Realization of Deflection-type Bridge instruments to determine soil moisture using Research-Based Learning

E Yuliza¹, M M Munir¹, M Abdullah¹ and Khairurrijal¹,²

¹ Departments of Physics,
² Master Program in Physics Teaching,
Faculty of Mathematic and Natural Science, Institut Teknologi Bandung
Jalan Ganesa 10, Bandung 40312, Indonesia

E-mail: krijal@fi.itb.ac.id

Abstract. It is clear that the quality of education is directly related to the quality of teachers and the teaching methods. One of the teaching methods that can improve the quality of education is research-based learning (RBL) method. In this method, students act as the center of learning while teachers become the guides that provide direction and advice. RBL is a learning method that combines cooperative learning, problem solving, authentic learning, contextual case study and inquiry approach discovery. The main goal of this method is to construct a student that can think critically, analyze and evaluate problems, and find a new science from these problems (learning by doing). In this paper, RBL is used to improve the understanding about measurement using deflection-type Bridge that is implemented in the determination of ground water changes. In general, there are three stages that have been done. Firstly the exposure stage, then the experience stage and lastly the capstone stage. The exposure stage aims to increase the knowledge and the comprehension of student about the topic through understanding the basics concepts, reviewing the literature and others. The understanding gained in the exposure stage is being used for application and analysis at the experience stage. While the final stage is the publication of research results both verbally and in writing. Based on the steps that have been conducted, it can be showed that deflection-type Bridge can be utilized in soil moisture meter.

1. Introduction
As reflected by a general definition of research as “the organized, systematic search for answers to the questions we ask” [1] or a somewhat more elaborated definition as a “systematic process of inquiry consisting of three elements or components: (1) a question, problem, or hypothesis; (2) data, and (3) analysis and interpretation” [2], research is one important component in the advancement of science and technology. It was reported that higher education can be distinguished from other levels of education by the linking of teaching to creation and discovery [3]. The link is called as research-based learning (RBL), which is a learning method that integrates research with learning and immerses students in the culture of inquiry and research [4]. As a result, students have remarked on benefits such as: increased motivation to engage more deeply with course contents, greater confidence knowing where to start with the library and research, increased sense of inclusion in the class, more interactions, less intimidation, and higher quality of work as a result of dialogues and feedback [5-8].

Application of RBL in various fields have been reported. In physics, As a result, students have remarked on benefits such as: increased motivation to engage more deeply with course contents, greater
confidence knowing where to start with the library and research, increased sense of inclusion in the
class, more interactions, less intimidation, and higher quality of work as a result of dialogues and
feedback [5-8]. A specific route to apply RBL in medical education has been discussed [15]. On the
other hand, efforts in embedding RBL in social science education such as geography, literature and
social science was started [16, 17, 18].

In this paper, the RBL method was used for the making the soil moisture meter using a simple type
bridge deflection measurement. The deflection measurement bridge type is equipped with a VU (volume
unit) meter and a bridge configuration which serves to verify the soil water content. Further, the soil
moisture meter can be used to determine the water content of the soil in an effort to produce early
warning system of landslide.

2. Methodology
In conducting this project, students worked in a small group with a lecturer and a tutor as guides who
gave inputs and also acted as research collaborators. In the development of the soil moisture meter that
will be used to determine the water content of the soil in the early warning system of landslides, the
RBL model that includes the following three stages of students’ research involvement [4] has been
adapted.

1. Exposure stage
   This initial stage has the following characteristics: a) developing and acquainting students to
   additional and related materials, b) developing the analytical and technical tools of the additional
   and related materials, and c) exposing students to recent or ongoing research done by faculty
   members. In other words, this stage aims to improving students’ knowledge and comprehension
   about the additional and related materials.

2. Experience stage
   This stage has the following characteristics: a) enriching students with related advanced
   knowledge, b) facilitating students to learn and work independently, and c) facilitating students
   to gain a good command on communication skills. Therefore, this stage aims to developing and
   improving students’ competences in application and analysis of the related advanced knowledge
   and gaining communication skills.

3. Capstone stage
   This final stage is served in the students’ projects that should have the following characteristics:
   a) application of previous overall experience of learning and research to perform the projects
   with a high degree of autonomy, b) presentation of results both written and orally, and c)
   scientific publication. So, this stage aims to synthesizing and evaluating students’ known
   knowledge and having communication skills.

3. Result and Discussion

3.1. Exposure stage (Bloom’s taxonomy: understanding + comprehension)
Sensor is material or a component that is sensitive to changes in physical or chemical properties, hence
it can be used to detect the environmental changes. The recent advancement in sensor technology
contributed substantially in fields including – but not limited to – disaster mitigation, industry, and
education. Usually, a certain treatment is needed to convert the change in environmental conditions
detected by the sensors to the physical units like current and voltage. One of the instrumentation systems
that are capable to do this is a bridge circuit. A bridge circuit is generally used as an element of variable
converter in the measurement system and it produces output voltage that changes according to the
physical changes that occur [19]. A very small change of capacitance, resistance, and induction can be
detected accurately using the bridge measurement principle. Generally, there are two types of bridges, the deflection type and the null type. The deflection type is normally used for determining the magnitude of the physical change while the null type is used for calibration [19]. Therefore, the determination of bridge type is done according to device specification and the desired application. This study is focused on the discussion about deflection-type Bridge.

The schematic diagram of deflection-type Bridge is shown in figure 1. The deflection-type bridge consists of four resistors R1, R2, R3 and Ru as unknown resistances. The output voltage VO varies as the resistance Ru changes. When Ru= R1 it is clear that VO=0 (since R2= R3). The voltage source is used battery or others through the points AC. Based on theory, output of measurement can be calculated by using equation 1:

\[ V_o = \left( \frac{R_u}{R_u + R_3} - \frac{R_1}{R_1 + R_2} \right) \]

Figure 1. The Deflection-Type d.c Bridge [19]

The measured value in this bridge can be read using voltmeter or other similar devices. One of the devices that is utilized to replace the function of a voltmeter is a VU meter.

A VU (volume unit) meter as shown in figure 2 is a device that is commonly used to represent signal level in audio equipment. Along with its development, this device is also applied as measurement display. Basic principle of the VU meter uses the principle of moving coil meter. This device contains a rectangular coil that rotate around an iron core which acts as a permanent magnet [19]. The pointer of VU meter rotates when a d.c current is flowing through to the coil. The amount of rotation of the coil is proportional to the current that through to the coil [19].

Figure 2. A VU Meter

In sensor technology, various sensors like capacitive and resistive sensor have been developed. In this study is focused on resistive sensor, which is sensitive to changes in resistance. One of the resistive
sensors is a watermark sensor. This specific kind of sensor is used to measure a change of groundwater content in hydrology and agriculture. Generally, watermark is a solid state electrical resistance sensor that consists of external component that’s made of a porous ceramics and internal matrix structure containing two electrodes [20]. The internal matrix of the sensor is consisted of synthetic porous materials which serve as water absorber. The change of water content around the sensor is represented as a change of resistance. The resistance of watermark sensor decreases with the increases of the volume of water content. The Watermark sensor is shown in figure 3.

![Watermark Sensor](image)

**Figure 3. Watermark Sensor**

Watermark sensor is a resistive sensor where physical change will change the resistance value. This sensor can be used to detect changes in the groundwater content. The changes of water condition inside the Watermark sensor related to variation of water in soil surrounding the sensor. However, the output of the sensor is resistance. To change the sensor output from resistance to voltage, the bridge-type deflection can be used. The preference on the deflection type was because the bridge can be used to determine the value of physical change.

3.2. *Experience Stage (Bloom’s taxonomy: application + analysis)*

Landslide is one of main major disaster in around the world. Geographical structure, climate condition and increase in population play major role to the increasing frequency of landslide occurrence [21-24]. Based on the historical data of landslide, rainfall is the main triggering factor in many landslides event. However, since soil characteristics, the topography, seepage and covering vegetation affect water infiltration into the ground [25, 26, 27], hence the measurement of the change in groundwater content can be effectively used for early warning systems of landslides. Generally, soil with more water content has better electric conduction. Therefore, changes in water content of ground will alter the resistance and specifically the increase of groundwater content will decrease the resistance.

As stated in exposure stage, watermark sensor is a resistive sensor that can be used to detect changes in water content, hence its usefulness in landslide early warning system. Before the instrumentation system is used to measure water content, some preparatory step is done to adjust the system. The first step was to determine the resistance components of the bridge circuit and a VU meter as display of output voltage. The resistors R1, R2 and R3 were chosen to have value of resistance 1500Ω and resistance of VU meter about 845Ω. The measurement of sensor response is done after the components and Watermark sensor are assembled such as figure 3. Based on this measurement, the pointer deviated to the right but the output result was not displayed correctly. Theoretically, the output display in VU meter is influenced by its internal resistance. If the resistance value is smaller, the ensuing error would be higher. The results of the experiments conducted verified this theory. To solve the problem, the internal resistance of the VU meter had to be increased by adding resistor that are connected serially as in Figure 4 below.
According to the theory about basic principle of bridge measurement and the real problems on the field, a research to building a soil moisture meter has been developed. To reduce the error in measurements, a correction in circuit schematic is required. In the experiment with soil sample, a bridge circuit shown in Figure 4 was used. The VU meter’s resistance is increased using external resistance which was connected serially to the VU meter. The bridge components and the external resistance of VU meter (Rm) were assembled according to figure 4. To observe the sensor response as function of water volume water accurately, this experiment was conducted using dried soil. The soil was heated in the oven at temperature 105 OC for 24 hours to relieve the water content on the soil. This treatment was done based on the standard method for determining soil moisture, the gravimetric method.

The measurement result of this can be seen in figure 5 below. A sample of dried soil was inserted to a cup and then water is periodically poured. While this procedure is done, the change in VU meter was observed. The results show that there are decreases on soil resistance during the addition of water content of the soil. Decreasing of the resistance value indicates that the soil is better on conducting electricity, so the pointer of VU meter deviates. It would deviate further to the left as the water content is higher.
According to measurement result using various water volumes, a correlation curve between voltage and volume of water in an exponential function was obtained and it shown in figure 5. The limitation in measurement variation caused this curve have low regression value, thus an improved result is obtained by adding water variation. In this experiment, the sensor response is measured with 50 ml water increment. The addition of water was based on the soil characteristics and the sensor response to a change of water amount. When a limited amount of water was added, it did not spread uniformly so that the sensor responded as if there were no change. Nevertheless, the output characteristics observed corresponds to general resistive sensor characteristics.

Watermark sensor consists of two electrodes and synthetic porous material that embedded in the sensor. The water around the sensor would be absorbed by porous material and the values were measured after the water content in the soil and the material reached equilibrium. The characteristic curve of the sensor has the same trend as the discharging curve of a capacitor. When this is analyzed using capacitor principles, the synthetic material would serve as dielectric material that is positioned between two electrodes. With these characteristics, there are saturation states where the increasing of volume of water does not affect the sensor output. In the case of landslides that are induced by the increasing of water volume, the ground movement might occur in saturated state. In this condition, the change of the resistance is not affected by the increase of water volume. However, there are also increases in volume, load and pore pressure which lead to the instability of the soil.

4. Conclusion
Based on the RBL model learning steps, the soil moisture meter has been successfully created. This meter can be used to determine the change in groundwater content. The result shows that the increase of water content on the ground will lower its resistance. Besides, it is found that the output characteristic of the sensor is exponential such as capacitor discharge curve. Thus, when the soil has been saturated, the addition of water does not change the resistance value. In some cases, landslides occur when the soil has reached saturation.

References
[1] Hatch E and Lazaraton A 1991 The research manual: Design and Statistics for applied linguistics (New York: Newbury House) p 1
[2] Nunan D 1992 Research methods in language learning (New York: Cambridge University Press) p 3
[3] Butcher C, Davies C and Highton M 2006 Designing learning: From module outline to effective teaching (New York: Routledge)
[4] Waris A, Haryono S, Sutrisno W, Haryanto F, Iskandar A A, Bijaksana S, Sutarno S and Arifin P 2006 Proc. The 6th Annual SEAAIR Annual Conf. – Transforming Higher Educatio, for the Knowledge Society (Langkawi) (Australia: JIRSEA) pp 131-9
[5] Blackmore P and Cousin G 2003 Educational Developments 4 pp 24-7
[6] Knutson K, Smith J, Nichols P, Wallert M A and Provost J J 2010 Bringing the excitement and motivation of research to students; using inquiry and research-based learning in a year-long Biochemistry laboratory: Part 11—Research-based laboratory—A semester-long research approach using malate dehydrogenase as a research model Biochemistry and Molecular Biology Education 38 pp 324-9
[7] Jiang F and Roberts P J 2011 An investigation of the impact of research-led education on student learning and understandings of research J. University Teaching & Learning Practice 8(2) Article 4
[8] Brew A and Jewell E 2012 International Journal for Academic Development 17(1) pp. 47-58
[9] Sutrisno W, Satira S and Arifin P 2006 Proc. The 6thSEAAIR Annual Conf (Langkawi) (Australia: JIRSEA) pp 252-6
[10] McKagan S B, Handley W, Perkins K K and Wieman C E 2009 Am. J. Phys. 77 pp 87-94
[11] Zhu G and Singh C 2012 Phys. Rev. ST Phys. Educ. Res. 8 010118
[12] Louangrath P 2015 *Proc. 2nd Int. Conf. Innovation in Education (Nakhon Pathom)* (Thailand: Institute for Innovative learning Mahidol University) pp 182-191
[13] Tang X-J, Lu Y and Liu N 2014 *Proc. Int. Conf. Advanced Information and Communication Technology for Education (Dalian)* (Paris: Atlantis Press) pp 83-6
[14] Hamilton J 2011 *Medical Journal of Islamic Republic of Iran* 25(2) pp 53-6
[15] Hassan S 2013 Applying research-based learning in medical education through the route of special study modules: Notes from the UK *SA-eDUC. J.* 10 pp 1-26
[16] Nicholson D T and Geogr J 2011 *Higher Educ.* 35 pp 529-49
[17] Saputra K S 2013 *Proc. Int. Conf. English Language Teaching (Melaka)* (ICELT) pp 1-11
[18] Berdahl L 2014 Engaging undergraduates in social science research: The taking the pulse of saskatchewan project *Collected Essays on Learning and Teaching (CELT)* 7 pp. 100-105
[19] Morris A S 2001 *Measurement and instrumentation principle Third edition* (MA USA: Butterworth Heinemann)
[20] Mark S, Payero J O, VanDeWalle O, Rees J and Zoubek G 2014 *Principle and operational characteristics of watermark granular matrix sensor to measure soil water status and its practical applications for irrigation management in various soil textures* (Lincoln: University of Nebraska-Lincoln Extension)
[21] Nadim F, Kjekstad O, Peduzzi P, Herold C and Jaedicke C 2006 *Landslides* 3 pp 159-173
[22] Ramesha M V and Vasudevan N 2012 *Landslide* 9 pp 457-474
[23] Yurui S, Lammers P S, Daokun M, Jianhui L and Qingmeng Z 2008 *Sensor Actuat. A-Phys A* 147 pp 352-357
[24] Arnhardt C *et al.* 2007 *Geotechnologien Science Report*
[25] Chae B G and Kim M I 2012 *Environ Earth Sci.* 66 pp 1973-86
[26] Blasio F V 2011 *Introduction to the physics of landslides* (New York: Springer)
[27] Carter M R and Gregorich E G 2008 *Soil sampling and methods of analysis, Second Edition* (New York: Taylor and Francis Group)