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THERMAL EXPANSION AND HYDROSTATIC PRESSURE EXPERIMENT USING COMMON MATERIALS FOR SUPPORTING SCIENCE EDUCATION A RURAL AREA AT CENTRAL SULAWESI, INDONESIA

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ABSTRACT

Experiments are needed in science learning. However, the instruments used cost high; thus, it is difficult to find, especially in rural areas. The purpose of this study was to develop a low-cost tool for science learning. This science experiment has been successfully developed from inexpensive common materials. Research and Development design employing Gall and Borg Model was used in developing the science instruments. Analysis, design, fabricate, validate, revising, and implementation were the steps in producing the devices. Observation sheet and questionnaire were used for evaluating and validating the instrument. The subject of this study was students of SMPN 1 Sigi, Sigi Sub Province, Central Sulawesi. After designed and fabricated, the devices were validated by two judges to know the practicality and convenience. The tools were set up to demonstrate the expansion concept of gas and liquid; also, to establish the presence of hydrostatic pressure inside the fluid. The N-gain analysis was performed to know the increase of student understanding after employing the instruments in science learning. The results showed that student understanding was increased by about 30.13% after using devices in science learning. In other words, the designed tools were succeeded in introducing the concept of gas and liquid well and in establishing the fact that the higher hydrostatic pressure of the fluid is discovered in a deeper location inside the liquid. Based on the success, the devices were socialized to other science teachers in the area.

Keywords: thermal expansion, hydrostatic pressure, and rural areas.

INTRODUCTION

Science learning involves the use of abstract concepts (Rakbamrung et al., 2015). It is , therefore, essential to make use of experimental methods that can be well understood. Understanding the concept of science will be a very challenging task for students if it is taught only by using a teacher-centered learning method. In the paradigm, the students are taught to physically observe the phenomena being studied (Aguilar et al., 2017; Arista & Kuswanto, 2018; Saehana et al., 2018).

Complete laboratory instruments are required to enhance science learning in classrooms for the reason that almost all scientific concepts are associated with real-life phenomena (Carvalho-Santos et al., 2013). However, not all schools have the completeness of the practicum, especially those in rural areas of central Sulawesi (Indonesia). It, therefore, takes the creativity of teachers to design simple instruments, ensuring

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science can still be taught (Richie & Kuswanto, 2015; Saleh & Mazlan, 2019). On the other hand, students' motivation to the study science is still low (Alivernini & Lucidi, 2011; Ali et al., 2018). Thus, the instruments must not only be able to assist learning, but also boost the students' learning interest.

Scientific instruments used in observing and demonstrating science phenomena in rural areas should be, of course, made of low-cost materials. It can be designed and constructed by taking advantage of used tools such as electronic devices or other locally available materials (Ali et al., 2018; Bakhtibaeva et al., 2016). The necessary development process such as designing, testing, and validating have to be done before the science instruments can be applied in the learning process (Hanif & Winarno, 2019; Hill et al., 2015; Juleha et al., 2019).

Rediansyah et al. (2015) have designed a scientific instrument for the concept of electric fields, making use of a mosquito racket and baby oil. This instrument has successfully revealed the presence of static electric fields for similar and different types of charge. Moreover, Widiyatmoko et al. (2011) have also been successful in assembling unsophisticated spectrometers from simple materials and digital cameras to show the diffraction phenomena and the light spectrum. The electromagnetic effect was also demonstrated with a relatively simple instrument (Koudelkova, 2016; Ivanov & Nikolov, 2016). However, other science instruments for science concept such as thermal expansion and pressure has not been designed and applied in learning. Those concepts are necessarily understood by students referring to the 2013 curriculum. In the rural area of Central Sulawesi (Indonesia), thoughts of expansion and hydrostatic pressure are taught utilizing the teacher-centered learning method. The unavailability of instruments in a laboratory gives the teacher no access to the necessary practice tools. Nevertheless, both concepts can be taught using some readily available simple equipment (Parappilly et al., 2015; Rakkapao et al., 2013). Therefore, research on the development of science experimental equipment from the materials available around us is significant to do, considering the fact that the results obtained can be used to improve the quality of science learning.

Through the course of this paper, we developed science instruments from everyday materials intending to improve the junior high school students' understanding about expansion and hydrostatic pressure at school in the rural area of Central Sulawesi, Indonesia. The result of this study is expected to enhance science education in Central Sulawesi of Indonesia. This research is also a preliminary study for the development of simple, practical equipment for other scientific concepts.

METHODS

The components used in making scientific instruments can be easily found in the course of everyday life. These components are a bottle used for holding water, rubber tube, pipette, balloon, and hose. The tools and materials were assembled, as illustrated in Figure 1 to 4. Research and Development design with Gall and Borg Model were adopted in developing the science instruments (Ali et al., 2018; Arends, 2012; Borg & Gall, 2003). The production steps include problem analysis, design, fabrication, validation, revision, and implementation. Once created, the scientific tools were then calibrated and verified by two experts to know the practicality, convenience, and quality of the device. The instrument was calibrated by comparing with standard measurement in a physics laboratory. Validation was carried out by measuring the physical parameter in the experiment, which has resulted in relevant data. Questionnaires were also used by the experts to judge the quality of the instrument to see if all aspects of the device were in proper category. Evaluations of the devices using observation sheets were also carried out during the application of the tools in science learnings. Moreover, the test of thermal expansion concept and pressure inside the liquid consisting of 10 items were administered to the students, and an n-gain analysis as written in Equation 1 was done.

$$(S_{posttest}-S_{pretest})/(S_{maximum}-S_{pretest}) \qquad (1)$$

Information:
$S_{posttest}$ = post-test score
$S_{pretest}$ = pre-test score
$S_{maximum}$ =maximum score (100)

RESULTS AND DISCUSSION

In this paper, a simple scientific experiment was designed to show the thermal expansion of liquid (water) as illustrated in Figure 1. In this illustration, a bottle containing green liquid was heated by a simple heater. The liquid then expanded and moved up through a pipette. Figure 1 shows the increase of liquid expansion in the pipette due to a rise in temperature. At 50°C, the height of the expanded liquid in the pipette (l) was 3cm (as shown in Figure 1a). At 60°C, the height rose to 4 cm (as shown in Figure 1b). Then, in Figure 1c, the expanded liquid in the pipette had risen to about 6 cm. Therefore, an increase in the temperature results in a higher liquid expansion (Tipler & Mosca, 2008).

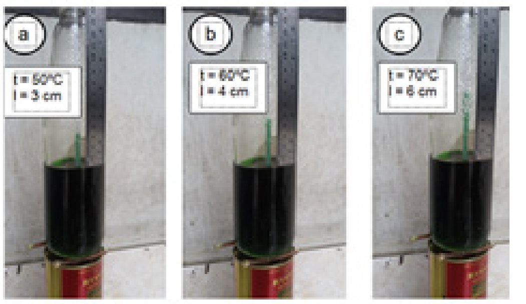

Figure 1. The Scientific Instrument in Liquid Expansion Concept at Different Temperatures

In this paper, an experiment for thermal expansion of the gaseous concept was also conducted as illustrated in Figure 2. In this illustration, an extension of gas can be observed when the bottle was heated. This experiment translates that an increase in temperature (from 32°C to 60°C) could increase the expansion of gas. Bubbles of gas were observed to be vibrating and expanding during this experiment (Hill, 2019; Kácovský, 2019; Pluta & Hryniewicz, 2012).

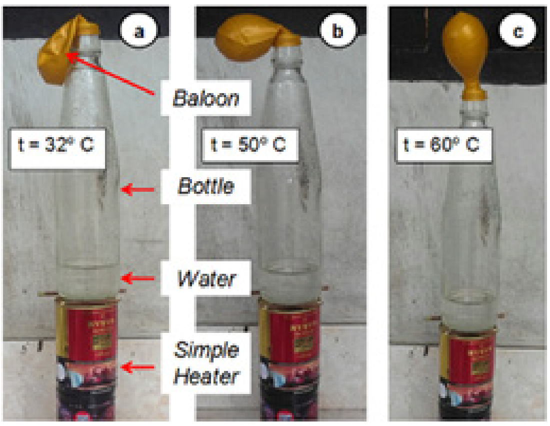

Figure 2. The Simple Scientific Instrument in Gaseous Expansion Concept: (a) Initial Condition of Gas Inside a Balloon (At 32°c); (b) Increase in Gas Indicated by Partially Inflated Balloon (At 50° C), and (c) More Inflated Balloon (at 60°C).

An experiment showing the presence of hydrostatic pressure in liquid is illustrated in Figure 3. In this experiment, four holes were punctured on a bottle, and covered with pieces of paper labelled 1, 2, 3 and 4. If the labelled paper was released, squirting out water, this indicated the presence of hydrostatic pressure. From the observation, the distance travelled by the water flow varies depending on the height of the hole. The higher the hole from the base, the farther the distance travelled by the jets of water.

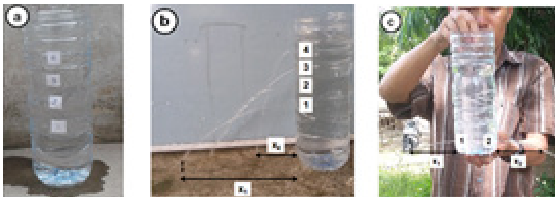

Figure 3. Scientific Instrument for Pressure on the Liquid: (a) Design of Instrument; (b) Experiment Showing the Liquid Pressure at a Vertical Point; and (c) Experiment Showing the Liquid Pressure at a Horizontal Point

The instrument designed in Figure 4 also demonstrates the presence of hydrostatic pressure in the liquid. The experiment done in this study was practical and efficiently carried out this demonstration. It can be observed in Figure 4a that before the funnel was dipped into the bottle, the water level on both sides was the same (equilibrium condition). When the pipe was submerged, there was an increase in the water on one side (Figure 4b). Still, when the funnel was dipped further down to the bottom, an increase in the water level can be observed (Figure 4c). It could, therefore, be concluded that the water in the bottle has hydrostatic pressure. The higher the water depth, the greater the hydrostatic pressure (Balta & Korganci, 2017; Bani-Salameh, 2017).

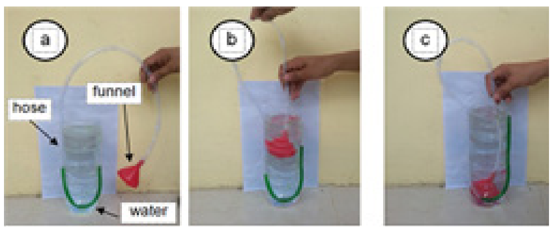

Figure 4. Scientific Instrument for Detecting Pressure in the Liquid: (a) Initial Condition; (b) Liquid Pressure Near the Surface; and (c) Liquid Pressure at the Bottom of the Bottle

Material and instrument experts were validators who assessed the quality and feasibility of the instruments from the aspect of design, quality and effectiveness of the instruments as shown in Table 1. Overall, evaluation results concluded that the instruments were in a "good" category with an average value of 3.17.

Table 1. The Validation Results

No	Aspect	Score	Category
1	Practical	3.25	Good
2	Quality and feasibility	3.00	Good
3	Effectiveness	3.33	Very good
4	Convenient	3.00	Good
	Average	3.17	Good

The instrument was tested to 7 senior high school students. The test was done through questionnaires with a Likert scale and the results can be seen in the Table 2. The obtained assessment results were then analyzed and it was found that quality was very good with an average value of 3.70.

Table 2. Results of Instrument Testing

No	Aspect	Score	Category
1	Instrument appearance	3.75	Very good
2	Quality of the instrument	3.33	Very good
3	Motivation to learn science concept	4.00	Very good
4	Convenient	4.00	Very good
	Average	3.70	Very good

Implementation of the Designed Scientific Instrument

The scientific instruments have been designed and can now be used in learning science. Some of these trials have been conducted and yielded good results. The trials were held in Junior High School, as shown in Figure 5, and the experimental results of the tools to 30 students were recorded in Table 3. The students' average score increased after experiencing learning using designed instruments for both concepts. By employing an n-gain analysis, it was found that the mean score was 30.13%

Table 3. N-Gain Result after Scientific Instrument Applied

Concept	Average of Student Score		N-Gain (%)
	Before	After	
Thermal Expansion	61.0	91.5	29.89
Hydrostatic Pressure	63.0	94.0	30.37
Mean			30.13

In the dissemination process of the instruments, we invited a few science teachers from the rural areas of Central Sulawesi. Through this process, information regarding methods of learning science in Junior High Schools was obtained. One of the significant challenges has been the unavailability of scientific instruments in schools. The teachers also stated that the teacher-centered learning method was applied in learning science in the rural area, and it has resulted in low student motivation and learning outcomes.

The instruments were then introduced through demonstrations. The participants (teachers) gave remarks, stating that the scientific instruments were easy to use as it has an attractive design and can be efficiently applied to science learning. They were interested in the fact that the devices were of recycled based materials. It gives hope that science instruments designed from recycled materials can overcome the lack of scientific instruments in rural areas.

Figure 5. Implementation of Learning with the Use of Scientific Instruments: (a) A Teacher Organizing the Students into Smaller Groups; (b) the Teacher Demonstrating the Use of Simple Science Media; (c) Students Employing the Modest Science Media for the Experiment; and (d) Discussion between the Teacher and the Students.

Figure 5 shows the instrument experience results in science learning at SMPN 1 Sigi. The teacher gave pretest, and then the students were organized in a small group following the cooperative learning model (Astra et al., 2015). Then, the concept of thermal expansion and hydrostatic pressure inside the liquid were demonstrated by the teacher using the instruments. The experiments were done by the student, and discussions were also performed to know the concept (Balami, 2015). The posttest was given to the students to understand their knowledge after following the learning process.

By employing n-gain formula, the improvement of student knowledge was revealed. It was found that their understanding of the concepts increased by 30%. The students can understand the concepts because of the observations, direct experiments, and discussion performed during the learning. This fact is in line the findings of previous studies which stated that direct interaction such as group discussion would enrich the students' knowledge as they transfer information to others. As a result, the students' understanding of the concepts being learned increased significantly (Syahrul & Setyarsih, 2015; Ulfa & Sugianto, 2015).

CONCLUSION

The scientific instruments have been successfully made for thermal expansion and hydrostatic concept. The thermal expansion and hydrostatic pressure in the liquid can be established with the use of these instruments. In this expansion concept experiment, it was revealed that the development of gas and liquid increased alongside an increase in heating temperature. The designed devices also succeeded in establishing the fact that a higher hydrostatic pressure of the fluid is discovered in a deeper location inside the liquid. The instruments were then implemented in science learning and familiarised with science teachers in rural areas. The tools have been applied in science learning for thermal expansion and hydrostatic pressure concept in SMPN 1 Sigi. By employing an n-gain analysis, it was found that the student understanding increased by 30% after using instruments in science learning. Developing other low-cost devices for other science concepts were needed to improve student understanding, particularly those who live in rural areas.

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