

# Design and Evaluation of an LM741 Op-Amp-Based Analog Filter Trainer Kit for Vocational Electronics Learning

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**Abstract** - This study aims to design and evaluate an LM741 op-amp-based analog filter trainer kit as a practical learning medium for vocational electronics education. The study was motivated by the limited availability of hands-on instructional media for the subject of Electronic Circuit Applications, particularly in analog filter topics at SMK Semen Padang. This limitation reduces students' opportunities to observe frequency response characteristics directly and may affect their motivation, engagement, and conceptual understanding. The research employed a Research and Development approach using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation. The developed product consists of a compact trainer kit and practical laboratory worksheets covering four active analog filter circuits: low-pass filter, high-pass filter, band-pass filter, and band-stop filter. The trainer kit uses the LM741 operational amplifier as the main active component and is arranged on an acrylic panel to support laboratory-based learning. Product feasibility was evaluated through media expert validation, material expert validation, and student practicality testing. The media expert validation obtained a score of 92.66%, categorized as very valid, while the material expert validation obtained a score of 84.5%, categorized as valid. Practicality testing involving 11 students of grade XI Industrial Electronics Engineering showed an average score of 87.36%, categorized as very practical. These findings indicate that the developed analog filter trainer kit is feasible and practical for supporting hands-on learning activities and helping students understand analog filter concepts through direct experimentation.

**Keywords** - Analog filter, LM741, Op-Amp, Trainer Kit, Vocational Electronics Learning.

## I. INTRODUCTION

The rapid development of technology has significantly influenced the quality and direction of educational practice, particularly in vocational education. Technology-supported learning can improve students' access to information, increase learning flexibility, and support more interactive instructional activities [1], [2]. In technical and vocational education, the learning process should not only emphasize theoretical understanding but also strengthen practical competence through laboratory activities, demonstrations, and direct experimentation [3]. Therefore, the availability of appropriate instructional media is an important factor in helping students connect conceptual knowledge with real electronic circuit behavior.

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Vocational high schools are expected to prepare students with competencies that are relevant to industrial and technological needs. In electronics-related programs, students are required to understand component characteristics, circuit operation, signal behavior, measurement procedures, and troubleshooting techniques. However, many electronic circuit concepts are abstract and difficult to understand when delivered only through lectures or conventional explanations [4]. Practical learning media are therefore needed to make circuit behavior visible, measurable, and easier to analyze. A trainer kit can support this need because it allows students to observe input-output relationships, conduct measurements, and compare experimental results with theoretical principles [5], [6].

One of the topics that requires strong practical support is analog filter circuitry. Analog filters are electronic circuits used to pass or attenuate signals based on frequency characteristics. They are commonly classified into low-pass filters, high-pass filters, band-pass filters, and band-stop filters, each with a different frequency response and application domain [7]. Understanding these filters requires students to recognize concepts such as cut-off frequency, gain, bandwidth, attenuation, and frequency response curves. Without sufficient practical media, these concepts may remain abstract and difficult for students to relate to real circuit performance [8].

Operational amplifiers are widely used as active components in analog circuit design because they can provide signal amplification, impedance buffering, and flexible circuit configuration. The LM741 operational amplifier remains commonly used in basic electronics learning because it is widely available, relatively inexpensive, and suitable for introducing fundamental op-amp-based circuit applications [9]. In analog filter design, operational amplifiers can be used to implement active filters that provide better gain control and sharper response characteristics than purely passive RC networks [10]. Therefore, an LM741-based trainer kit can serve as a practical medium for introducing the relationship between theoretical filter design and actual circuit response.

Instructional media have a major role in improving student engagement, motivation, and conceptual understanding. Media that involve direct manipulation and measurement can encourage active learning because students do not only receive information but also test, observe, and interpret physical phenomena [11]. Previous studies have shown that practice-oriented learning media and trainer kits can improve student skills in electronics and vocational learning environments [12], [13]. In addition, the integration of laboratory worksheets can make practice activities more structured by providing learning objectives, circuit procedures, observation tasks, and evaluation questions [14].

Based on preliminary observation and interviews with teachers of Electronic Circuit Applications at SMK Semen Padang, the availability of instructional media for analog filter practice remains limited. This condition reduces students' opportunities to experience varied hands-on learning activities and may affect their learning interest, motivation, and achievement. The evaluation of learning outcomes also indicates that some students have not reached the expected learning achievement criteria. This situation shows a gap between the practical learning needs of analog filter topics and the available learning facilities in the school [15].

Several previous studies have developed electronic trainer kits and practice-based learning media for vocational education. These studies generally indicate that trainer kits can support concept visualization, improve learning practicality, and help students perform experiments more independently. However, the availability of a specific trainer kit for analog filter learning using LM741 operational amplifiers is still limited in the observed learning context. In particular, students need a trainer kit that covers several types of analog filters in one compact panel and is supported by laboratory worksheets for structured laboratory activities.

To address this need, this study designs and evaluates an LM741 op-amp-based analog filter trainer kit as a practical learning medium for vocational electronics education. The trainer kit includes four types of active analog filters, namely low-pass filter, high-pass filter, band-pass filter, and band-stop filter. The product is arranged on an acrylic panel and equipped with practical laboratory worksheets to guide student experiments. The feasibility and practicality of the trainer kit are evaluated through media expert validation, material expert validation, and student practicality testing.

The main contributions of this study are as follows:

1. Designing and developing an LM741-based analog filter trainer kit that integrates LPF, HPF, BPF, and BSF circuits in one instructional platform;
2. Preparing practical laboratory worksheets to support structured laboratory learning on analog filter characteristics;
3. Evaluating the feasibility of the trainer kit through media expert and material expert validation; and
4. Evaluating the practicality of the trainer kit based on student responses in vocational electronics learning.

## II. RESEARCH METHOD

### A. Development Framework

This study employed a Research and Development (R&D) approach to design, develop, and evaluate an LM741 op-amp-based analog filter trainer kit as a practical learning medium for vocational electronics education. The R&D approach was selected because the main objective of the study was not only to investigate a learning problem, but also to produce an instructional product and evaluate its feasibility and practicality in a real learning context [16].

The development model used in this study was ADDIE, which consists of five stages: analysis, design, development, implementation, and evaluation. This model was considered appropriate because it provides a systematic sequence for developing instructional media, starting from identifying learning needs, designing the product, developing the prototype, implementing it with users, and evaluating the final product [17]. In this study, ADDIE was used to guide the development of the analog filter trainer kit and its supporting practicum laboratory worksheets.

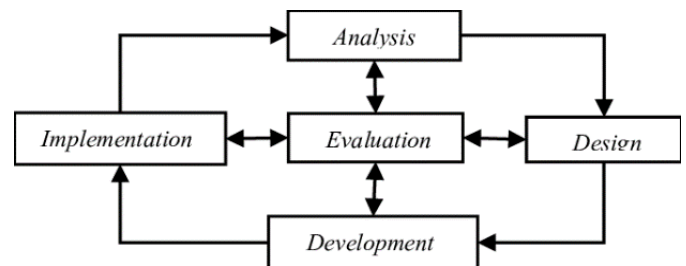


Fig. 1. ADDIE development model used in the analog filter trainer kit development.

### B. ADDIE Development Procedure

The research procedure followed the five stages of ADDIE. The activities conducted at each stage are summarized in Table 1.

Table 1  
ADDIE development procedure in this study

| Stage    | Main activity                                                                                                      | Output                                                       |
|----------|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| Analysis | Identifying learning problems, media limitations, and students' practical learning needs in analog filter material | Requirement specification for the trainer kit                |
| Design   | Designing the trainer kit layout, analog filter circuits, and practicum laboratory worksheets                      | Product design, circuit plan, and laboratory worksheet draft |

|                |                                                                                     |                                                                 |
|----------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| Development    | Building the trainer kit prototype and preparing supporting learning materials      | LM741-based analog filter trainer kit and laboratory worksheets |
| Implementation | Conducting product trials with grade XI Industrial Electronics Engineering students | Student practicality data                                       |
| Evaluation     | Analyzing expert validation and student practicality responses                      | Feasibility and practicality level of the product               |

In the analysis stage, observations and interviews were conducted with the Electronic Circuit Applications teacher at SMK Semen Padang. The analysis showed that practical learning media for analog filter material were still limited, causing students to have fewer opportunities to directly observe filter characteristics and frequency response behavior. This condition became the basis for developing a trainer kit that could support hands-on learning activities.

In the design stage, the trainer kit was designed to include four types of active analog filters: low-pass filter (LPF), high-pass filter (HPF), band-pass filter (BPF), and band-stop filter (BSF). Each filter circuit was designed using the LM741 operational amplifier as the main active component. The laboratory worksheet was also prepared at this stage and included learning objectives, required tools and components, work procedures, observation tasks, and evaluation questions. The use of structured worksheets is important in laboratory learning because it helps students follow experiment procedures and connect measurement results with theoretical concepts [18].

In the development stage, the trainer kit was constructed based on the designed circuit and panel layout. The product was developed in the form of an acrylic-based trainer board equipped with input, output, and ground terminals to support signal measurement using laboratory instruments. At this stage, the trainer kit and laboratory worksheet were validated by media and material experts to determine their feasibility before being tested with students.

In the implementation stage, the validated product was tested with grade XI students of the Industrial Electronics Engineering program at SMK Semen Padang. The purpose of this stage was to determine the practicality of the trainer kit when used in practical learning activities. Student responses were collected using a practicality questionnaire.

In the evaluation stage, validation and practicality data were analyzed quantitatively. The evaluation results were used to determine whether the trainer kit was feasible and practical as a learning medium for analog filter practice.

### C. Trainer Kit Design

The trainer kit was designed as a compact rectangular board with dimensions of 20 cm × 15 cm. This size was selected to make the trainer kit easy to place on a laboratory table while still providing sufficient space for circuit labels, terminals, and measurement access points. The trainer panel was made of 3 mm acrylic, which functioned as the main mounting structure and provided protection for the components installed on the rear side of the board.

The trainer kit contains four analog filter circuits: LPF, HPF, BPF, and BSF. Each filter section is separated and

labeled to help students identify the circuit under test. The front panel provides access terminals for signal input, output, and ground using banana jacks, so that students can connect the trainer kit to a function generator and oscilloscope more easily. The components, including resistors, capacitors, and LM741 op-amps, are placed on the rear side of the panel to keep the front layout clean and to make the signal flow easier to observe during practice.

The design emphasizes readability, safety, and practicality. A clear layout is important in electronics trainer kits because students need to identify circuit blocks, connect measurement instruments, and compare the behavior of different circuits without being distracted by complex wiring [19]. The separation of each filter circuit also allows students to perform experiments independently for each filter type and compare their frequency response characteristics.



Fig. 2. Physical dimension and panel layout of the analog filter trainer kit.

### D. Practicum Laboratory worksheet Design

The trainer kit was supported by practicum laboratory worksheets to guide students during laboratory activities. The laboratory worksheets were designed to help students perform experiments systematically and reduce procedural ambiguity during practice. Each laboratory worksheet included the experiment title, learning objectives, brief theory, required equipment, circuit identification, work steps, data table, analysis questions, and conclusion section.

The laboratory worksheets covered the four filter types implemented in the trainer kit. For the LPF and HPF experiments, students were guided to observe the relationship between input frequency and output amplitude and to identify the cut-off frequency. For the BPF and BSF experiments, students were guided to observe the passband, stopband, and frequency region where the filter produced maximum transmission or attenuation. Through these laboratory worksheets, students were expected to connect theoretical filter concepts with actual circuit measurements.

### E. Research Instruments

The research instruments consisted of expert validation questionnaires and student practicality questionnaires. The expert validation questionnaires were used to assess the feasibility of the trainer kit and laboratory worksheets from the perspective of media experts and material experts. Media expert validation focused on technical quality and media utilization, whereas material expert validation focused on

content quality, learning objectives, and instructional suitability.

The practicality questionnaire was used to collect student responses after using the trainer kit in learning activities. The assessed aspects included content and objectives, learning quality, technical quality, and media utilization. The questionnaire used a five-point Likert scale ranging from 1 to 5, where higher scores indicated more positive responses. Likert-scale questionnaires are commonly used in educational product evaluation because they allow expert judgments and user responses to be quantified systematically [20].

The assessment aspects used in the validation and practicality testing are shown in Table 2.

Table 2

Assessment aspects for validation and practicality testing

| Evaluation type      | Respondent      | Assessed aspect                                                                    |
|----------------------|-----------------|------------------------------------------------------------------------------------|
| Media validation     | Media expert    | Technical quality and media utilization                                            |
| Material validation  | Material expert | Content quality, learning objectives, and instructional quality                    |
| Practicality testing | Students        | Content and objectives, learning quality, technical quality, and media utilization |

#### F. Data Analysis Technique

The data obtained from expert validation and student practicality questionnaires were analyzed using descriptive quantitative analysis. The score from each aspect was converted into a percentage to determine the feasibility and practicality category of the developed trainer kit.

The percentage score was calculated using the following equation:

$$P = \frac{\sum X}{\sum X_{max}} \times 100\%$$

where  $P$  is the percentage score,  $\sum X$  is the total obtained score, and  $\sum X_{max}$  is the maximum possible score. The resulting percentage was then interpreted using validity and practicality criteria. Higher percentage values indicated that the trainer kit was more feasible or more practical for use in learning activities.

The media expert validation, material expert validation, and student practicality results were then compared to determine the overall quality of the developed trainer kit. The results of this analysis are presented in the Results and Discussion section.

### III. RESULTS AND DISCUSSION

#### A. Prototype Implementation of the Analog Filter Trainer Kit

The development process produced an LM741 op-amp-based analog filter trainer kit designed for practical learning in the Electronic Circuit Applications subject. The trainer kit was implemented as an acrylic-based instructional board that integrates four active analog filter circuits, namely low-pass filter (LPF), high-pass filter (HPF), band-pass filter (BPF), and band-stop filter (BSF). Each filter circuit was placed in a separate section and provided with clear labels to help students identify the circuit type, input terminal, output terminal, and ground connection.

The trainer kit was equipped with banana jack terminals for input, output, and ground access. This design allows students to connect the trainer kit to a function generator and oscilloscope during laboratory activities. The use of separated terminals also supports repeated measurements and reduces the possibility of wiring errors during practice. Resistors, capacitors, and LM741 op-amps were installed on the rear side of the trainer panel to maintain a clean front-panel layout and to make the learning interface easier to observe.

This implementation supports practical learning because students can directly compare theoretical filter characteristics with actual circuit behavior. Similar trainer-kit-based instructional media have been reported to improve students' practical engagement and help them understand electronic circuit concepts through direct experimentation [21], [22].



Fig. 3. Front view of the LM741-based analog filter trainer kit.

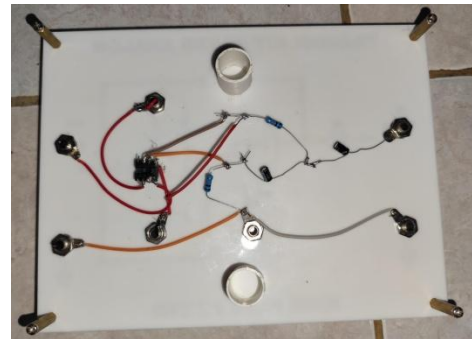


Fig. 4. Rear view and component placement of the analog filter trainer kit.

#### B. Frequency Response Simulation of the Analog Filter Circuits

Before the trainer kit was implemented and used in classroom trials, circuit simulations were conducted to verify whether each filter circuit followed the expected theoretical response. The simulation covered all four analog filter types implemented in the trainer kit: LPF, HPF, BPF, and BSF. This step was important to ensure that the circuit design was technically appropriate before being transferred into the physical trainer kit.

The LPF circuit showed the expected behavior by passing low-frequency signals and attenuating high-frequency signals. The cut-off frequency was observed around  $\pm 2$  kHz, indicating that the circuit can be used to demonstrate the transition between passband and stopband regions. In contrast, the HPF circuit attenuated low-frequency signals and allowed higher-frequency signals to pass. These two responses are useful for helping students compare opposite filter behaviors in frequency-domain analysis.

The BPF circuit only passed signals within a certain frequency range and showed maximum gain around the center frequency. Meanwhile, the BSF circuit attenuated signals within a certain frequency band and passed signals outside that band. These simulation results indicate that the four circuits worked according to the fundamental characteristics of active analog filters. Therefore, the simulation results provided a technical basis for continuing the development into the physical trainer kit. The use of simulation before hardware implementation is relevant in electronics learning because it allows students and instructors to predict circuit behavior, reduce design errors, and connect theoretical calculations with measured responses [23].



Fig. 5. Simulated frequency response of the low-pass filter circuit.

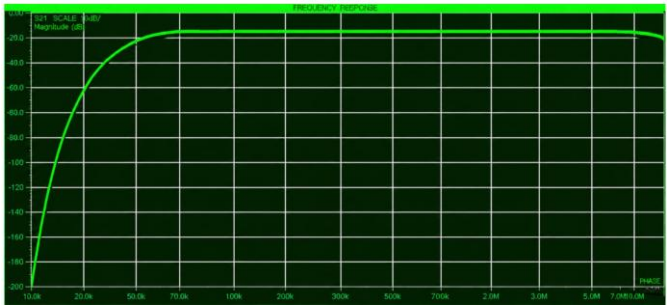


Fig. 6. Simulated frequency response of the high-pass filter circuit.

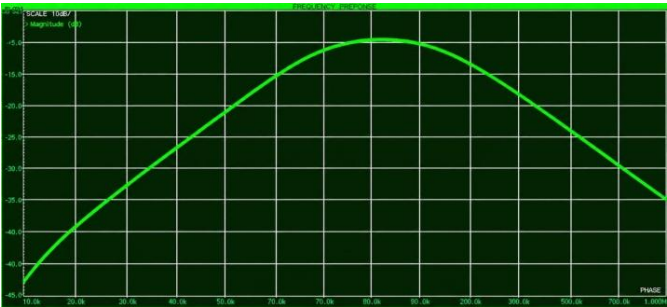


Fig. 7. Simulated frequency response of the band-pass filter circuit.



Fig. 8. Simulated frequency response of the band-stop filter circuit.

Table 3  
Summary of simulated frequency response characteristics

| Filter type            | Expected response                                                                | Main observation from simulation                                                                                                                  | Instructional interpretation                                                           |
|------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Low-pass filter (LPF)  | Passes low-frequency signals and attenuates high-frequency signals               | The output response remains high in the low-frequency region and decreases after the cut-off region, with the cut-off observed around $\pm 2$ kHz | Suitable for demonstrating passband, cut-off frequency, and high-frequency attenuation |
| High-pass filter (HPF) | Attenuates low-frequency signals and passes high-frequency signals               | The output response is low at the lower-frequency region and increases as the input frequency becomes higher                                      | Suitable for comparing inverse behavior between LPF and HPF                            |
| Band-pass filter (BPF) | Passes a selected frequency band and attenuates frequencies outside the passband | The output response reaches its maximum value around the middle-frequency region and decreases outside the passband                               | Suitable for demonstrating center frequency and bandwidth concepts                     |

Table 3 summarizes the simulated behavior of the four analog filter circuits. The LPF and HPF responses provide a direct comparison between low-frequency and high-frequency selectivity, while the BPF and BSF responses introduce more selective frequency-domain behavior. Although only the LPF cut-off region was explicitly observed around  $\pm 2$  kHz, the overall simulation patterns show that all filter circuits followed their expected theoretical characteristics. These results support the use of the trainer kit as an instructional medium for introducing frequency response, passband, stopband, cut-off frequency, and bandwidth concepts before students conduct hardware measurements.

### C. Hardware Functional Response of the Filter Circuits

After the simulation stage, the filter circuits were implemented on the trainer kit and functionally observed using laboratory instruments. The hardware test was conducted to verify whether each filter section produced the expected qualitative response when connected to a signal source and observed through the output terminal. The test focused on confirming the basic response behavior of each filter rather than calculating detailed measurement parameters such as gain, bandwidth, or attenuation slope.

Table 4  
Functional hardware response of the analog filter circuits

| Filter type | Hardware observation                                                                                                                            | Functional interpretation                                                                      |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| LPF         | The output signal remained observable at lower input frequencies and decreased when the input frequency was increased beyond the cut-off region | The LPF section functionally demonstrated low-frequency passing and high-frequency attenuation |
| HPF         | The output signal was weak at lower input frequencies and became more observable as the                                                         | The HPF section functionally demonstrated high-                                                |

|     |                                                                                                            |                                                                    |
|-----|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
|     | input frequency increased                                                                                  | frequency passing and low-frequency attenuation                    |
| BPF | The output signal was most observable within a selected frequency region and decreased outside that region | The BPF section functionally demonstrated frequency-band selection |
| BSF | The output signal decreased in a selected frequency region and remained observable outside that region     | The BSF section functionally demonstrated frequency-band rejection |

The hardware response showed that each filter section could be used to demonstrate the intended behavior during laboratory practice. However, the hardware observation was still qualitative and did not yet include detailed numerical comparison between simulated and measured values. Therefore, the present hardware verification should be interpreted as functional confirmation rather than a complete frequency-response characterization. A more rigorous evaluation should include measured cut-off frequency, center frequency, gain, bandwidth, and attenuation using a function generator and oscilloscope.

#### D. Media Expert Validation

Media expert validation was conducted to evaluate the feasibility of the trainer kit from the perspective of technical quality and media utilization. The validation results are presented in Table 5.

| No. | Assessment aspect  | Mean score | Total score | Maximum score | Percentage (%) |
|-----|--------------------|------------|-------------|---------------|----------------|
| 1   | Technical quality  | 4.8        | 71.5        | 75            | 95.33          |
| 2   | Media utilization  | 4.5        | 22.5        | 25            | 90.00          |
|     | Average percentage |            |             |               | 92.66          |

The technical quality aspect obtained a score of 95.33%, while the media utilization aspect obtained a score of 90.00%. The average validation score from the media expert was 92.66%, which falls into the very valid category. This result indicates that the trainer kit has good physical design, component arrangement, readability, and technical suitability for laboratory use.

The high score in technical quality shows that the trainer kit design is considered suitable for practical learning activities. The separate filter sections, labeled terminals, compact acrylic panel, and accessible measurement points help make the trainer kit easier to use and observe. The media utilization score also indicates that the product is considered useful as a learning medium for supporting analog filter experiments.

These findings are consistent with previous studies showing that well-designed trainer kits can improve the clarity of practical learning activities by providing structured and observable hardware interfaces [24].

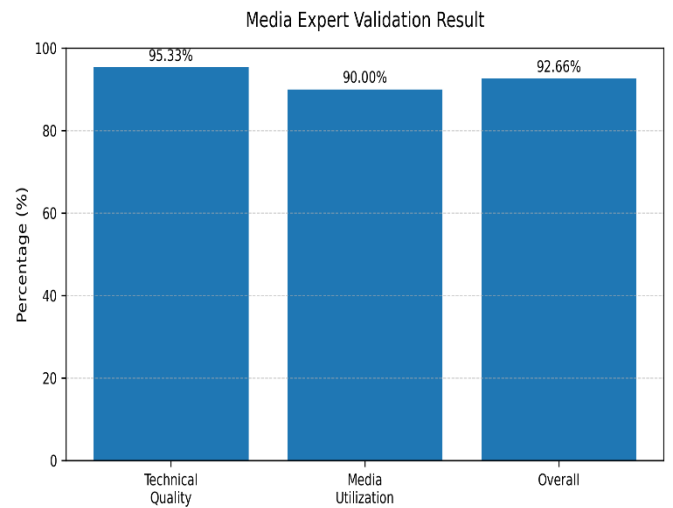


Fig. 9. Percentage result of media expert validation.

#### E. Material Expert Validation

Material expert validation was conducted to assess the suitability of the trainer kit and laboratory worksheet from the perspective of content quality, learning objectives, and instructional quality. The validation results are shown in Table 6.

| No. | Assessment aspect              | Mean score | Total score | Maximum score | Percentage (%) |
|-----|--------------------------------|------------|-------------|---------------|----------------|
| 1   | Content quality and objectives | 4.3        | 43.0        | 50            | 86.00          |
| 2   | Learning quality               | 4.15       | 41.5        | 50            | 83.00          |
|     | Average percentage             |            |             |               | 84.50          |

The content quality and objectives aspect obtained a percentage of 86.00%, while the learning quality aspect obtained 83.00%. The average material expert validation score was 84.50%, which falls into the valid category. This result indicates that the trainer kit content is aligned with the analog filter material and can support the intended learning objectives.

The validation result also shows that the laboratory worksheet and trainer kit are suitable for guiding students through analog filter experiments. The laboratory worksheet provides structured activities such as identifying circuit types, connecting measuring instruments, observing frequency response, recording data, and interpreting results. These elements are important because analog filter topics require students to understand not only circuit symbols and formulas, but also the actual response of circuits to changing input frequency.

Although the material validation score was lower than the media validation score, it still indicates that the product is feasible for learning use. The difference suggests that future improvements may focus on enriching theoretical explanations, adding more guided questions, and including clearer links between simulation results and experimental measurement tasks.

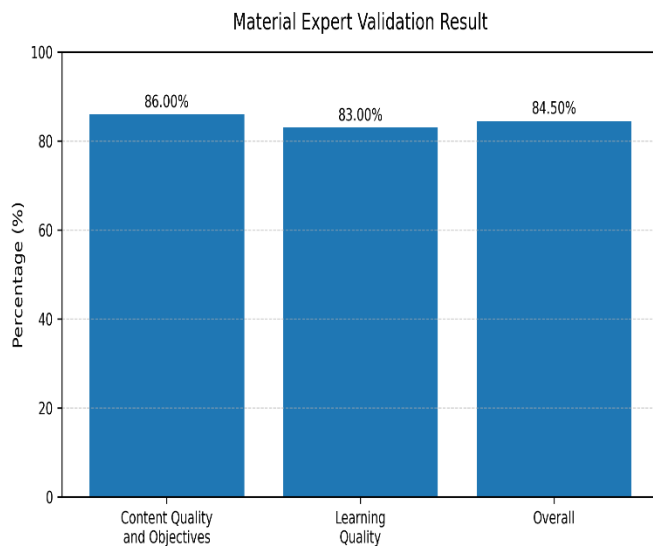


Fig. 10. Percentage result of material expert validation.

#### F. Student Practicality Testing

After expert validation, the trainer kit was pilot-tested with 11 students of grade XI Industrial Electronics Engineering at SMK Semen Padang. The term pilot test is used because the number of participants was limited and the evaluation focused on initial user practicality rather than broad generalization. The practicality questionnaire assessed four aspects: content and objectives, learning quality, technical quality, and media utilization. The results are summarized in Table 7.

Table 7  
Student practicality test result

| No. | Assessment aspect      | Percentage (%) | Category       |
|-----|------------------------|----------------|----------------|
| 1   | Content and objectives | 82.54          | Very practical |
| 2   | Learning quality       | 88.48          | Very practical |
| 3   | Technical quality      | 88.08          | Very practical |
| 4   | Media utilization      | 92.12          | Very practical |
|     | Average percentage     | 87.36          | Very practical |

The overall practicality score was 87.36%, which falls into the very practical category. This result indicates that students considered the trainer kit easy to use and useful for supporting analog filter practice. The highest score was obtained in the media utilization aspect, with 92.12%. This shows that students perceived the trainer kit as helpful for practical learning and suitable for use during laboratory activities.

The content and objectives aspect obtained 82.54%, which is still categorized as very practical but represents the lowest score among the four aspects. This result suggests that some students may still need additional explanation or stronger guidance to fully connect the trainer kit activities with theoretical filter concepts. Therefore, the laboratory worksheet can be improved by adding more examples, frequency response interpretation tasks, and guided comparison between LPF, HPF, BPF, and BSF.

The high practicality score supports the view that hands-on media can increase learning engagement and help students understand technical concepts through direct experimentation. In vocational electronics learning, a trainer kit is not only a tool for demonstration but also a medium for developing measurement skills, circuit analysis, and procedural accuracy [25].

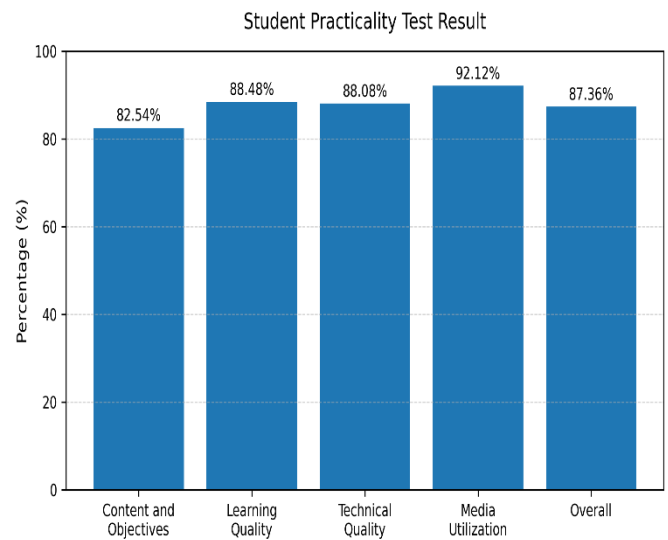


Fig. 11. Percentage result of student practicality testing.

#### G. Overall Discussion

The results show that the LM741-based analog filter trainer kit is feasible and practical for use as an instructional medium in vocational electronics learning. From the design perspective, the trainer kit integrates four filter circuits in one compact panel, allowing students to compare the behavior of LPF, HPF, BPF, and BSF directly. From the technical perspective, the simulation results and functional hardware observations indicate that each filter circuit follows its expected response pattern. From the instructional perspective, validation and practicality results show that the product is suitable for supporting practical learning activities.

The media expert validation score of 92.66% indicates that the trainer kit has strong technical quality and good usability as a learning medium. The material expert validation score of 84.50% indicates that the content and instructional structure are appropriate for the analog filter topic. The student practicality score of 87.36% further confirms that the product is easy to use and supports practical learning activities. Since the student test involved only 11 participants, the practicality result should be interpreted as an initial pilot-test finding rather than a broadly generalizable conclusion.

These findings suggest that the trainer kit can help address the limited availability of practical learning media for analog filter topics at SMK Semen Padang. By using the trainer kit, students can directly observe frequency response behavior, practice measurement using laboratory instruments, and connect theoretical concepts with real circuit operation. The presence of practicum worksheets also helps make the learning process more structured and reduces uncertainty during laboratory work.

It is important to clarify the scope of the findings. The present study evaluates the feasibility and practicality of the developed trainer kit, not its direct effectiveness in improving student learning outcomes. Therefore, the high validation and practicality scores should be interpreted as evidence that the product is appropriate, usable, and acceptable for practical learning activities. They should not yet be interpreted as direct evidence of improved conceptual understanding or learning achievement. To make such a claim, future studies should include learning effectiveness testing using pre-test

and post-test designs, control or comparison groups, and a larger number of participants.

However, several limitations should be noted. First, the hardware response test was still functional and qualitative, while physical measurement results such as cut-off frequency, gain, bandwidth, and attenuation were not yet reported quantitatively. Second, the comparison between simulation and hardware measurement results was not analyzed numerically. Third, the practicality test involved only 11 students, so broader classroom testing is needed to strengthen generalization. Future development should include experimental measurement of each filter response, learning effectiveness testing, and wider implementation involving more students and teachers.

#### IV. CONCLUSION

This study designed and evaluated an LM741 op-amp-based analog filter trainer kit as a practical learning medium for vocational electronics education. The trainer kit was developed using the ADDIE model and implemented in the form of an acrylic-based instructional board containing four active analog filter circuits: low-pass filter, high-pass filter, band-pass filter, and band-stop filter. The trainer kit was also supported by practicum laboratory worksheets to guide students in observing frequency response characteristics, connecting measurement instruments, recording experimental data, and relating practical results to theoretical concepts.

The results show that the developed trainer kit is feasible and practical for use in analog filter learning. The media expert validation obtained an average score of 92.66%, which falls into the very valid category, indicating that the product has strong technical quality and good media utilization. The material expert validation obtained an average score of 84.50%, categorized as valid, showing that the content, learning objectives, and instructional structure are appropriate for the analog filter topic. In addition, the practicality test involving 11 grade XI Industrial Electronics Engineering students obtained an average score of 87.36%, categorized as very practical. These findings indicate that the trainer kit is easy to use, supports laboratory activities, and helps students observe the characteristics of analog filters through direct experimentation.

Despite these positive results, several limitations should be acknowledged. This study evaluated the trainer kit mainly through expert validation and a limited student practicality pilot test, while learning effectiveness was not yet measured using pre-test and post-test data. In addition, the simulation results of LPF, HPF, BPF, and BSF were supported by functional hardware observations, but detailed physical measurement data such as cut-off frequency, gain, bandwidth, and attenuation were not reported quantitatively. Therefore, the findings should be interpreted as evidence of feasibility and practicality rather than direct evidence of learning effectiveness.

Future work should include quantitative measurement of each filter response using a function generator and oscilloscope, comparison between simulated and measured frequency-response data, and effectiveness testing involving larger student groups. Further development may also improve the practicum worksheets by adding more guided analysis tasks, troubleshooting activities, and frequency response

interpretation exercises so that the trainer kit can provide stronger support for conceptual understanding and practical competence in vocational electronics learning.

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