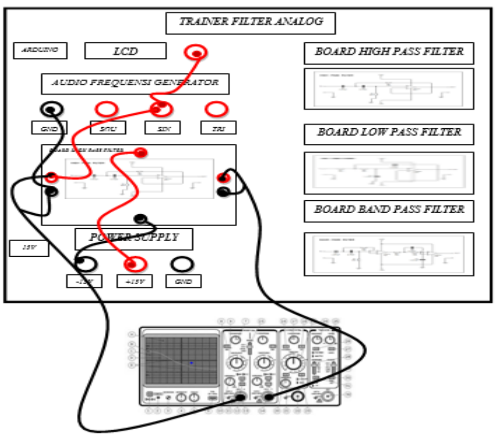


Fig. 2. Design of analog filter trainer.

2.2 Stages of Product Development

The stages of product development are outlined as follows:

a. **Analysis**: The initial stage of this research involved a needs analysis. Through direct observation at universities, researchers identified problems and needs related to learning electronic circuits. The focus of observation was on lecturers of the Electronics Series course and students of the Electrical Engineering Education study program.
b. **Design**: Based on the analysis results, the design of jobsheets and trainers was tailored to the basic competencies that students must master in the Electronics Circuit course.
c. **Development**: The designed products were then validated by two media experts and two material experts to ensure their quality and relevance to the learning objectives.
d. **Implementation**: After the validation process, the analog filter trainer was implemented in the learning process in Juli 2024. The trial was conducted in a class of 27 students.
e. **Evaluation**: The final stage of the research was the evaluation of the analog filter trainer's effectiveness as a learning medium. The evaluation was conducted by analyzing student responses and assessing the practicality and effectiveness of the trainer in achieving the learning objectives. The results of this evaluation are expected to demonstrate that the developed trainer is suitable for use as quality teaching material.

2.3 Data Collection Techniques

The data collection techniques in this study are as follows:

a. **Observation**: Research data were obtained through direct observation of lecturers teaching Electronics Circuit courses in the Electrical Engineering Education study program. This observation aimed to identify the applicable curriculum, student characteristics, and existing learning facilities and media.
b. **Questionnaire**: In addition to observation, data were also collected through the distribution of questionnaires. The assessment questionnaire was given to media experts and material experts to measure the feasibility of analog filter trainers as learning media. Additionally, the questionnaire was administered to students to determine their level of satisfaction and the effectiveness of the trainer in the learning process.

2.4 Data Analysis Techniques

The data analysis process in this study began with instrument validation. Following Sugiyono's guidelines (2013), as referenced in Lukman et al. (2023) [9], the instruments tested by experts were further analyzed to ensure their validity. Subsequently, the reliability of the instrument was assessed using the Kuder-Richardson 21 (KR-21) reliability coefficient, as applied by Azahra and Wasis (2023) [10]. Finally, the feasibility of the trainer was evaluated using the rating scale presented in Table 1.

Table 1. Categories of media and material feasibility.

No.	Score (%)	Feasibility Category
1	81% - 100%	Very Feasible
2	61% - 80%	Feasible
3	41% - 60%	Fairly Feasible
4	21% - 40%	Less Feasible
5	0% - 20%	Very Less Feasible

3 Results and Discussions

This research resulted in the development of an innovative product: an analog filter trainer, which has been physically realized as shown in Figure 3. This trainer is expected to serve as an effective learning medium, capable of fostering interest in learning and enhancing student motivation in studying analog filter circuits.

Fig. 3. Analog filter trainer.

3.1 Product Functionality Testing

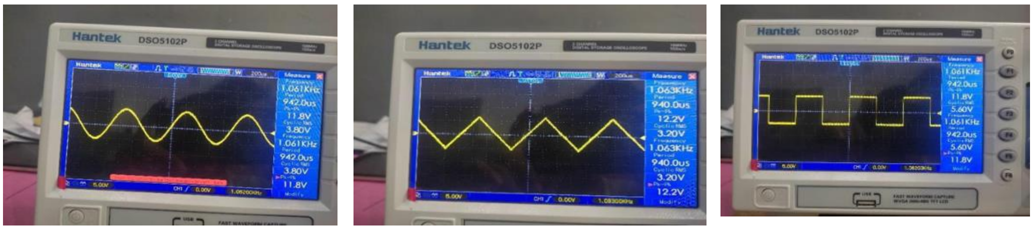
This test was conducted on both the input and output of the trainer. The following are the results of the tests performed:

a. Testing the 12 VDC power supply regulator: This test was conducted to ensure the performance of the 12 VDC voltage regulator that supplies power to the audio frequency generator (AFG). A step-down circuit was used to adjust the voltage. The complete test results are presented in Table 2.
b. Testing the audio frequency generator (AFG): The performance of the AFG was tested on three main aspects: output waveform, output frequency, and output

amplitude. The tests were conducted by setting the amplitude at 2 Vp-p to measure various frequencies and setting the frequency at 1 kHz to measure amplitude variations. The frequency measurement results are shown in Figure 4 and Table 3, while the amplitude measurement results are presented in Table 4.

Table 2. Test results of 12 VDC power supply.

Measurement	Input Voltage (AC)	Regulator Output Voltage (DC)		
		7815	7915	*Stepdown*
1	220	14,8	-14,9	11,31
2	220	14,8	-14,9	11,31



a b c

Fig. 4. Output waveforms; (a) sine; (b) saw; (c) square.

Table 3. Output frequency range test results.

Range	*Output Frequency* (Hz)					
	Sine		Saw		Square	
	Min	Max	Min	Max	Min	Max
1	8	140	8	140	8	140
2	84	1,3 k	84	1,3 k	84	1,3 k
3	862	14,01 k	862	14,01 k	862	14,01 k
4	8,67 k	32,7 k	8,67 k	32,7 k	8,67 k	32,7 k

Table 4. Amplitude test results.

Test	*Amplitudo Output* (Vp-p)					
	Sine		Saw		Square	
	Min	Max	Min	Max	Min	Max
1	0	11,2	0	12	0	20
2	0	11,2	0	12	0	20

3.2 Media Feasibility

The results of the media experts' assessment of the IoT-integrated PLTS monitoring system are presented in Table 5. To facilitate visualization, the percentage of feasibility for each aspect of the assessment is illustrated in the pie chart in Figure 5. Based on the media experts' evaluation, this monitoring system is considered highly feasible for use. The appearance, physical, and usability aspects received average scores of 84%, 89.68%, and 90%, respectively. Overall, the system achieved a feasibility score of 87.83%.

Table 5. Media validation results.

No	Assessment Aspect	Average Score	∑ Result Score	∑ Max Score	Percentage
1	Appearance	3,3	16,8	20	84%
2	Physical	3,5	28,7	32	89,68%
3	Usability Aspects	3,6	7,2	8	90%
	Total				87,83%

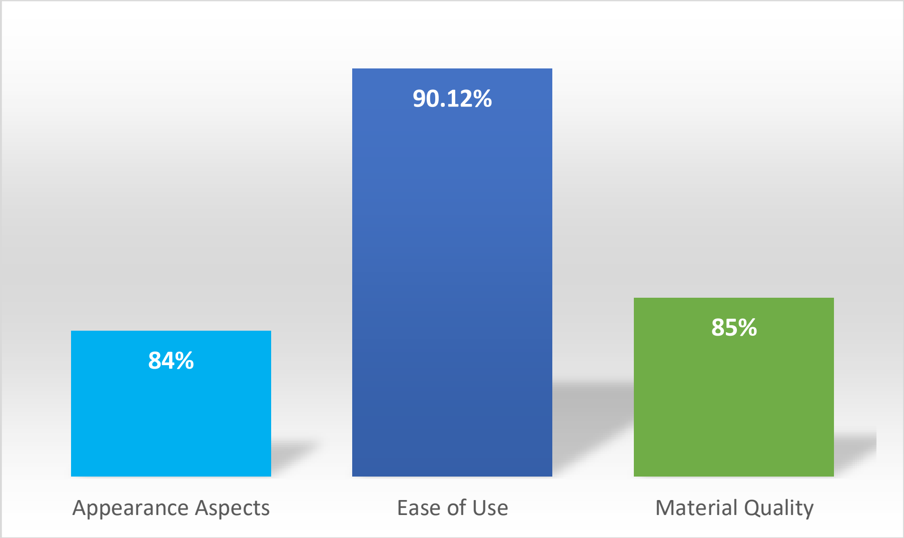


Fig. 5. Percentage of media feasibility.

3.3 Material Feasibility

The results of the material experts' assessment of the teaching module are presented in Table 6. To facilitate visualization, the percentage of module feasibility across various aspects is displayed in the pie chart in Figure 6. Based on the experts' assessment, this teaching module is deemed highly feasible for use. The material, language, and presentation aspects received average scores of 81.66%, 90.62%, and 82.50%, respectively. Overall, the module received a feasibility score of 84.16%.

Table 6. Material validation results.

No	Assessment Aspect	Average Score	∑ Result Score	∑ Max Score	Percentage
1	Material	3,2	29,4	36	81,66%
2	Language	3,6	14,5	16	90,62%
3	Presentation Aspects	3,3	6,6	8	82,50%
	Total				84,16%

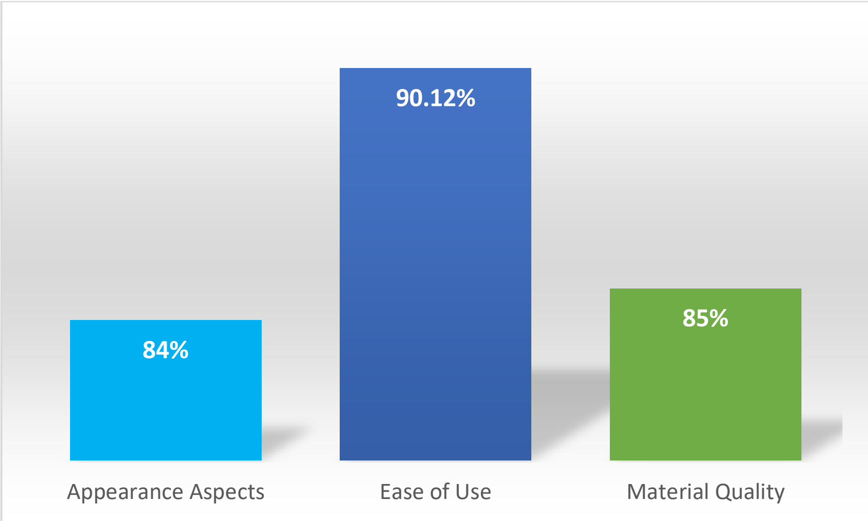


Fig. 6. Percentage of material feasibility.

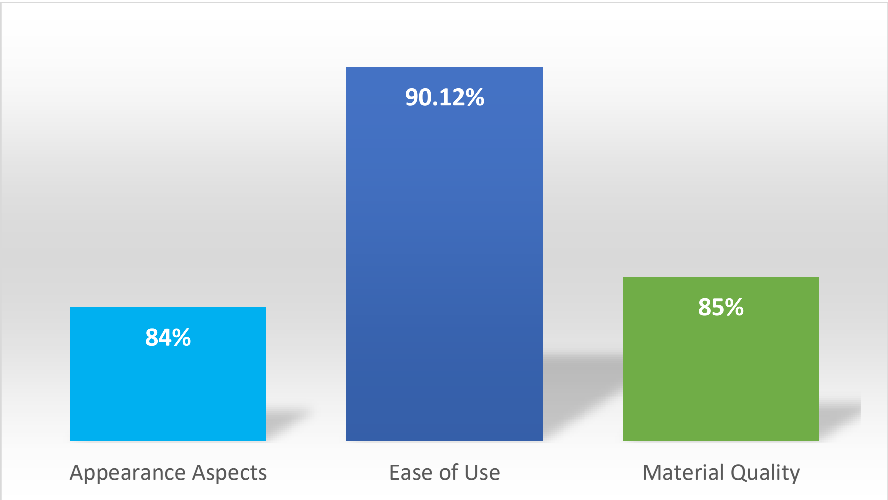


Fig. 7. Percentage of student responses.

3.4 Student Response

Student responses to the analog filter trainer as a learning medium were evaluated across three main aspects: appearance, ease of use, and material quality (see Figure 7). The evaluation results indicate that students responded very positively to this trainer. Specifically, the appearance aspect received an average score of 84.26%, ease of use 90.12%, and material quality 85.00%. With an overall average score of 85.67%, it can be concluded that the analog filter trainer has effectively increased students' interest and understanding of filter circuit material.

3.5 Discussion

The discussion of this research shows that the development of the analog filter trainer provides an effective solution to the challenges faced in electrical engineering practicums, particularly in the study of analog filters. With its innovative design, this trainer significantly enhances students' understanding of fundamental analog circuit concepts without relying on expensive and fragile hardware. Testing results indicate that the trainer is capable of producing accurate waveform and frequency outputs, confirming its suitability for practical use.

Moreover, this trainer offers substantial benefits in terms of affordability. With lower production costs compared to actual equipment, students can conduct experiments more frequently without the limitations of laboratory equipment. The use of this trainer also reduces the risk of equipment damage, making it more cost-efficient for educational institutions.

From a learning perspective, media and material validation results show that this trainer is highly effective in supporting the learning process. Students can easily grasp the material through clear jobsheets and guides, as well as the intuitive interface of the trainer. Positive feedback from students further strengthens the evidence that this tool not only enhances their learning motivation but also improves their ability to understand the concepts and applications of analog filters.

4 Conclusions

The research project aims to develop an analog filter trainer as an effective and efficient practicum tool to enhance students' understanding of fundamental concepts and practical skills in electrical engineering education. The study employs the ADDIE model (analysis, design, development, implementation, and evaluation) to develop the learning media, which includes a low-pass filter (LPF), a high-pass filter (HPF), and a band-pass filter (BPF), along with a jobsheet to support practicums in electronics circuits.

The developed analog filter trainer incorporates key components such as an audio frequency generator circuit, an audio filter circuit block, an LCD, and a rotary switch. The test results show that the trainer meets the specified criteria and received high validation from media experts (87.83%) and content experts (84.16%). Student responses were also very positive, with a rating of 85.67%.

The use of the analog filter trainer as a practicum tool has been demonstrated to enhance students' understanding of basic electronics circuit concepts and practical skills. Additionally, the use of the trainer reduces costs, and the risk of hardware damage compared to using expensive and fragile hardware for practicums. The researchers hope that this research will contribute to the development of innovative and effective practicum media for electrical engineering education.

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