Designing learning apparatus to promote twelfth grade students’ understanding of digital technology concept: A preliminary studies

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Abstract. A preliminary learning design using relay to promote twelfth grade student’s understanding of logic gates concept is implemented to see how well it’s to adopted by six high school students, three male students and three female students of twelfth grade. This learning design is considered for next learning of digital technology concept i.e. data digital transmission and analog. This work is a preliminary study to design the learning for large class. So far just a few researches designing learning design related to digital technology with relay. It may due to this concept inserted in Indonesian twelfth grade curriculum recently. This analysis is focus on student difficulties trough video analysis to learn the concept. Based on our analysis, the recommended thing for redesigning learning is: students understand first about symbols and electrical circuits; the Student Worksheet is made in more detail on the assembly steps to the project board; mark with symbols at points in certain places in the circuit for easy assembly; assembly using relays by students is enough until is the NOT’s logic gates and the others that have been assembled so that effective time. The design of learning using relays can make the relay a liaison between the abstract on the digital with the real thing of it, especially in the circuit of symbols and real circuits. Besides it is expected to also enrich the ability of teachers in classroom learning about digital technology.

1. Introduction
Today, the digital technology material has been included in the educational curriculum in Indonesia for twelfth grade of senior high school. In the curriculum, students are expected to understand the transmission of digital and analog data and can understand its application as well in real life. Knowledge of digital technology for high school students constructed from the understanding of logic gates so that knowledge of digital technology has an abstract phenomenon. One teacher’s obstacle in class when they are faced with abstract physical phenomena is making that physical abstract phenomena to become more concrete so it can be understood more easily by the students. The real circuit of logic gate symbols must be understood by students in real circuits so as to connect students’ knowledge to digital and analog data transmission materials.

An important aspect of my operating philosophy as a training manager is that people can most rapidly accept a new technical concept if they can visualize it and relate it to something in their past experience.
In this spirit, I suggest that the broadcast engineer or technician who has not yet acquired enough knowledge of digital technology to feel comfortable about his ability to read logic diagrams can benefit by a brief study of the functional relationships between the standard logic symbols and familiar relay circuits. Relays have been around for a great many years, and their operation is easy to visualize; relays can be used, therefore, to illustrate the basic simplicity of the concepts involved in even the most complex of digital circuits. As shown in Figure 1 [1].

![Figure 1](image.png)

**Figure 1.** The two-input AND gate are functionally equivalent to a pair of relays with their contacts connected in series.

Relay design is one way of procuring physics learning media as an effort to build concrete concept of logic gate in addition to the use of transistors and IC (Integrated Circuit). Excess relay if it is used as logic gate is shown in Table 1.

| Relay design        | Transistor or ICs                                     |
|---------------------|-------------------------------------------------------|
| - Relays show the concreteness of a logic gates. | - Logic gates are still abstract because the conductor network inside the transistor or IC is not visible |
| - Design of logic gates can be tailored to the needs | - ICs are manufactured into raw components which are unchangeable |
| - Not easily damaged compared to transistors and ICs | - Sensitive to power supply installation error. |
| - Easier to obtain than transistors or digital ICs   | - Difficult to obtain especially digital IC in the outside of urban area |

Components such as switches can be used to show the working principle of logic gates. But it becomes complicated when the experiments of logic circuit gates are more complex because the switch is manually enabled. While the application of digital technology in real life generally consists of the arrangement of several logic gates. Such as the Up-Counter circuit and Binary Converter Decimal (BCD) series which will be part of the learning of digital technology materials in the classroom.

2. Methods

2.1. Relay design as logic gate

Relay design steps on digital technology materials such as Figure 2. The two planned phases are designing and assembling and applying in the classroom.
Some relays are designed so that it becomes a logic gate circuit. There are three logic gates that are designed. Logical gates of NOT, Logical gates of OR and AND for two inputs.

**Table 2. Steps in designing relay.**

| Steps in designing relay | Explanations |
|-------------------------|--------------|
| Identify the needs      | - Literature study  
- Taking the characteristics of students into account |
| Design of logic gate relays | - Power Supply used 12 Volt.  
- First, design logic gates NOT, OR and AND must be use relays on the project board. Relay design is shown in table 3.  
- Designing AND logic gates with two inputs  
- Designing logic gates in flip-flop and up-counter circuits |
| Identify the required components | - Selecting a relay that is neither too small nor too large.  
- Relays have simple circuit construction especially on NO (Normally Open) switch and NC (Normally Close). In this study used only one switch NO and NC and easily visible when the switch is working.  
- Attentive to relay quality. Adapted to the needs and presence of tools in a region.  
- Seven segment displays are used which are large to be seen from a far.  
- Seven segment displays can be made using incandescent lamps with 12 volt or adjustable voltage. |
| Assembling              | - Assemble with transparent acrylic cover and floor.  
- Provide information or instructions in certain parts of the body such as symbols, voltage terminals, input and output terminals. |
| Try Out                 | Adjust logic gate relays with truth tables such as table 3 that exist as a feasibility test. |
| Revision tool           | Repaired to complete the lack of relay design |
| Preparation of student worksheets | The product of the logic gate relay design is combined with the Student Worksheet (SW). The worksheet is designed to be interactive with media relay logic gates so that the learning is student centered. While the teacher as a facilitator in learning. |
Steps in designing relay | Explanations
--- | ---
Application in learning | In order to get a better understanding of students’ understanding of the concept of logic gates, a good learning design is needed as well.
Distribution of questionnaires and revisions if necessary | Likert scale is used to obtain students’ response to the media. This section can be developed in other ways to obtain student responses.

**Table 3.** Symbol of logic gates, truth tables and Relay design as logic gates.

| Logic gate [1,2,3] | Truth table [1,2,3] | Relay design of Logic Gates |
| --- | --- | --- |
| ![Logic gate symbol](image1.png) | ![Truth table](image2.png) | ![Relay design](image3.png) |

2.2. **Learning by using relay**
Six high school students were taken randomly which consist of 3 girls and 3 students. Before the lesson begins, in practicum room, it had been installed three cameras with two fixed position cameras in each group and one free camera is used to record and take the pictures from various angles. But the camera is more focused on learner’s whey they assemble the logic gate of NOT on part 3 activities.

**Table 4.** Implementation of logic gate by using relay.

| Meeting section | Teacher activity | Students activity | Expected students |
| --- | --- | --- | --- |
| Part 1 | Introduction - Inform digital technology in Basic Competency in Curriculum 2013 at Indonesia | Interactive Frequently asked questions about the application of logic gates on digital technology | Students understand the importance of knowledge about |
| Meeting section | Teacher activity | Students activity | Expected students |
|-----------------|------------------|------------------|-------------------|
| **Activity**<br>assembles<br>electrical circuits one loop with power supply, one switch, one lamp and connecting cable | - Inform the application of logic gates on digital technology in real life<br>- Inform the application of relay to logic gates<br>- Recall the symbol of electronics component along with the circuit symbol scheme<br>- Guiding students to practice assembling simple electrical circuit with the circuit symbol scheme<br>- Facilitate discuss about the cause of the bulb to light<br>- Inform there is a condition voltage of "1 (High)" and vice versa condition "0 (Low)" [4]<br>Apply relays in a circuit<br>- Position groups with 3 female students in one group and 3 students in other groups<br>- Inform relay symbols and relay working principles<br>- Explains the project board and how it is used<br>- Guiding students to assemble relays in circuit<br>- Guiding Interactive Discussion Questioning relates to the assembly of relays in the circuit | - Assemble electrical circuit of one loop guided symbol scheme consisting of one lamp, one switch, connecting cable.<br>- Analyze the working principle of the circuit about the cause of the lights on the set made.<br>- Interactive discussion to the working principle of the relay<br>- Designing symbol’s circuit with a relay<br>- Complete the previous circuit on the project board by using the NO switch from the relay to a circuit consisting of one lamp, one relay, one switch and a connecting cable plus a power supply.<br>- Exemplifies the truth table through a symbol’s circuit from activities part 1.<br>- Guiding students to understand NOT’s logic gates using a single switch through a symbol’s circuit and specifying its truth table | - Understand electricity in the circuit and has the skills to assemble a circuit assisted schematic symbol of the circuit. |
| **Part 2**<br>Application of switch replacement relay in series of part 1 activities | - Interactive discussion of examples given by teachers<br>- Determine the logic gate truth table NOT, OR and AND under teacher guidance<br>- Designing symbol’s circuit with a relay<br>- Complete the previous circuit on the project board by using the NO switch from the relay to a circuit consisting of one lamp, one relay, one switch and a connecting cable plus a power supply. | - Understand the working principle of relay<br>- Skillfully apply relays in series<br>- Understand the working principle of the NO and NC switches on the relay when the current through the switch on the relay so that the lamp turns on<br>- Understand the working principle of logic gates of NOT, OR and AND on symbol circuits gate well<br>- Can complete the truth table of each logic gate<br>- Interactive discussion of examples given by teachers<br>- Determine the logic gate truth table NOT, OR and AND under teacher guidance | - Understand the working principle of logic gates of NOT, OR and AND on symbol circuits gate well<br>- Can complete the truth table of each logic gate |
| **Part 3**<br>Logical gates of NOT, OR and AND | - Through Student Worksheet (SW), students assemble NOT’s logic gate using NC switch from relay on project board<br>- Define the assembly truth table and compare | - Can assemble NOT’s logic gate circuit well and correctly<br>- Able to explain the working principle of NOT’s logic gate<br>- Understand logic gates of OR and AND using two switches through symbol’s circuit and specifying the truth table | - Can assemble NOT’s logic gate circuit well and correctly<br>- Able to explain the working principle of NOT’s logic gate |
| **Part 4**<br>Designing NOT’s logic gates using NC switch on relay | - Students are separated from groups into individuals sitting far apart.<br>- Facilitate NOT’s logical gate assembly and designing activities | - Through Student Worksheet (SW), students assemble NOT’s logic gate using NC switch from relay on project board<br>- Define the assembly truth table and compare | - Can assemble NOT’s logic gate circuit well and correctly<br>- Able to explain the working principle of NOT’s logic gate<br>- Interactive discussion of examples given by teachers<br>- Determine the logic gate truth table NOT, OR and AND under teacher guidance |
Meeting section | Teacher activity | Students activity | Expected students |
--- | --- | --- | --- |
Part 1 | - Demonstrate logic gates of OR or AND that have been assembled on the project board. | - From logic gates of OR and AND relays, students analyze the working principle of logic gates (logic gates relay not assembled students anymore). | - Understand the working principle of real logic gates starting from active relays to NO or NC switch functions until generating truth tables. |
 | - Guiding students to understand the working principle of logic gates of OR and AND by realizing the electric current passing through each conductor. | - Collecting completed assembly on project board and SW. | - Can assemble logic gates of OR and AND using relay in circuit. |
 | - Together with students Comparing the use of switch with a relay on logic gates of NOT, OR and AND. | - Students sit back according to their respective groups. | - | |
 | - Describes logic gate using relay as builder of flip-flop circuit, Up-Counter circuit. | - Interactive discussion of teacher demonstrations about logic gates of OR and AND. | - | |
 | - Describe the flip-flop circuit and the Up-Counter circuit as the builder of Binary Converter Decimal. | - Students assemble logic gates of OR and AND using relays. | - | |

For the efficient time and achievement of the expected competencies are provided only NOT logical gate assembly while logic gates of OR and AND are simply demonstrated in determining the truth table. Then clarified by using the switch in the circuit.

### 3. Results and discussion

Students can understand between a series of symbols with simple circuits or real objects but confusion in more complex circuits. This shows that learners need a lot of practice. Part 1 prepares students with an understanding of the circuit with the symbol with the real circuit and the ability to assemble the circuit. However, it has been introduced about "high" or "low" voltage conditions. Part 2 Students get relay knowledge and NO switch and NC switch on relay as well as train assembly in electrical circuit. Part 3 Students get knowledge of logic gates of NOT, OR and AND with symbols and concrete objects but still using manual switch. Part 4 collaborates students' knowledge of logic gates in concrete form with the ability to assemble circuits to understand parts of digital technology materials.

Based on the analysis of the video, it is found the comparison of learning between female students and male students.

**Table 5. Analysis of practicum video logic gate NOT by using relay.**

| Meeting section | Female student | Male student |
| --- | --- | --- |
| Part 1 | - Students showed enthusiasm for the digital technology material and there is a student who looks neutral. - Students successfully assemble a series of lights, one switch and power supply using connecting cable by working although there is confusion. | - Students show curiosity to the continuation of learning activities after attentive to examples of application of digital technology materials. |
### Meeting section

| Female student | Male student |
|----------------|--------------|
| when applying a series of symbols on the assembly. | Each student can assemble a series of lights, one switch and power supply using connecting cable and the same as other students have confusion when presented a series of symbols. |
| This is because not yet accustomed to practicum, especially with the assembly of a series of series of symbols. | |
| - The three students discussed each other and gave the idea to design the relay in series. They work together on a project board but in turn. | - Students mostly work alone first, then declare the results obtained for discussion. |
| - Students need guidance when using symbol relay on the design of a series of symbols[3] | - The difficulty also lies in applying the symbol relay in the design of a symbol-shaped circuit. |
| - Although the description of the project board has been given but most students have not been able to install the relay correctly in the project board. | - Students cannot install the NO relay switch properly and correctly in the project board even though the description of the project board has been informed. |
| - There is a student assemble with a short circuit. | - Having guided the student teacher first to produce the circuit correctly |
| Part 2 | |
| Students discuss each other when understanding the teacher’s explanation of logic gates and truth tables using symbols. | Each student understands the working principle of the logic gate and the truth table generated through a manual switch circuit. |
| Part 3 | |
| - Students can assemble relays and currents make relays work but difficulty using NC relay switch into circuit on project board. Even a student looks less understood than other students | - Students can assemble the relay and current flows so the light is on but the circuit has not match the logic gate NOT. There is a student who managed to assemble the circuit in the project board correctly but the circuit of symbols that are made is still wrong. |
| - Have not successfully completed a logic gate of OR and AND assemblies with relays and one student still have motivation to continue | - Have not successfully completed a logic gate of OR and AND assemblies with relays but still have the motivation to continue |
| Part 4 | |

Activities performed by male students precede female students in correct assembly. Female students have difficulty wiring connecting cables even sometimes connected briefly. There are also female students who are less interested in assembling but prefer to listen and pay attention only.

### 4. Conclusions

Students’ ability in absorbing knowledge is varied. For example, female students tend to hold many misconception of electric circuit [6]. The difficulty in understanding electric circuit is also described by Gunstone et al [7]. Understanding the electricity in the circuit is the initial knowledge of planting the concept of logic gates on the material of digital technology. From video analysis and students’ answers in worksheet and project board assembling result in practicum activities as well as taking into account the availability of time, it is recommended that: 1) students understand first about symbols and electrical circuits; 2) the Student Worksheet is made in more detail on the assembly steps to the project board; 3) mark with symbols at points in certain places in the circuit for easy assembly; 4) assembly using relays by students is enough until is the NOT’s logic gates and the others that have been assembled so that
effective time. Until NOT’s logic gates is sufficient to the next stage of learning. With the AND's logic gates can already be used as a digital signal-forming circuit.

Designing learning using relay is expected to enrich the ability of teachers in classroom learning about digital technology in the current curriculum. In addition, designing learning using this relay helps teachers in redesigning the learning of digital technology using relays. The design of this relay can be developed into a circuit of Binary Converter Decimal (BCD) according to subsequent material on the application of technology in everyday life [8 - 11].

Binary numbers can be converted to decimal by mathematical calculations while BCD circuits are hardware devices that function like those calculations (software). So, behind the real series of BCD (hardware) there is a mathematical calculation (software) that is abstract. Just like the abstract symbol and the object as the real thing. This is where the relay function connects between real and abstract in digital technology material.

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