Design of hydraulic tools for students’ practicum

M Maison¹, F Ilfan² and J H Triyanto³

¹ Program Studi Pendidikan Fisika, Universitas Jambi, Jl. Raya Jambi – Ma. Bulian KM. 15, Jambi 36361, Indonesia
² Program Studi Teknik Lingkungan, Universitas Jambi, Jl Tribrata KM. 11, Jambi 36364, Indonesia
³ Program Studi Teknik Sipil, Universitas Jambi, Jl Tribrata KM. 11, Jambi 36364, Indonesia

*maison@unja.ac.id

Abstract. Fluid mechanics and hydraulics subject is a subject that explains the concepts of the nature of fluids (liquids and gases) when stationary or moving, or when interacting with other fluids or solid objects. One of the courses in this subject related to hydraulics is about open channels. Many students have difficulties understanding this material and not able to describe abstract concepts because they were not doing experiments with the open channel. The purpose of this research is to develop hydraulic devices for open channels that can be used by students for practicum. The methods used to develop these tools are the study of literature, determination of design concepts, exploration of design scenarios, toolmaking, testing, evaluation, and improvement the tools. These tools are also equipped with a microcontroller to regulate water flow, the slope of the water-retaining plate to display hydraulic jumps and adjust the pump power. The test results show that the tool can provide consistent results, both from flowrate, weir overflow coefficient, and Froude numbers.

1. Introduction

Fluid mechanics is the science that deals with the properties of fluids when stationary (static) or when moving (dynamic) [1], and their interactions with solid objects or with other fluids within a certain range. The branch of fluid mechanics that studies the movement of fluids while in closed and open channels is called hydraulics [2]. In everyday life, various phenomena in nature are very closely related to this science. This science also provides enormous benefits for the development of various fields of science, such as in almost all fields of engineering, biology, physics, and medicine. Various designs in the field of water, such as drainage (rainwater channel), water supply, wastewater management, and machinery equipment in industry require this field of fluid mechanics.

The concept of hydraulics learning emphasizes physical aspects, so if it cannot be displayed or imagined in real life, the concept will be difficult for students to understand. In the study of fluid mechanics and hydraulics, there are various main study materials, including: fluid pressure and statics (fluid when stationary), floatation and stability, fluid kinematics, Bernoulli and energy equations, fluid dynamics in closed channels, and fluid dynamics in open channels [2]. Students should master the concepts in these various materials in order to become competent graduates.

According to the Accreditation Board for Engineering and Technology (ABET), an international accrediting organization in the engineering field, an engineering graduate must have the ability to design...
a system, component or process that can meet the required standards [3]. This shows that an engineering scholar must master basic concepts and be able to apply them in analyzing things that occur in nature, and have the ability to apply what he knows in the form of buildings, devices, or other types of products.

One effort to improve students' understanding is to use a model that is made according to the material to be conveyed and is a simplification of the conditions that occur in nature. The model can be audiovisual, or physical model. Audiovisual models that describe fluid mechanics are numerous on the internet because indeed the spectrum of fluid mechanics courses is very broad and is common in various fields of science. However, students' understanding and skills cannot be developed if they only rely on lecture and audiovisual materials. They need to be assisted with physical learning media, so that they can be touched, can be seen and can be modified.

The laboratory is a very important component in engineering education. From this laboratory trained the skills needed by an engineer, including communication skills, knowledge, teamwork, ethics, and the ability to obtain information that is used to support students' understanding of theoretical concepts [4]. Furthermore, Edward [5] explained that the purpose of learning through practice, included in 4 large groups, namely:

- Cognitive learning, which is often explained by the integration of theory and practice;
- Inquiry methodology, including the formation of hypotheses, design and methodology of experiments, as well as evaluations of experimental results;
- Relationship with the profession that will be undertaken;
- Personality development, such as communication skills, writing reports, and teamwork.

An engineering graduate must be able to process three basic resources in creating technology, namely energy, material and information [6]. These skills can be trained with practical education, both in the laboratory and outdoors.

To carry out the practicum, it usually requires a large fee and in this fluid mechanics practicum, laboratory equipment that are commonly used are relatively high cost and imported from industries abroad. By developing the practicum tool, it is expected that the costs incurred for the procurement of laboratory equipment can be reduced and students can use it to learn so that a good level of understanding and ability to solve problems related to fluid mechanics especially in hydraulics can be achieved.

Nikolic et al. [7] evaluating the improvement of learning ability and satisfaction of students in engineering laboratory activities by evaluating it from the cognitive, psychomotor and affective sides. From their research results, it is known that students were satisfied with laboratory activities. Students were able to improve their analytical skills in the cognitive and psychomotor skills. Nikolic et al. [7] findings suggest that the design of learning must promote psychomotor development, not just cognitive.

In designing practice in a laboratory, limitations must be known, such as the limits where the device is stored, the cost of procuring and maintaining the equipment, and the ease of removal. Furthermore, it is necessary to know the condition of students, such as what topics are most difficult to understand, what phenomena are difficult to imagine, and what topics are most important to be mastered by students [8].

There are many studies using physical models in the field of fluid mechanics. The aim is to reduce the influence of various variables in the undesirable nature. The material in fluid mechanics that is used in physical models related to open channels can be found in studying the phenomenon of hydraulic jumping, sedimentation in channels, the effect of channel branching on the channel's basic morphology, etc.

Neluwaala et al. [9] examine the hydraulic jump characteristics that occur in channels with a rough channel base at different flow rates. The hydraulic parameters assessed are water depth and discharge at different channel bottom roughness. This study shows that the channel bottom roughness reduces the jumping distance from the channel threshold and reduces the water depth ratio at the start and end points when compared to the slippery channel bottom. A mathematical formula was also produced from the study which showed a comparison between the hydraulic jump characteristics and the roughness density (distance between obstructions) at the base of the channel and the height of the roughness.
Tuyen and Cheng [10] examines flow resistance in slippery, rectangular open channels with a low aspect ratio. Aspect ratio (α) is the ratio between channel width and water depth. This study uses an equation which is a modification of the Prandtl friction equation introduced by Cheng et al. [11] to determine the friction factor (f) which is a function of Reynolds numbers and aspect ratios. The results showed that the calculation using the equation showed results that matched the measurement data, with an error of 1.32%.

Yuan et al. [12] examined the basic morphology of channels and hydrodynamics at the meeting of two open channels by analyzing morphological and hydrodynamic changes due to flowrate ratios. This study uses a straight open channel with a branching angle of 90° in the laboratory. To see the basic morphology of the channel, sand is used as the sediment. From their results, it is known that a large flowrate ratio will result in changes in the basic morphology of the channel becoming clearer and its dimensions becoming larger.

Zhang et al. [13] examined the effect of vegetation on flow structure and kinetic energy of gradually varied flow-through experiments using open channels with plants that do not sink as a barrier to flow. Plants used in the form of reeds with different densities. The results showed that the presence of vegetation caused a change in flow type from M1 to M2 in the section where vegetation was present, and the change was stronger when the plant density was higher. The vertical velocity of flow changes with changes in plant density, and the distribution becomes irregular at high plant densities, so it does not follow the classical velocity distribution equation. The total kinetic energy increases gradually in the area with plants and reaches its maximum as it approaches the end of the area and decreases sharply when it is 1 meter after the vegetation area. From this study, it can be identified areas that are potentially affected by erosion.

Aliza et al. [14] conducted a study of the coefficient of flow resistance in the open channel. At the bottom of the channel a different kind of grass plant is added to assess the effect of the plant on average velocity, flow rate and coefficient of flow resistance. The distinguishing factors are vegetation type, depth of flow, and vegetation regulation. The results show that the flow resistance coefficient increases with increasing depth and flow. However, the flow velocity is inversely proportional to the flow resistance coefficient which is influenced by the physical structure of the vegetation such as leaf length. It can be concluded that vegetation in open channels gives a big influence on the coefficient of flow resistance, velocity and flow rate.

2. Methods

2.1. Design of hydraulic tool
The design concept is used to adjust the limiting conditions to the type of tool to be made. Limiting conditions can be in the form of storage, costs, and ease of moving. For this reason, the device must be designed according to the existing restrictions. To design the Auto CAD software is used. Figure 1 shows the results of the tool design. In designing the tool, it must be known what scenarios will be made, both from the material, the mechanism of the tool, or the software that will be used.
2.2. Development of the hydraulic tool
The development of tools is an iterative process, considering that the actual conditions cannot be entirely following the plan. During the manufacturing process, problems are encountered which must be solved effectively and efficiently. The open channel experiment tool can be seen in Figure 2.

2.3. Testing and evaluation
After the device is built, a test is performed to find out whether the device is working as planned or not. If not, then it evaluates which parts need to be improved or what method is best to be implemented to solve them. From the test results, it is known that there are some deficiencies in the tool, such as leakage, open flow in the pipe due to too large diameter, and lack of pump power to create a hydraulic jump.

2.4. Revision of tools and data validation
From the results of the evaluation, it can be seen what parts of the equipment need to be repaired, and what methods are best for fixing it. Repairing the lack of tools is done carefully considering that it will
bring problems to other parts if not observed. After the tool is as planned, it needs to be validated. Validation is an attempt to obtain data on the work tools according to the correct data. From the evaluation results added several adjustments such as the type of acrylic glue used, pipe diameter, and pump type.

3. Results and discussion

3.1. Experiment 1: Determination of flow rates on open channels

The purpose of this experiment is to provide students with an understanding of flow rates on open channels. From this experiment, we learned about the hydraulic radius, flow velocity, average flowrate, and type of flow.

Experimental procedures include: determining the segment to be measured, preparing a water level gauge, sketching a channel cross-section, starting the pump by adjusting it on the monitor screen, measuring the flow velocity manually, measuring the water level and cross-sectional area, calculating time with a stopwatch, and perform a manual discharge calculation and compare it to the percentage of pump power set through the monitor screen. Measurements were made several times with different pump power percentages.

![Performance test for determining the flowrate.](image)

Figure 3 shows the results of manual discharge measurements at different pump power percentages, starting from 70% to 100%. The measurement results show that the data is satisfactory enough to regulate water flow through the pump power settings. Measurement error may occur due to delay in using the stopwatch. The measurement results become data used to calibrate the data in the flowmeter control program.

3.2. Experiment 2: Determination of flow parameters in the measuring barrier

The purpose of this experiment is to provide students with an understanding of determining the flow rate through the measuring barrier. This flow rate measurement is widely used in measuring the flow rate of industrial wastewater. The experimental procedure includes the preparation of the measuring barrier used, setting the flow rate, and measuring the water level in the measuring barrier. Measurements were made 5 times with 2 types of different bulkhead measuring shapes.
4. Conclusion
The use of simple materials to build experimental devices in the laboratory is still very possible. Through the construction of these tools, students who mostly have difficulty understanding basic materials in fluid mechanics, especially those related to hydraulics, find it easier to understand their concepts and practices. In addition, this can open up opportunities for more in-depth studies of phenomena that occur in open channels.

Acknowledgments
This research was funded by the Faculty of Engineering, Jambi University.

References
[1] Young D F, Munson B R, Okiishi T H, and Huebsch W W 2011 *A brief introduction to fluid mechanics* 5th ed. (New York: John Wiley & Sons, Inc) p 2
[2] Cengel Y A and Cimbala J M 2018 *Fluid mechanics: Fundamentals and application* (New York: McGraw-Hill) p 2
[3] Munro J M 2002 A design experiment for the fluid mechanics laboratory in *ASEE Annual Conference Proceedings* pp. 1123–1129.
[4] Rathod S S and Kalbande D R 2016 Improving laboratory experiences in engineering education *J. Eng. Educ. Transform*
[5] Edward N S 2002 The Role of Laboratory Work in Engineering Education: Student and Staff Perceptions *Int. J. Electr. Eng. Educ.* 39 pp. 11–19
[6] Feisel L D and Rosa A J 2013 The role of the laboratory in undergraduate engineering education *J. Eng. Educ.* 94 pp. 121–30
[7] Nikolic S, Suesse T F, and McCarthy T J 2015 Relationship between learning in the engineering
laboratory and student evaluations *Proceedings of the Australasian Association for Engineering Education Annual Conference* pp. 1–9.

[8] Budny D and Torick D 2010 Design of a multi-purpose experiment for use in a fluid mechanics lab *Proceedings - Frontiers in Education Conference, FIE*

[9] Neluwala N G P B, Karunanayake K T S, Sandaruwan K B G M, and Pathirana K P P 2013 Characteristics of hydraulic jumps over rough beds – An experimental study *Eng. J. Inst. Eng. Sri Lanka* 46 pp. 1–7

[10] Tuyen N B and Cheng N-S 2012 Flow resistance in smooth rectangular open channels with low aspect ratios *J. Hydraul. Eng.* 138 pp. 817–21

[11] Cheng N S, Nguyen H T, Zhao K, and Tang 2011 Evaluation of flow resistance in smooth rectangular open-channels with modified Prandtl friction law *J. Hydraul. Eng.*, 137 pp. 441–50

[12] Yuan S, Tang H, Xiao Y, Qiu X, and Xia Y 2017 Water flow and sediment transport at open-channel confluences: an experimental study *J. Hydraul. Res.* 56 pp. 333–50

[13] Zhang H Y, Wang Z Y, Xu W G, and Dai L M 2015 Effects of rigid unsubmerged vegetation on flow field structure and turbulent kinetic energy of gradually varied flow *River Res. Appl.* 31 pp. 1166–75

[14] Aliza Ahmad N, Ali Z M, Mohd Arish N A, Mat Daud A M, and Amirah Alias N F 2018 Determination of flow resistance coefficient for vegetation in open channel: Laboratory study *IOP Conference Series: Earth and Environmental Science* 140 012019