Realization of Null-type Bridge Instrument to Determine Water Level to Anticipate Flood Using Inquiry-based Learning

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Abstract. Teaching method and quality of teacher is some factors that determine quality of education. One of learning methods to increase students understanding is Inquiry-based Learning (IBL) that places students’ questions, ideas, and observations as the center of learning. In this method, students worked in a group to learn through a process of inquiry by a stimulus question from the lecturer. In this paper, the IBL method was used to improve understanding in null-type measurement by using bridge circuit as a variable conversion to determine the level of water and its application. In this method, a group of three students was to inquire the topic. There are six steps that has been done: (i). stimulation, a stimulus question from a teacher, (ii). problem statement, driving questions to be solved and to make hypotheses, (iii). data collection, searching information and doing experiments, (iv). data processing, analyzing the data, (v). verification, making sure the students have solved their equations, and (vi). conclusion, answering the questions and presenting the result of enquiry. Following the IBL method, it was shown that the null-type D.C. bridge circuit with an LDR (light dependent resistor) as a sensor can be used to measure water level for anticipating flood.

Keywords: Inquiry-based learning, Null-type Bridge, LDR, Water Level

1. Introduction

Based on the Oxford Learner’s Dictionaries, inquiry is the act of asking questions or collecting information about somebody/something. In this modern era, a transformation has been beginning in learning approach from teacher-centered learning (TCL) to student-centered learning (SCL) in several colleges [1]. TCL as a passive mode of learning has a characteristic of the delivery of information in which students are simply expected to accept and learn. Inquiry-based learning (IBL) is a term of SCL in which students learn more about phenomenon/issue through enquiry by observation [2]. Encouraging learning by inquiry, a student-centered method, self-directed learning, and active learning activities are the key attributes of EBL that can make students experience the processes of building knowledge [3]. Methods of learning in IBL place students’ questions, ideas, and observations at the center of learning. Students work in a small group to do an investigation including (i) searching information about a problem, (ii) engaging in evidence-based reasoning, and (iii) solving the problem [4]. A teacher in IBL
acts as a facilitator who gives a challenge/problem to students, help them in problem identification, and guide them to solve the problem [5]. According to Sanjaya [6], IBL should concern about five principles: developing intellectual-oriented, interaction, asking a question, learning to think, open-minded. As a result, students have many advantages. First, IBL can increase students’ motivation of learning so that students will have greater understanding by learning more about the material. Second, students acquire experience in a range of intellectual and social capabilities. Then, IBL can increase many skills of students, such as analytical skill, literacy skill, research skill, problem-solving skill, critical thinking, etc. [7-11]. Application of IBL in department of physics, students remarked on benefits, such as increasing motivation of learning and having a greater understanding about the material in course deeply, training self-reliance to the investigation about a problem, increasing skill in research; acquiring experience in social capabilities such as working together with a partner [7-11]. It was said that we will learn more by seeking information to answer a question than we just learn from material written in a book or given by a lecturer [12]. The IBL make students gain more information about a topic in a course to develop their understanding and know the application of the topic.

In this paper, the IBL method was used for making water level measurement using a null-type of D.C. bridge. The null-type bridge measurement was equipped with a VU (volume unit) meter, a bridge configuration with LDR (light dependent resistor) as a sensor. This prototype gauge was used to determine water level from null position, where the null position is defined as critical level point to inform the preparation of flood evacuation.

2. Methodology
In the process, three students were grouped into one small group with a lecturer and a tutor as facilitators. Every group was given a topic by the lecturer to solve the problem. The topic of our group was to make a null-type bridge instrument to measure a water level. To solve this topic, the IBL method was used. Generally, the IBL method consists of the following steps [13].
1. Stimulation
   In this step, the lecturer begins giving a question or an instruction to the group of students to read and learn an issue that has a problem.
2. Problem statement
   The group of students identifies issues and chooses interesting issues to be solved. Then, these issues are framed in the form of questions or hypotheses.
3. Data collection
   To solve the issue, the group of students finds as many as possible related sources, i.e., books, journals, interview, observation, experiment, etc.
4. Data processing
   All collected information are processed, formulated, calculated, and interpreted to certain confidence level.
5. Verification
   Based on the results of data processing, questions or hypotheses are examined if they have been answered or verified or not.
6. Conclusion
   From the results of verification, the group of students concludes the results of research that has been done.

3. Results and Discussion

3.1 Stimulation
Measurement techniques have been of immense importance ever since the start of human civilization. There are three main applications about measurements. First, measurements are used to regulate the transfer of goods in barter trade to ensure that exchange were fair. Secondly, as monitoring function, i.e.
to monitor certain values of quantities such as room thermometer, barometer in a laboratory, etc. Lastly, as an automatic feedback of control systems in which it acts as monitoring as well as giving action as adjustment to quantity value to be stable [14]. In Department of Physics of Institut Teknologi Bandung, the Measurement Methods and Data Processing course is compulsory and describes measurement systems and how to process data gained from measurements in order to be readable. One of the aspects of assessments of this course is to build a measurement instrument from given topics. The lecturer gave a project to the group of students with a topic: null-type level measurement with a bridge circuit as a variable conversion unit for some applications. The design of measurement system using sensors and devices as well as its applications were determined by the group of students.

3.2 Problem Statement
The applications of liquid level measurement are divided into four areas: (i) point level detection to avoid overfilling or excessive of tank, (ii) continuous measurement to measure the level of media, (iii) density and (iv) interface measurements [15]. Null-type measurement is a type of measurements that has special applications, which are mostly used in calibration since it has only one value that represents one special condition known as datum level to be compared to a measured quantity. For a deadweight gauge with 1 kg datum level for instance, measurement of weight is done by checking if the pointer has pointed to 1 kg (datum level). If the pointer points to datum level, the quantity value corresponds to the measured one. Then, the question arose, what level will be measured and what is/are the application(s) of null-type measurement for the datum level? Moreover, in a measurement system with a bridge circuit as variable conversion unit, its sensor can be resistive, capacitive, or inductive. The second question is what sensor is suitable to observe the level change with good sensitivity, automatic, and inexpensive? In addition, for the measurement that can be done effectively without having large errors, what is the suitable design for a level measurement system so that it is independent of unwanted variables? As each instrument has specific sensitivity, the further question is what is the deviation of the level measurement?

3.3 Data Collection
Sensors are components that are sensitive to physical or chemical change in their surrounding environment. Outputs of the sensors are in the forms of voltage and current that can be read with voltage indicating and testing instruments, such as moving coil meter, moving iron meter, clamp on meter, etc. Sensor outputs due to the change of environmental condition are in the form of resistance, inductance, capacitance, and currents. To convert those parameters into voltage, a variable conversion unit such as a bridge circuit can be used. The bridge circuit can detect very small change in resistance, inductance, and capacitance components [16]. Moreover, the bridge circuit output is in the form of A.C. signal for inductance and capacitance measurements, while D.C. signal form is for resistance measurement. Regarding to the applications, the bridge circuit is divided into 2 types: null-type for calibration use in which it has only one measurement value to be compared and deflection-type for measurement use which is more convenient than the null-type [16]. As one value quantity measurement and a resistive sensor were used, this problem would use the null-type D.C. bridge circuit.

The null-type D.C. bridge circuit, which is also known as Wheatstone bridge, is shown in Figure 1. The circuit consists of 4 resistors, which are \( R_u \) as a sensor against the environmental change, two resistors with the same value, \( R_2 \) and \( R_3 \), and \( R_1 \) as a resistor to control null-point of the circuit. In general, if the galvanometer has \( V_m \) resistance as shown in figure 1, the output value \( V_m \) can be calculated with Equation (1) [16].

\[
V_m = \frac{V_1 R_m (R_1 R_2 - R_u R_2)}{R_1 R_2 (R_u + R_m) + R_u R_2 (R_1 + R_2) + R_m (R_1 + R_2)(R_u + R_1)}
\]  

(1)
The bridge circuit converted variable resistance into voltage in which the generated voltage could be observed using a VU Meter [17-19]. VU meter is a moving coil meter that is also voltage indicating and testing instruments. As it consists of rotating coil on iron core as a permanent magnet, the higher the current flows in the coil, the higher the deviation of coil rotation occurs [16]. On the outside, the pointer attached to coil to display coil rotation that is generated from current flow.

In Indonesia, floods are a frequent disaster in rain season. Floods cause many damages ranging to environmental damage to human fatalities and infrastructure damages [20]. To anticipate those bad effects, an instrument to monitor water level is needed so that people can prepare and reduce damages and losses caused by floods. In this case, water level measurement is required.

Based on theory, water level can be measured by using dipstick, float system, hydrostatic system, etc. [16]. In this case, a sensor to measure level is focused only on resistive-based one. One of the sensors that can be used in level measurement is potentiometer. The change in water level can be connected to turn the potentiometer. But, in water level measurement, we can use the characteristic of light intensity. Light intensity depends on the distance between a light source and an observer. The light source can be designed so that it can follow the water surface. The ups and downs of water cause the position of the light source changes and therefore changing the distance between the light source and observer; and thus changing the light intensity. The value of light intensity can be read by an LDR (light dependent resistor) sensor. Generally, LDR has an exponential relationship between resistance and light intensity. By measuring the change in the light intensity in which the change depends on the water level, this system can then be used as water level measurement.

The instrument was designed as given in Figure 2 based on the following consideration. To measure the water level, foam was used because it will float and follow the water level of the river. In order to prevent the foam from being carried away by the current, a movement path of the foam was created. A PVC pipe was used to restrict the horizontal movement, making the foam can only move vertically. The LDR sensor and electronic circuit were installed above the pipe so that it would not be exposed to water. The light source was installed above the foam so that it follows the water level. Therefore, the light intensity change depended on the water level and the change of water level could be detected by LDR.

The light intensity of the environment surrounding the instrument might change because of several factors. The unstable condition of the surrounding could affect the light intensity that the LDR received. To make the intensity inside the pipe remains constant in different environmental condition, the surface of the pipe was covered by using a black tape. This was done so that there were no light that passed...
through the pipe. Therefore, the light from the surrounding did not affect the light intensity inside the pipe.

Based on the multimeter measurement, the VU meter had the resistance of 840Ω and maximum current of 0.783 mA. Then, the resistance of LDR sensor was obtained at the range of 0-8 kΩ. Based on these characteristics, the value of R₂ and R₃ was adjusted to be 10.5 kΩ by calculation. The null-point was calibrated at 50 cm-water level. Experiment was done by dipping the instrument into water and changing the water level. Then, the change in VU meter needle was seen in the observation.

3.4 Data processing
The LDR used was characterized and its characteristic is given as resistance as a function of light intensity as shown in Figure 3. It was found that the resistance of LDR decreases dramatically when the light intensity increases in which the LDR has high resistance at the dark condition and low resistance at a high light intensity. This characteristic is the same as that given in ref. [21], where the resistance at the dark condition is around 10 kΩ and limit to 0 at very high light intensity.

The characterization of instrument response to water level was also done to see the relationship between the resistance and water level. Based on the characterization results, the relationship is given in Figure 4 with a linear relationship written as

\[ y = -0.0828x + 8.0304, \]  

where \( y \) is the resistance and \( x \) is the water level. It is shown that the curve has a negative gradient with the value of 0.0828 kΩ/cm. It means that when the water level increases one centimeter, then the resistance of LDR decreases by 0.0828 kΩ or 82.8 Ω. Based on theory, a higher water level makes the light intensity reaching the LDR higher because the light intensity proportional to inverse square of the distance [22] so that the resistance of LDR will be lower. As a result, a higher water level makes the resistance of LDR lower. The measurement was visualized by using a VU meter. The water level was converted into the resistance of LDR that will affect the output voltage on the VU meter. Using the distance of 50 cm as a null point, the relationship between the output voltage on the VU meter and the water level was obtained as depicted in Figure 5.
As shown in Figure 5, the relationship between water level \((x)\) and output voltage \((y)\) has a positive gradient with quadratic fitting given by Equation (3).

\[
y = 0.0516x^2 - 0.8575x - 2.7733
\] (3)

It explains that the increase of water level makes the output voltage higher. The rate of voltage change becomes higher when the water level reaches high level. From Figure 4, the resistance will be lower when the water level becomes higher. If the resistance becomes lower, the output voltage will become higher according to Equation (1). Therefore, it is right that the output voltage will be higher when the water level becomes higher.

3.5 Verification

Water level measurement using point level detection has more benefits. It can be used to anticipate the arrival of flood. The null-type measurement can be used as a sign. When the water level reaches the null point, people are signaled to evacuate immediately.

The design of the instrument has been made to be suitable for river water level measurement. The pipe caused the buoy to move only vertically across the pipe and would not be affected by the velocity of the stream. The buoy moved vertically according to the water level. When the buoy moved upward, the distance between the buoy and sensor decreased and thus increasing the light intensity inside the pipe. The light intensity was converted into the resistance using the LDR and converted further as an output voltage in the VU meter. The pipe was covered with black tape so that there was no light that passed through the pipe, which could create a different measurement in different places. Based on this instrument, measurement results showed precise results and only depended on the water level.

Based on experiment using the design in Figure 3, there was a linear relationship between the LDR resistance and water level as seen in Figure 4. For each change of height, there was a relatively same amount of change in the LDR resistance. This shows that the LDR monitors the height with a constant change, which is suitable to be used as water height sensor.

The relationship of VU meter to water level had a proportional relation. The higher the water level is, the greater the voltage change in the VU meter is. Based on this, when the water level had reached 50 cm, the slope of the graph became steeper, making the null-point area could be observed more accurately. This means that the instrument can effectively be used as a flood anticipation instrument.

3.6 Conclusion

Based on the verification results, it can be concluded that:

a. Level measurement with point detection principle is very useful to anticipate flood at a flood prone area so that it can reduce the loss caused by flood.
b. LDR sensor is excellent for monitoring the change of water level because it has a linear relationship with the resistance of LDR.

c. By using the instrument design in Figure 2 and covering the pipe by black tape, the intensity of light in the instrument only depends on the water level and will not be affected by the intensity of the environment surrounding the instrument.

d. The output voltage is very good to be used as flood anticipation because the higher the water level is, the greater the deviation on the VU meter and greater deviation means greater accuracy.

4. Conclusion
Under the IBL procedures, the null-type water level measurement with D.C. variable conversion has successfully been realized using an LDR as a prototype instrument to anticipate flood. The results showed that the increase of water level decreases the resistance of LDR linearly and increases the output voltage of VU meter. When the water level reached the height limit, the VU meter would show the pointer to the null-position as emergency signal.

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