Thermal Expansion and Hydrostatic Pressure Experiment Using Common Materials for Supporting Science Education in a Rural Area at Central Sulawesi of Indonesia

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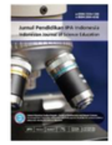

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Experiment were needed in science learning, however, the instrument used was a high cost so it is difficult to find in rural area. The purpose of this study was developed low cost instrument for science learning.This science experiment has been successfully developed from common materials at a low cost. Research and Development design employing Gall and Borg Model was used in developing both science instrument. Analysis, design, fabricate, validate, revising, and implementation were a step in producing the instruments. Observation sheet and a questionare were used for evaluating and validating the instrument. Subject of this study was student in SMPN 1 Sigi at Sigi Sub Province of Central Sulawesi.The developed instruments were also sosialized in science teacher at rural areas. N-gain analysis was used to know the increase of student understanding after employing instrument in science learning.A scientific instrument was set up to demonstrate the expansion concept of gas and liquid. It was also designed in order to establish the presence of hydrostatic pressure inside the liquid.After designed and fabricated, both instrument was validated by two judges to know the practical and convenient. For all category, it was found in a good category. In this expansion concept experiment, the expansion of gas and liquid increased alongside an increase in heating temperature. The designed instrument also succeeded in establishing the fact that the higher hydrostatic pressure of liquid is discovered in a deeper location inside the liquid. The instrument was then implementedin science learning, and familiarize with science teachers in rural areas. The instrument has been tested in science learning for thermal expansion and hydrostatic pressure concept in SMPN 1 Sigi. By employing n-gain analysis, it was found that the student understanding was increased about 30.13% after used instruments in science learning.

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 teacher centered learning methods. In the paradigm, students are taught to physically observe the phenomena being studied (Aguilaret 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 science can still be taught (Richie&Kuswanto, 2015; Saleh& Mazlan, 2019). On the other hand, students motivation to the study the science is still low (Ali et al., 2018).

Scientific instruments used in observing and demonstrating science phenomena in rural areas should be of low cost materials. It can be designed and constructed making use of electronic devices and can also be made from equipment locally available (Ali et al., 2018; Bakhtibaeva et al., 2016). The development process is required to follow certain steps such as: designing, testing and validating. Then finally, the science instrument can be applied in the learning process (Hanif&Winarno, 2019; Hill et al., 2015; Juleha et al., 2019).

Rediansyah et al. (2015) has designed a scientific instrument for the concept of an electric field, 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, Widiatmoko et al. (2011) has 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 thermal expansion and pressure has not been designed and applied in learning. Developing science instrument was required for improving quality of science learning.In this study, it was designed the instrument for learning thermal expansion and pressure inside the liquid because experiment for both science concept were contained in curriculum 2013 and it was also easy to apply in science learning specially in rural area.

In the rural area of Central Sulawesi (Indonesia), concepts of expansion and hydrostatic pressure were taught by means of teacher centered learning methods. The unavailability of instruments in a laboratory gives the teacher no access to the required 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 very important to do considering the results obtained can be used to improve the quality of science learning.

Through the course of this paper, we developed science instruments from common materials with the aim atimproving the understanding of students of junior high school in the rural area of Central Sulawesi, Indonesia. The scientific instruments were made for the purpose of thermal expansion concept and hydrostatic pressure. The result of this study is expected to enhance science education in Central Sulawesi of Indonesia. This research is also a preliminary study in the development of simple practical equipment for other scientific concepts.

METHODS

The components used in making the 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. Experimental tools and materials were assembled as illustrated in Figure 1 to 4. Research and Development design employing Gall and Borg Model was used in developing both science instrument (Ali et al., 2018; Arends, 2012; Borg& Gall, 2003). Problem analysis, design, fabricate, validate, revise, and implementation were a step in producing the instruments. Once created, the scientific tools are then calibrated and validated by two experts to know the practical, convenient and quality of the instrument. The instrument was calibrated by comparing with standard measurement in physics laboratory. Then, validated was done by measuring the physical parameter in experiment and it was resulted logical data. Questionnaires was also used by the expert to judge the quality of instrument. If all aspect of the instrument were in good criteria.Subject of this study was student in SMPN 1 Sigi at Sigi Sub Province.Then, the instrument were applied in science learning classrooms and it has been evaluated by observation sheet. Test of thermal expansion concept and pressure inside the liquid was about 10 item were made by teacher and it was given to the student and n-gain analysis as written in Equation 1 were also used.

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

With

$S_{posttest}$is a score when posttest

$S_{pretest}$is a score when pretest

$S_{maximum}$is a score maximum for the test (100)

Then, developed instruments were also sosialized to the teacher in science teacher at rural areas.

RESULTS AND DISCUSSION

In this paper, a simple scientific experiment was designed for the purpose of showing 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 expansion of the liquid in the pipette increasing 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 4cm (as shown in Figure 1b). Then, in Figure 1c the expanded liquid in the pipette had risen to about 6cm. Therefore, an increase in the temperature results in a higher liquid expansion (Tiplerand Mosca, 2008).

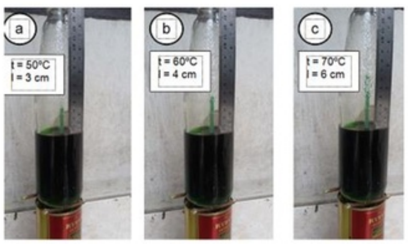

Figure 1. The scientific instrument in liquid expansion concept at different temperatures.

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

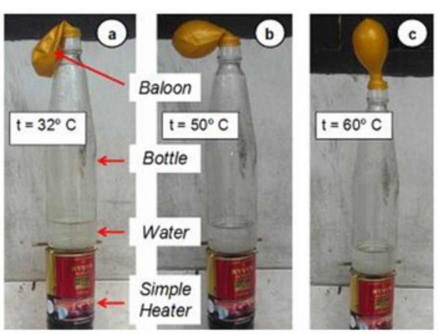

Figure 2. The simple scientific instrument in gaseous expansion concept: (a) Initial condition of gas inside balloon (at 32°C); (b) Increase in gas indicated by partially inflated balloon (at 50° C), and (c) Balloon inflated more (at 60°C).

An experiment showing the presence of hydrostatic pressure in liquid is illustrated in Figure 3. In this experiment, four holes are punctured on a bottle, and covered with pieces of paper labelled 1, 2, 3 and 4. If the labelled paper is released, squirting out water, this indicates 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 liquid. The conducting of this experiment was practical and easily 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 were the same (equilibrium condition). When the funnel was dipped, there was an increase of 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 can therefore be concluded that the water in the bottle has hydrostatic pressure. The greater the water depth, the greater the hydrostatic pressure(Balta&Korganci, 2017;Bani-Salameh, 2017).

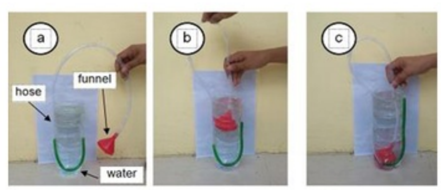

Figure 4. Scientific instrument for detecting pressure in the liquid: (a) initial condition; (b) liquid pressure near the surface; and (c) liquid pressure at the bottom of the bottle.

Material and instrument experts are validators who assess the quality and feasibility of the instrument from the aspects of design, quality and effectiveness of the instruments as shown in Table 1. Overall, the results of instrument evaluations get the "good" category with an average value of 3.17.

Table 1. 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

Quality of the instrument were tested to 7 of senior high school students. The test was done by using a questionnaire with a Likert scale and the results can be seen in the Table 2. The results of the assessment obtained are then analyzed and it was found that quality is 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 of these implementations have been conducted using these tools and yielded good results. They have been conducted in Junior High School as shown in Figure 5. Study results about 30 of the students was recorded in Table 3. Average of student score was increase after learning by using designed instrument for both concept. By employing 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 dissemination process of the instruments, we invited a few science teachers from the rural area of Central Sulawesi. Through this process, information regarding methods of learning science in Junior High Schools was obtained. One of the major challenges has been the unavailability of scientific instruments in schools. The teachers also stated that the teacher center 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 participant (teacher) gave remarks, stating that the scientific instruments were easy to use; it has an attractive design, and can be efficiently applied to science learning. He was interested in the fact that the instruments 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) Teacher organised the students into a small group, (b) The teacher demonstrates the use of instrument, (c) Students used the instrument for the experiment, (d) Discussion between teacher and the students.

Figure 5 show the implementation resulted instruments in science learning at SMPN 1 Sigi. The teacher give pretest and then students were organized in small group following cooperatif learning based 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 also applied by the student and discussions were done to know the concept (Balami, 2015). The posttest were given to student for knowing their knowledge after following learning process.

By employing n-gain formula, the improving of student knowledge was known. It was found that students understanding for the concepts was increase about 30%. The concepts can be understood by student because observation were done employing instrument. They also found the concept through experiment and discussion activity gave important information about the concept (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 expansion of gas and liquid increased alongside an increase in heating temperature. The designed instrument also succeeded in establishing the fact that the higher hydrostatic pressure of liquid is discovered in a deeper location inside the liquid. The instrument was then implemented in science learning, and familiarised with science teachers in rural areas. The instrument has been applied in science learning for thermal expansion and hydrostatic pressure concept in SMPN 1 Sigi. By employing n-gain analysis, it was found the student understanding was increased about 30.13% after used instruments in science learning. Developing others instrument for all concept in science learning were needed to improve student understanding.

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