Teaching Aids in Digital Electronics Practice through Integrating 21st Century Learning Skills using a conceptual approach

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Abstract. Difficulties using teaching aids, limited learning time, and student dependence on mastery of the material are things that educators need to pay attention to. Besides, mastering 21st-century skills which are critical thinking and problem solving, creativity, communication, and collaboration (4C skills) need to be integrated into learning to ensure graduate work readiness and it seems essential to develop a teaching aids that accommodates these various things. This article discusses the feasibility and effectiveness of practical teaching aids with a conceptual approach to incorporating 21st-century skills in mastering learning material. The conceptual approach is carried out through mind maps at the beginning of each chapter. The results of the material feasibility test, the media feasibility test, and the respondent's trial showed "Very Decent" results. Furthermore, the results show that the media able to accommodate the needs aspects of easiness, accelerate understanding, and group independence. In addition, based on quasi-experimental results, students who use the developed media have a significantly better achievement of 21st-century learning skills (alpha value> 0.05) compared to students who use the existing media. Thus, this teaching aid is effectively used in learning to improve 21st-century learning skills and also strategically able to help prepare graduates' readiness for work in the future.

1. Introduction

One that needs to be offered by educators in learning is adequate teaching aids [1]. Vocational education is higher education that prepares students to have jobs with certain applied skills [2]. The learning process in vocational education is still not supported by the use of instructional media that are appropriate to the needs [3]. Teaching aids in vocational education requires an academic approach and practice with different instructional design frameworks [4]. Graduates of vocational education need to have work skills, where one of its efforts through the use of practical media in learning that not only develops technical skills related to material also develops 21st-century skills [5]. Trilling and Fadel stated that 21st-century skills needed in learning are critical thinking skills and problem-solving, communication, collaboration and creativity and innovation [6]. Not much different from that, the four highest skills needed to work are creativity and innovation, analytical and problem solving, technical skills, communication, and collaboration [7]. In this 21st century, educators, especially in vocational
education, need to create teaching aids that can integrate 21st-century skills in technical mastery of the material. This needs to be done to ensure readiness to work for vocational education graduates.

Hands-on teaching aids in vocational education is needed to develop practical skills both technically and non-technically. One effort that can be an alternative is the development of media in the form of objects (real objects) and assigning assignments according to their use in the vocational field directly (contextual). In this article, the teaching aids referred to in the form of trainers. The trainer is a teaching aids for technical practice that presents the actual function or performance or as the original as a tool to train or develop both technical and non-technical skills. Trainers are developed to make it easier for students to develop skills that need to be achieved in learning. Practical learning is closely related to practical activities that carry out a series of practicum activities. To support this, trainers need to be equipped with job sheets. Job sheet is a guide that contains operational work steps and work drawings as material that will be practiced to make or complete a job so as to maximize understanding in the effort to form basic abilities. Job sheet aims to enable students to learn independently with or without teacher guidance [8], presents teaching materials that facilitate students to interact with the material provided, presents tasks and work steps that enhance students’ mastery of the material, train student learning independence, and facilitate educators in assisting the practical activities process [9]. Trainers who are equipped with a Job sheet will support the independence of students.

Most teaching aids are the result of inappropriate designs [10]. Design requires in-depth analysis of learning needs. By conducting an in-depth analysis, the teaching aids produced will be in accordance with the objectives of media development needed as a tool to help educators overcome their limitations to improve the effectiveness of learning. The point that needs to be underlined regarding the use of teaching aids is related to its function as an intermediary between educators and students to obtain information. Therefore, the teaching aids developed is not to replace the role of educators in learning. The results of the initial research indicate that the teaching aids used in the practical learning of the Digital Engineering Practices course are still simple that has not accommodated the entire material and have limited time. In addition, existing teaching aids have not integrated 21st-century skills in their use for the achievement of learning goals. This article presents the development of practical teaching aids in Digital Electronics courses in terms of development, implementation, and evaluation. Characteristics that want to be highlighted are related to media functions to facilitate the integration of 21st-century skills, both technically in the form of concept understanding, problem-solving skills and critical thinking, creativity and non-technical abilities such as communication, collaboration, and independence. The density of material in the learning plan that is faced with time constraints encourages the development of hands-on characteristic teaching aids that can bridge these problems.
2. Teaching Aids On The Practice Of Digital Engineering With A Conceptual Approach To Developing 21st Century Skills

![Figure 1](image1.png)

**Figure 1.** Trainer, Job sheets and manual books that have been successfully developed

The conceptual approach is carried out by providing a mind map at the beginning of the chapter to bring together the students' initial knowledge, the concept of the material provided and the contextual linkages of the material. Students are actively able to maintain the concept permanently because it begins with "warming up" to find out the meaning of the concept through categorizing student opinions and concepts by connecting the information guides on the mind map [11]. The development stage is the realization of the design stage, namely the creation of trainers, job sheets, and manual books. The development stage is carried out based on a design from the results of an in-depth analysis. The design results in the paper are manifested in the physical form of trainers, job sheets, and manual books. At this stage, high accuracy and focus are needed so that the results of the design can be completely poured into the physical form. The trainer is made using white milk acrylic material with a thickness of 3 mm and 5 mm, the size of the trainer made is 64 cm x 52.5 cm x 9.2 cm. Job sheet is printed using A4 quarto size A4 paper (21 x 29.7 cm) weighing 70 grams. The cover is printed using 170 grams of colored Art Paper. Manual book is made with a size of 22.5 cm x 15.5 cm landscape orientation, made in book form with 4 sheets of paper or 1 cover of 7 pages and printed using 230 grams of ivory paper.

After the product manufacturing phase is complete, then a performance test is performed (the implementation stage). That test which aims to find out that the product that has been made functioning properly and if there is a malfunction can be repaired immediately before proceeding to the feasibility testing stage by experts. Performance tests are carried out by researchers using performance testing instruments. Performance tests are divided into 3 stages: pre, process, and post. At the pre-stage, checking the availability of luminous space, 220 VAC electricity, table and banana plug cable is available. At the process stage: (a) testing the trainer electrical system (power button, power indicator, live trainer, trainer tension); (b) toggle and led testing; (c) testing 7 led segment; (d) testing all IC modules (Logic Gate, Boolean Algebra, Digital Arithmetic, Clock Pulse Generator, Flip-Flop, Decoder, Synchronous-Asynchronous Counter, Shift Register, Multiplexer-Demultiplexer, ADC) by creating the circuit and matching the IC output with the truth table; (e) light testing, response and LCD digital visualization display characters and buttons; (f) testing of knob, adjustable voltage source display and output; (g) project board testing; (h) tightness testing of all female plug bananas; (i) testing the process of training the trainer and testing the voltage after the trainer is turned off, whether there is still electricity or not. In the post phase, the tightness and strength of the casing trainer are tested by pressing the points of the trainer, then testing the ease of transfer and storage of the trainer. The performance test results are stated very well according to the design and specifications specified with a 100% success percentage.
The evaluation phase begins with validation by Media Experts and Material Experts using a feasibility test instrument that refers to the theories of Riana & Susilana [12]. Assessment by material experts includes aspects of material quality and usefulness. Aspects of material quality consist of suitability with learning objectives, conformity with the material and suitability with student characteristics. Aspects of benefit consist of functions to simplify and expedite the learning process, attract students' interest and creativity and improve skills (21st-century skills) and students' competencies. Assessment by media experts includes aspects of appearance, technicality, and usefulness. The aspect of the display consists of the layout of the components, the suitability of the size and shape, the attractiveness of the trainer visually, the good performance to support the practicum activities. Technical aspects consist of ease of use of trainers and quality of trainers. Aspects of benefit consist of the function to improve skills (21st-century skills) and students' competencies, providing creative space and attracting learning interest in students, facilitating and facilitating the learning process.

The feasibility test begins with demonstrating the trainer to experts, then the expert conducts a feasibility assessment of the trainer, job sheet and manual book on the feasibility testing instrument. After being declared feasible by media experts and material experts, the trainer was tested by students. Assessment by students used to obtain data in the form of product quality in terms of the level of student satisfaction as users. Assessment consists of aspects of material quality, technicality, appearance, and usefulness. The procedure for testing the respondents (students) is by dividing students into small groups (2-3 people), then each group is given a manual book and job sheet with different material ranging from basic material to complex material. Then, the group of students who have been divided, alternately do the practicum in accordance with their respective job sheets to complete. After completing the practicum in groups using job sheets and trainers, a questionnaire is distributed and students fill out questionnaires according to their opinions. Feasibility instruments are prepared using a rating scale using four scales (1-4). After the data is obtained, then the conversion of the assessment score becomes four categories (Very Decent, Decent, Less Decent and Unworthy). The score is converted according to Sudjana [13], where the category is very decent with \( Mi + 1.5 Sdi < X \leq Mi + 3 Sdi \) in the score range of \( 3.25 < X \leq 4 \); decent category with \( Mi < X \leq Mi + 1.5 Sdi \) in the score range \( 2.5 < X \leq 3.25 \); category of less decent with \( Mi - 1.5 Sdi < X \leq Mi \) in the range of \( 1.75 < X \leq 2.5 \); and the unworthy category with \( Mi - 3 Sdi < X \leq Mi - 1.5 Sdi \) in the range of \( 1 < X \leq 1.75 \).

The results of the material feasibility test, the media feasibility test, and the respondent's trial showed the results of "Very Decent". Data can be presented in Figure 2. These results indicate that: (a) the teaching aids must be truly utilized as appropriate and to facilitate certain learning experiences that can only be obtained from the media; (b) the teaching aids that are made must be easy to use by the user and have an attractive appearance; and (c) teaching aids are made based on the characteristics and needs of students and the learning objectives that are expected to be achieved (12). In addition, comments from students' assessments include: (a) the developed practice media has complete features so that it can accommodate all the subject matter and make it easier for students to understand the material being taught; (b) practical media that is developed is easier to use / operate, the colours used in practice media are also very interesting for students to study; and (c) the practical media developed is very helpful in practice, and easier and faster to practice, the colors used in practice media are also very interesting for students to learn, and easy to operate.
Suggestions provided by media experts, material experts and students include: (a) Need more details about the images on Job sheet; (b) Need to be given information “related / not related” in the answer column 1-7 Table 2; (c) Need to be given a point on the IC image; (d) Fix the Half Subtractor Truth Table; (e) Fix the Boolean Algebra theorem material; (f) Add IC Counter 7490 material; (g) Better trainers are made smaller and use stronger materials; (h) What if the use of IC at the practicum is more than that available to the trainer. For suggestions, a to f have been corrected according to the advice given by the evaluator. Related to suggestions to reduce the size of the trainer, the researcher cannot follow up, because the size of the trainer has adjusted the size of the practice component and the use of trainers in groups. However, further research can consider the evaluator’s input on the size of a smaller trainer while still containing elements of the components needed in practice. In addition, large sizes were chosen by researchers because the practice was designed to be carried out in groups. It is designed to develop 21st-century learning skills such as communication and collaboration. Working (learning) in groups increases participants’ sense of participation because they can collaborate and conduct a variety of different ways of communication through student-centered approaches [14].

Therefore, involving the participation of other students when using trainers because of the large reach of trainers is one of the efforts to develop collaboration and communication skills conducted by researchers. The assignment in the discussion section written in Job Sheet is in the form of problems related to the subject matter in accordance with its use in the real world. These problems require students in the group to identify, analyze and ultimately find the best solution to the problem. Problem-solving activities in a group of students is an effort to develop communication skills [15]. In addition, these activities support the integration of 21st-century learning skills, in the form of communication, collaboration, critical thinking, and problem-solving, where creativity is also possible as a result of the comparison of several solutions from members into a solution resulting from group thinking. If during practice, more ICs are needed than those installed in the trainer (especially to develop creativity), project boards and additional ICs are stored in the trainer’s storage drawer. Additional ICs needed by students can be assembled on the project board. This has been taken into consideration by researchers based on deep needs analysis at the analysis stage as an effort to develop 21st-century learning skills, namely creativity, critical thinking and problem-solving.

After the feasibility test shows that the teaching aids can be used to achieve learning objectives, namely the integration of the application of 21st-century skills in the achievement of mastery of material that is faced with time constraints, then the effectiveness test is carried out. Technical implementation of the effectiveness test is to divide the two groups, where one group uses the existing teaching aids and another group uses the teaching aids developed in this study. The method used is quasi-experimental by performing several controls consisting of (a) the same teacher; (b) the same...
learning time (1st learning hours to 4th learning hour); (c) the same material; and (d) the same test instrument. Critical thinking skills and problem-solving using multiple choice test instruments with the aspects of identify, analysis, explore and apply solution [16]. Instruments that assess performance and product aspects, where criteria for performance aspects are flexibility, originality, fluency and elaboration used to determined creativity skills, while the criteria for product aspects are the novelty, elaboration and resolution [17]. Communication skills use instruments that assess the use of clear aspects of language, adequate non-verbal communication, pauses, offers to ask questions and check for understanding [18]. Collaborative skills use instruments that assess aspects of accepting opposing viewpoints, giving elaborate explanations, asking for help, providing help, negotiating, coordinating group activities, listening attentively, and giving feedback [19].

Based on the design, it is expected that the development of teaching aids able to accommodate the needs of easiness, accelerate understanding, develop independence and improve 21st-century learning skills (critical thinking and problem solving, creativity, communication, and collaboration). With accommodation aspects of these needs, the mastery of the material technically by the students can be achieved, because these aspects have included the unity of competence (knowledge, attitude, and skills). Table 1 shows a summary of the results of proving the achievement of media accommodating these seven aspects. Teaching aids were able to produce assessments from evaluators (media experts, material experts, and students) with very decent value in the aspect of usefulness (easiness indicators). One indicator of usefulness is the convenience so that this learning tool facilitates students in learning. These facilities are accommodated from (a) trainers using plug & play systems, (b) the use of banana plug color variations for certain pin functions, and practice components according to job sheets, and (c) additional components according to the curriculum integrated into the trainer in the storage drawer. Another thing that is excellent to this teaching aids according to the design based on analysis is accommodating to be able to accelerate the understanding of students' concepts. These advantages are evident from the acquisition of very reasonable values on the display and technical aspects. Accommodating efforts to accelerate understanding is obtained from mind map at the beginning of the chapter, the visualization of digital signals on the trainer and there is information on IC pins and schematic diagrams or components in the trainer. In addition, job sheets support the establishment of group independence. This can be proven from the "independence" indicator as a technical aspect of the assessment instrument that gets a score that can be interpreted as very decent.

### Table 1. Summary of the results of achieving aspects of media development needs

| No. | Aspects                        | Evidence                                                                 | Scores                                                   |
|-----|--------------------------------|--------------------------------------------------------------------------|----------------------------------------------------------|
| 1   | Easiness                       | Easiness indicators in usefulness aspect have been valued very decent     | Material expert = 4                                       |
|     |                                |                                                                          | Media expert = 3,5                                       |
|     |                                |                                                                          | Students = 3,8                                          |
| 2   | Accelerate Understanding       | Display and Technical aspect have been valued very decent                 | Media expert = 3,85 (display)                            |
|     |                                |                                                                          | and 3,95 (technical)                                     |
|     |                                |                                                                          | Students = 3,91 (display)                                |
|     |                                |                                                                          | and 3,92 (technical)                                     |
| 3   | Group Independence             | Independence indicators in Technical aspect have been valued very decent | Media expert = 4                                       |
|     |                                |                                                                          | Students = 3,7                                          |
| 4   | Critical Thinking And Problem Solving | The analysis shows that critical thinking and problem-solving skills | DM = 95                                                  |
|     |                                |                                                                          | and EM classes are significantly better than EM classes  | - EM = 76,67                                             |
|     |                                |                                                                          |                                                          | - α = 0.0053                                             |
| 5   | Creativity                     | The analysis shows that creativity skills in DM class are significantly   | PeQ (DM) = 3,5                                          |
|     |                                |                                                                          | better than EM classes                                  | - PrQ (DM) = 3,71                                       |
|     |                                |                                                                          |                                                          | - PeQ (EM) = 3,04                                        |
| Classes | Performance Questionnaire (PeQ) = 0.038 | Product Questionnaire (PrQ) = 0.0199 |
|---------|--------------------------------------|-------------------------------------|

6 Communication

| Communication | The analysis shows that communication skills in DM group are significantly better than EM group | - Q DM = 3.6 | - Q EM = 3.2 |
|--------------|---------------------------------------------------------------------------------|-----------------|-----------------|
|              |                                                                                 | $\alpha$ Q = 0.0257 | $\alpha$ IR = 0.0158 |
|              |                                                                                 | IR DM = 88.3 | IR EM = 73.3 |

7 Collaboration

| Collaboration | The analysis shows that collaboration skills in DM group are significantly better than EM group | - DM = 3.71 | - EM = 3.13 |
|--------------|-------------------------------------------------------------------------------------------------|-----------------|-----------------|
|              |                                                                                               | $\alpha$ = 0.0488 | $\alpha$ = 0.0488 |

Note: DM: developed media; EM: existing media; $\alpha$: Significance value; PeQ: Performance Questionnaire; PrQ: Product Questionnaire; Q: Questionnaire; IR: Individual Report

Quasi-experimental results between DM groups and EM groups for all 21st-century learning skills of four-C skills (4Cs) showed significant differences (alpha value> 0.05) with higher scores in the DM group. This shows that the teaching aids that have been developed are effectively able to improve 21st-century learning skills. There were assignments in groups on the job sheet and there were assignments to arrange the series according to the job sheet is the efforts of researchers to improve critical thinking skills and problem-solving. There were assignments to set up a different set of circuits that have been practiced on job sheets and there were assignments of projects that are the efforts of researchers to increase creativity. There were an assignment to making individual reports and discussion of problems on Job sheet is the researchers' efforts to improve communication skills (written and oral). Group practices and project assignments are researchers' efforts to improve collaboration skills. Assessment of critical thinking skills and problem-solving, creativity and individual reports (communication) is carried out by researchers, while assessment of communication and collaboration skills is carried out by other colleagues in the same group.

3. Conclusion

The construction of knowledge is assumed to occur largely based on the stimulus provided by others where prior knowledge is activated, doubts and questions are shared, answers or justification will be sought together, information is exchanged, and then the new knowledge created [20]. The development of teaching aids for digital electronics practice courses by integrating 21st-century learning skills surely can foster students' knowledge. This media are easy to use, help overcoming time constraints and able to support developing group independence. Development results were in the form of trainers, job sheets and manual books.

The performance test results are stated very well according to the design and specifications specified with a 100% success percentage. The results of the material feasibility test, the media feasibility test, and the respondent's trial showed very decent results. Furthermore, the results also shown that the media is able to accommodate the needs of aspects of easiness accelerate understanding, and group independence. In addition, based on quasi-experimental results, students who use the developed media have a significantly better achievement of 21st-century learning skills (alpha value> 0.05) compared to students who use the existing media. Thus, this teaching aid is effectively used in learning to improve 21st-century learning skills, so that it is strategically able to prepare graduates' readiness to work in the future.
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