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Incorporating the 21st Century Skills in The Development of Learning Media for Analog Electronics II Practicum

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Abstract. This was a Research and Development study aimed to develop practical learning media in the forms of a trainer and a module for Electronics Engineering Education students in Analog Electronics II Practicum course. The R&D model applied in this study consisted of four phases: assessment/analysis, design, development, and evaluation. The trainer as an object media consisted of: 1) a circuit blok, including (a) a voltage feedback, (b) a phase-shift oscillator, (c) a regulated power supply, and (d) a wien-bridge oscillator; 2) a reverse engineering blok; 3) a project board blok; and 4) a power blok. Meanwhile, the text media were modules containing both the materials and the jobsheets about the practicum manual, and consisting of specific sub-chapters on how to develop the 4Cs of the 21st century skills. The trainer performance showed that all blocks in this media were functioning properly. The feasibility of this media was rated 3.3 (highly feasible), 2.97 (feasible), and 3.3 (highly feasible) by the media experts, the material experts, and the users respectively. These results indicated that the trainer was ready to be used in helping the students to understand the materials and to develop the 21st century skills, namely critical thinking and problem solving, creativity, communication, and collaboration.

1. Introduction

Yogyakarta State University (YSU) is one of the teacher training institutions in Indonesia. Law Number 12 Year 2012 states that higher education as a part of national education has a strategic role in educating the life of the nation and developing science and technology[1]. In addition, to improve the nation's competitiveness in facing globalization in all fields, higher education institutions are expected to be able to generate cultured, creative, tolerant, and democratic intellectuals who have strong characters and have the courage to stand for the truth for the sake of the nation. Therefore, YSU is also expected to contribute in the efforts to reach those goals.

In line with the goals of national education, YSU has made various improvements in all fields, including improving the quality of human resources, management, facilities, and finance. As stated in YSU's 2015-2019 Strategic Plan in the education section, to be a WCU, YSU has to carry out development in materials, resources, and methods using various approaches that are in accordance with the substance of the materials[2]. Therefore, lecturers are required to conduct an in-depth and intensive study of various models, strategies, and methods that may generate innovations. One example of the innovations expected from lecturers is that the lecturers can develop an innovative learning process, including the use of innovative media, so that the students can be active, creative, and outstanding.



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To answer those demands, Electronics Engineering Education Study Program (EEESP) strives to make innovations in the field of teaching, particularly in Analog Electronics II Practicum course. The reconstruction of this course is carried out by developing the 4Cs in the 21st century, namely critical thinking and problem solving, communication, collaboration, and creativity[3]. The Electronics Engineering Education Study Program as a vocational training institution has to equip the students with the 4Cs competences for their specific expertise. By doing so, EEESP will generate graduates/outputs who are ready to work in their expertise field. The lack of both basic and applied competences of the graduates, particularly in applying technology, team work, collaboration, creativity, critical thinking in problem solving, and communication, leads to some weaknesses in their competences. These problems are expected to be overcome by the development of HOTS through the 4Cs competences. For that reason, EEESP needs to conduct a learning process that both provides experiences and integrates the skills needed by the students to be able to compete in the 21st century job competition. This is in line with Sudira's assertion[4] that to be successful in the 21st century, employability skills are required. These employability skills include three main skills, namely fundamental, personal management, and teamwork skills. Furthermore, as mentioned earlier, innovations in the learning process are needed to create a quality learning process. The learning process is about not only knowing, but also implementing the concepts being learned and incorporating the employability skills.

Based on the survey results, the learning process in Analog Electronics II Practicum course was carried out using basic and inadequate practicum equipment. This shortcoming certainly hindered the students' learning process. For example, one package of practicum equipment was used by 5 – 6 students, while ideally one tool was used only by one student. This could slow the students' learning process down and hamper their understanding of the materials. Moreover, the practicum equipment they used was still analog so that the operation required more precision and accuracy. This could result in another problem for the students coming from senior high school in that they were not used to utilize, assemble, and operate the equipment. To overcome this problem, a kind of learning media needs to be developed, in this case, a trainer. This analog electronics as a learning media is expected to be able to help the students understand the practicum materials they learn. This trainer will stimulate the students to think critically, solve problems, work in a team, communicate, collaborate with their group, and implement their knowledge creatively. This condition triggered the urgency to develop a trainer for Analog Electronics II course as an effective learning media to be used by the students of EEESP. Furthermore, this trainer cannot only be used as a positive input to improve the students' involvement in the laboratory practicum activity, a reference for the students in carrying out their practicum, but also as a consideration for further study. In preparing a skilled workforce that fits the demand of the progressive era, it is necessary to create human resources equipped with the 21st century skills. Through the 21st century learning, the students are expected to possess various skills, including life and career skills, skills in learning and innovating, and skills in utilizing information, media, and technology. The use of media in practical learning needs to be pursued to support vocational education graduates who have technical engineering skills as well as 21st century learning skills[5].

Other than having teaching skills, teachers are required to have the needed competences and become an expert in their expertise field. Teachers are said to be competent in their field if they are able to combine their knowledge with an in-depth understanding of what should be used in learning and how to deliver it in the learning process so that the students can understand it well. In the 20th century, this combination is called as Pedagogical Content Knowledge (PCK). As the time passes, technological advances cannot be avoided. Entering the 21st century, teachers not only have to make use of technological advances, but also adjust their teaching to the existing developments if they do not want to be left behind. Teachers are said to be an expert in their field if they are able to combine content, pedagogy, and technology in their teaching and learning process. This combination is called Technological Pedagogical and Content Knowledge (TPACK). A TPACK Framework consists of three parts of knowledge: content, pedagogy, and technology. Koehler asserts that many teachers have insufficient ability in integrating technology

3 into the teaching and learning process, and the efforts they make in that process are limited and monotonous[6]. Shulman affirms that an effective teaching requires a special type of knowledge, called Pedagogical Content Knowledge (PCK)[6]. Further, he adds that teaching does not only require an understanding of the content, but also necessitate instructional strategies and skills that suit the students well. Therefore, Technological Pedagogical and Content Knowledge (TPACK) emerges as an integration between technology and learning process and as an extension of the characterization of teacher's knowledge as proposed by Shulman.

2. Method

This Research and Development study employed a four-phase development model, consisting of assessment/analysis, design, implementation, and evaluation phase. The assessment/analysis phase was carried out through a pre-survey in several classes in Electronics Engineering Education Study Program. This survey was intended to investigate the development of learning media used in the Analog Electronics II Practicum Course. This phase was divided into two: pre-survey and survey. The former was to ensure, strengthen, and support the assumption regarding the existing problems. This pre-survey was carried out without employing any validated instruments, as it was just to clarify the real condition in the field. It was conducted from February to May 2017. In the latter phase, survey, the researchers employed the validated instruments. The survey was from March to April 2017 in the same place setting.

Needs assessment was intended to determine the results and identify the gap between the current condition and the desired one. For this phase, an instrument development for both the needs assessment and analysis took place. The needs assessment was through a field survey, aimed to: 1) know the currently used media and identify the knowledge and skills needed to solve the problems, 2) determine the ideal system, 3) make a list of important goals, and 4) identify differences by looking for the differences between the ideal and the actual conditions. Front-End-Analysis (FEA) was carried out in this study to bridge the gap between the existing situation and the desired one and eventually to solve the problems. There are nine components of FEA, covering the analysis of: 1) audience, 2) technology, 3) situation, 4) task, 5) critical incident, 6) objective, 7) media, 8) extant data, and 9) cost. The design phase was the planning of the project content. A design is essential for a project to run properly. The product design in this study was presented in the pre-implementation of the learning.

The implementation phase was directly related to the technical matters in this study, meaning that the product was developed based on the referred development model. This phase was the realization of the design and development phase. In this phase, the development of the Analog Electronics II trainer was expected to be completely finished. The alpha and beta testings were also conducted in this phase. If the results of these two testings were all in "good" category ($3.4 < X \leq 4.2$), the implementation could then be continued to the evaluation phase. The last phase, evaluation, was carried out to answer the main research problem, i.e. to develop an Analog Electronics II trainer. For this purpose, it was necessary to identify the accuracy levels, functions, material contents, and instructions for using the module in the learning process. This evaluation phase was conducted in the teaching and learning process of Analog Electronics II course through collecting, processing, and analyzing information systematically to solve problems. Without this evaluation, it would be difficult to determine whether the problems had been solved or not.

This study employed two try-out subjects, one for beta testing, and one for evaluation phase. These research subjects consisted of three categories: potential users (smart students), average users (ordinary students), and slow learner users (low-ability students). These subjects and categories were chosen and determined based on their academic data (GPA and daily scores). The data obtained in this study were of two types: 1) qualitative data from the results of needs assessment/analysis, alpha testing, and beta testing, and 2) quantitative data from the evaluation results. In the development model, product try-out

was in the implementation phase. This try-out was to ensure that the developed Analog Electronics II trainer could answer the research questions. The followings are the details of the product try-out: The design try-outs were conducted in two stages: alpha and beta testings. Both were carried out to make it possible for the experts or users to find more errors in the product to be used as recommendations for further revision. The alpha testing was for identifying and eliminating as many errors as possible before finally being used by the end users. The testings were done after the media, both the trainer and the module, were developed by the stakeholders that were not involved in the study and had expertise in this field. The alpha testing instrument was needed to ensure the validity of the trainer performance. The experts involved in this testing were the experts in hardware development, the experts in teaching and learning, and practitioners. Unlike the alpha testing that was done by experts, the beta testing was completely done by the users (potential users, average users, and slow learner users). The users were informed of the beta testing procedures and were asked to assess both the trainer and the module using the validated instrument. The results of this testing were used for revising the trainer.

This study involved two main activities, namely media development (the trainer and its module) and evaluation. The instruments used in the former activity were three different questionnaires, each for gathering data in the needs assessment and analysis, measuring the results of the alpha testing, and measuring the results of the beta testing. Meanwhile, the instrument for the evaluation phase was an evaluation questionnaire. The Needs Assessment and Analysis Instrument (NAAI) was used as the basis for this research and development study. The instrument was developed based on the analyses of audience, task, objective, and media. The Alpha Testing Instrument (ATI) was for verifying the feasibility of both the trainer and the module. The validation was carried out by four experts (two material experts and two media experts). The Beta Testing Instrument (BTI) was employed to know the performance of the trainer and the module, viewed from the users' standpoints. The students as the users were given a questionnaire to ascertain the suitability of the product being developed. The data analysis method was quantitative and evaluative descriptive analysis. This method was chosen for Research and Development study does not involve hypothesis testing. In the first stage, the researchers tested the feasibility of the product hardware used in the Analog Electronics II Practicum course. The descriptive analysis technique was carried out to determine the media feasibility.

3. Results

A needs assessment survey was carried out to 1) know the condition of the existing learning media and identify the knowledge and skills needed to solve the problems; 2) set the ideal system; 3) make a list of important objectives; and 4) identify the differences between the ideal and actual conditions. This needs assessment covered four aspects: audience analysis, task analysis, objective analysis, and media analysis. As the data were obtained, the researchers and the Analog Electronics II lecturer had a Focus Group Discussion. The followings are the results of the audience analysis: 1) the prerequisite courses required for Analog Electronics II course were Analog Electronics I and Instrumentation & Measurement; 2) the students had to have practical experiences in assembling circuits based on the circuit scheme on the project board and carrying out simulations using application; 3) most of the students were males; 4) the students were from senior or vocational high school; and 5) the students were used to having practicum in groups. From this analysis, the researchers agreed that the developed media should accommodate in-groups practicum learning that facilitated the development of the students' skills in assembling a circuit, both to speed up the assembly process and to be used for further development. This was considered able to accommodate the difference in the students' previous educational background. The results of the task analysis are: 1) the conventional practicum tasks included preparing equipment and materials, assembling the circuit, collecting the data, analysing, and reporting; 2) the aforementioned tasks were coupled with presenting the practicum results; 3) the task loads were adjusted to the practicum objectives; and 4) the practicum activities covered assignments and

assessments that accommodate all competence components (cognition, affection, psychomotor, and 4Cs). This task analysis led to the development of a learning media that accommodated practicum activities that had previously been accommodated and those that needed to be added, namely assignments and assessments. The objective analysis resulted in the formulation of the materials to be developed by referring to the syllabus, namely 1) explaining and analyzing a voltage feedback circuit, 2) applying a regulator power supply circuit, 3) explaining and analyzing an audio oscillator circuit, and 4) applying an active filter circuit. In addition, the prior learning process had not accommodated the development of the 4Cs of the 21st century skills: communication, collaboration, creativity and innovation, and critical thinking and problem solving. Therefore, the learning media to be developed did not only refer to the syllabus, but also focus on developing the 4Cs. The communication skill was developed through report writing, group discussion, and presentation on the practicum results. Collaboration skill was improved through in-group practicum by providing a trainer that could be used in groups (big size), conducting group discussion, assigning the students with a project in which each group member had a specific task to develop one part of the whole project that would eventually be put together. Creativity and innovation skills were sharpened through assignments in a group discussion. An example of these assignments was that the students were asked to assemble a circuit that was different from the one they had in the previous practicum, but with the same function, in which the process was facilitated by the trainer project board. Another example was a project assignment with a completely new task or an innovation from the existing work. Meanwhile, critical thinking and problem solving skills were developed through group discussion, assessment at the end of the practicum, project assignment, and area reverse engineering activities. Therefore, the results of objective analysis recommended the implementation of practicum activities that were intended to both ensure the subject matter mastery as determined in the syllabus and develop the critical thinking skill of the 21st century through 1) in-group learning, 2) group discussion, 3) reverse engineering practicum, 4) presentation on the practicum results, and 5) project assignment. The media analysis gave a description of the media to be developed. First, the object media was the one that developed skills with concrete realms. The object media was in the form of rectangular box without lid that was used horizontally. This media was in two forms: 1) a plug and play media completed with a project board, used to prove the theory (the students just put up the jumper or controlled the switch then calculated the measuring point), and 2) a real circuit to give an illustration of the final product or the circuit to be developed (reverse engineering). Second, text media was developed to support the object media. The text media were in two types: 1) a jobsheet, covering information on the student's identity, CPMK, practicum objectives, materials, equipment and instruments, OSH, procedures, discussion, assignments, and references, and 2) module, consisting of introduction, teaching and learning activities [the 1st teaching and learning: objectives, materials, summary, discussion, assignment, and references], the nth teaching and learning], and closing.

Since the media being developed involved technology, pedagogy, and knowledge aspects, the analysis should be based on TPACK. The initial stage was to formulate the desired ideal achievement, i.e. the students mastered both KKN Level 6 and the 4Cs of the 21st century skills (integrating technology into the learning process through TPACK). Table 3 summarizes the analysis of TPACK development.

Table 1. The results of TPACK analysis on the learning media in Analog Electronics II course

Content Knowledge	Technological Knowledge	Pedagogical Knowledge (learning theory)	(The 21st century skill) Critical thinking and problem solving; Creativity; Collaboration; Communication
Feedback circuit	Simulation Practicum	- Approach: Student-centered learning, group, laboratory - Model: Problem based learning	- Analyzing component functions, the results of input and output impedances, strengthening, and the response of frequency in the feedback circuit - Applying feedback circuit on the electronics devices (an innovation of the use of feedback)

Content Knowledge	Technological Knowledge	Pedagogical Knowledge (learning theory)	(The 21st century skill) Critical thinking and problem solving; Creativity; Collaboration; Communication
Regulator power supply	Practicum	<ul style="list-style-type: none"> - Strategy: collaborative learning - Methods: discussion, brainstorming, simulation, practicum - Approach: Student-centered learning - Model: Project based learning - Strategy: collaborative learning - Methods: discussion, brainstorming, simulation, practicum 	<ul style="list-style-type: none"> - Assigning tasks based on the results of the brainstorming in a group - Communicating the results of their work to their peers in a team effectively and efficiently - Analyzing component functions, working principles, and output voltage of a power supply circuit - Assembling a power supply circuit - Applying a power supply circuit to another electronic circuit - Assigning tasks based on the results of the brainstorming in a group - Communicating the results of their work to their peers in a team effectively and efficiently
Audio oscillator	Simulation Practicum	<ul style="list-style-type: none"> - Approach: Student-centered learning - Model: Problem based learning - Strategy: collaborative learning - Methods: discussion, brainstorming, simulation, practicum 	<ul style="list-style-type: none"> - Analyzing the differences between a phase-shift oscillator and a wien-bridge oscillator - Analyzing the differences in the output frequency of both oscillators - Analyzing the differences in the effects of variations of capacitors and resistors on both oscillators - Applying an audio oscillator on an electronic circuit - Assigning tasks based on the results of the brainstorming in a group - Communicating the results of their work to their peers in a team effectively and efficiently
Active filter	Simulation Practicum	<ul style="list-style-type: none"> - Approach: Student-centered learning - Model: Problem based learning - Strategy: collaborative learning - Methods: discussion, brainstorming, simulation, practicum 	<ul style="list-style-type: none"> - Analyzing the working principles of low pass filter, high pass filter, and band pass filter - Analyzing the differences among low pass filter, high pass filter, and band pass filter - Analyzing the op-amp functions in an active filter circuit - Applying an active filter circuits on electronic circuits - (The analysis results of the three) - Assigning tasks based on the results of the brainstorming in a group - Communicating the results of their work to their peers in a team effectively and efficiently

The specification of the Analog Electronics II trainer was developed based on the results of the needs analysis. The object media was in the form of a rectangular box, consisting of circuit blocks (a voltage feedback block, a phase-shift oscillator block, a regulator power supply block, and a wien-bridge oscillator block), a reverse engineering block, a project board block, and a power block. Meanwhile, the text media were in two types, namely a module on the materials and a jobsheet that contained a practicum

guideline and was divided into specific subsections to develop the 4Cs of the 21st century skills (group discussion, the HOTS assessment, project assessment, and presentation). As the media specification was set, the researchers began to develop the trainer and tried it out. The try-out results showed that the trainer had worked as expected and could be tested for feasibility. Meanwhile, the jobsheet and the module were printed in A4 format to be then tried-out. Before trying them out, the researchers checked the media thoroughly, both the format (layout) and the content of the materials, to ensure that the printing was in a good quality and the media were ready to be assessed by both the media and material experts.

The media experts viewed the developed media from its technicality, aesthetics, and practicality aspects, while the material experts assessed the material aspect. As evaluated by the media experts, the technicality, aesthetics, and practicality of the media were in “highly feasible” category with a gain score of 3.3, 3.4, and 3.3 respectively. In general, with an average score of 3.3, the media was highly feasible. However, in the technicality aspect, one expert gave a negative response to the “This media uses a separate power supply, so it is safe if there is damage to the power supply” indicator. For this expert, separating the power supply and the trainer would cause impracticality, but for the researchers, this separation would make it easier for the users to fix the power supply when there was damage on it. This response provided valuable feedback for further study to join the power supply and the trainer to make it more practical. Figure 1 presents the results of the feasibility test by the media experts and material experts.

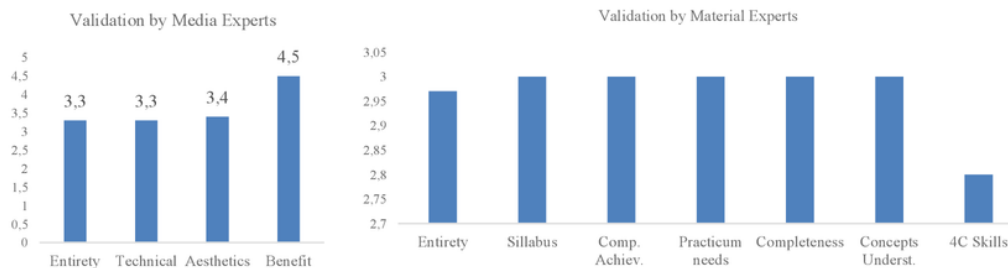


Figure 1. The Results of Feasibility Test by the Media Experts and Material Experts

The material experts evaluated the media in terms of 1) the suitability with the syllabus, 2) the practicality in achieving the targeted competences, 3) the suitability with the practicum needs, 4) the completeness of the materials, 5) the easiness in transferring the concepts, and 6) the integration of the 4Cs skills. They considered the media “feasible” to be used in all of the six aspects with a score of 3 in all aspects but in “the integration of the 4Cs skills” aspect with a score of 2.8. Overall, the media was in “feasible” category with an average score of 2.97. However, one of the experts did not agree on one indicator in “the integration of the 4Cs skills” aspect, i.e. “this media encourages the students to experiment in the practicum”. For him, the media did not provide enough experiment variations. The researchers argued that this was affected by the limited time allotment. This feedback could be used as a recommendation for further study to develop more experiment variations. After the media were evaluated by the experts, they were then tried out by the users/students. This try-out was intended to identify the feasibility of the media to be used in the learning process viewed from the students’ standpoints. In general, the students perceived the media to be feasible with a score of 3.3, and yet five indicators were in “unfeasible” category with a score of 2. Those indicators were 1) the materials are suitable for the basic concept of Analog Electronics II course, 2) the practicum media consist of complete equipment that support the practicum activity, 3) the media offer opportunity for the students to study independently, 4) overall the media are interesting, and 5) the colors used in the modul are harmonious.

In responding to the negative response to “the materials are suitable for the basic concept of Analog Electronics II course” indicator, the researchers added some materials on the basic concept of Analog Electronics II in the module. For “the practicum media consist of complete equipment that support the practicum activity” indicator, the researchers added a measuring instrument in the storage drawer. For “the media offer opportunity for the students to study independently” indicator, the students gave negative response because they thought that the word “independently” meant that they had to work individually, while the intended meaning of this word was that the students could finish their task in groups without relaying on their lecturer’s guidance. To improve the attractiveness of the media, the researchers printed the cover and some parts of the jobsheet and the module in colors. In addition, the researchers recolored the jobsheet and the module to make the colors more harmonious using fewer colors in one page.

4. Conclusion

The practicum media for the students of EEESP that integrated the 21st century skills had been successfully developed in the forms of a trainer as the object media and a module as well as a jobsheet as the text media. The trainer consisted of: 1) circuit blocks (a voltage feedback block, a phase-shift oscillator block, a regulator power supply block, and a wien-bridge oscillator block), 2) a reverse engineering block, 3) a project board block, and 4) a power block. Meanwhile, the text media were a module on the materials and a jobsheet that contained a practicum guideline and was divided into specific subsections to develop the 4Cs of the 21st century skills (group discussion, the HOTS assessment, project assessment, and presentation). The performance test showed that all blocks in the trainer functioned properly. These learning media were evaluated by media experts, material experts, and users with a result of 3.3 (highly feasible), 2.97 (feasible), and 3.3 (highly feasible) respectively. These results indicated that the trainer was ready to be used in the learning process to help the students understand the materials and develop their 21st century skills, namely critical thinking and problem solving, creativity, communication, and collaboration.

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