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Development of Centrifugation Tool to Improve Laboratory Performance and Problem Solving Skills

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Abstract: This study aims to develop centrifugation tool to improve performance in the laboratory and problem solving skills. The research method used is Research and Development (R&D) with 4D model. The results showed that the developed centrifuge was declared according to the material, had educational value, was durable, precise in measurement, efficient and safe for students based on the responses of teachers and students respectively at 100% and 96.15% with very high criteria. Student performance scores in the laboratory have a distribution close to the average student performance score (91.52). The effectiveness of the application of centrifugation using the students' worksheet obtained good results in improving problem solving skills with moderate criteria (0.60) and giving moderate effect (0.42). Based on these results, the developed centrifuge was declared effective for improving laboratory performance and problem solving skills.

Keywords: centrifuge, student performance, problem solving.

Abstrak: *Penelitian ini bertujuan untuk mengembangkan alat sentrifugasi untuk meningkatkan kinerja di laboratorium dan keterampilan pemecahan masalah. Metode penelitian yang digunakan adalah metode Research and Development (R&D) dengan model 4D. Hasil penelitian menunjukan bahwa alat sentrifugasi hasil pengembangan dinyatakan sesuai materi, memiliki nilai pendidikan, tahan lama, tepat dalam peng¬ukuran, efisien serta aman bagi siswa berdasarkan tanggapan guru dan siswa masing-masing sebesar 100% dan 96,15% dengan kriteria sangat tinggi. Nilai-nilai kinerja siswa di laboratorium memiliki persebaran yang dekat dengan nilai rata-rata kinerja siswa (91,52). Keefektifan penerapan alat sentrifugasi dengan menggunakan lembar kerja siswa diperoleh hasil yang baik dalam meningkatkan keterampilan pemecahan masalah dengan kriteria sedang (0,60) dan memberikan pengaruh sedang (0,32). Berdasarkan dari hasil tersebut, alat sentrifugasi hasil pengembang¬an dinyatakan efektif untuk meningkatkan kinerja di laboratorium dan keterampilan pemecahan masalah.*

Kata kunci: *alat sentrifugasi, kinerja siswa, pemecahan masalah.*

▪ INTRODUCTION

Problem solving is one of the skills that must be possessed by students and is an important skill in facing challenges in the 21st century (Jonassen, 2011; Greiff, Holt, Funke, 2013; Varod, Alkalai, Geri, & Bedir 2019). The importance of problem solving skills is also stated in Nurdalilah's (2010) statement that problem solving is part of the curriculum in schools which is very important because in the learning and completion process, students are allowed to gain experience using the knowledge and skills they already have to apply to existing problems. So it has a positive influence on student learning outcomes (Kusuma, Utami, & Mulyani, 2021).

Problem solving skills are one of the basic human cognitive processes (Rahman, 2019) and are seen as a fundamental part of learning, especially science learning (Gok & Silay, 2010), because besides being studied in school, science is also needed in

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everyday life to meet human needs through solving problems that can be identified (Fadiawati & Syamsuri, 2018). Then the students solve the problem by using the science concepts they have understood. Students who have the ability to solve a problem will be able to apply the knowledge they have in the context of the problem at hand (Arimbawa, Sadia, & Tika, 2013).

In addition, science learning also has characteristics that emphasize more on a scientific approach (scientific approach). Scientific approach to learning is directly on the facts and the reality that exists around the student learning resulting in actually using observation and analysis in practice (Gunawan, In'am, Maretta, Utanto, Widhanarto, 2017). The students who applied a scientific approach had better problem-solving skills than students using the other approaches (Yulianti, Cycin, & Nandang, 2018). Learning using a scientific approach (scientific approach) which emphasizes processes and products is difficult to do without the support of the availability of tools, practicum materials, and other teaching materials, so that learning science, which is essentially learned through scientific work, is carried out through practical activities in the laboratory (Nahdiyaturrahmah, Pujani, & Selamet, 2020). Practicum is an activity carried out in a laboratory and is supported by a set of tools and laboratory infrastructure. Practicum is an important activity in science learning (Candra & Hidayati, 2020). This is reinforced by research conducted by Nisa (2017) which states that learning with the practicum method can improve students' understanding and learning outcomes in science learning.

For this reason, in learning science, students should solve a problem in the laboratory by doing practicum (Agustini, Subagya, & Suardana, 2015). In relation to problem solving, science learning in schools is usually related to natural phenomena. For example, the substances we need in everyday life are not available in nature in their pure state. We have to separate from the mixture, that's why separation of the mixture is necessary. Several applications of mixture separation in everyday life such as, Taking salt from seawater is done by evaporation and crystallization techniques (Xia, et al., 2019), essential oil recovery is done by distillation technique (Moradi, Fazlali & Hamedi, 2018; Fadiawati & Syamsuri, 2019). Getting clean water in areas where the water sources are polluted, namely by utilizing filtration techniques (Rezakazemi, Khajeh, & Mesbah, 2017).

Then to obtain soy milk without pulp by centrifugation technique, because the particle size is small and can pass through the filter so that the filtration technique is not able to overcome this problem. However, the centrifugation technique is not known and carried out by students, even though this technique must be achieved by students in the basic competence of junior high school students (Draftingteam, 2018). This is due to the unavailability of practical tools. Even though this practicum tool is very used in an educational institution (Puspasari, 2017) but not all educational institutions have complete or representative practicum tools to explain certain material (Wulandari, Susilo, & Kuswandi, 2016).

Completeness of facilities and infrastructure in schools is a very important factor so that practicum can take place, thus helping students in improving problem solving skills. Because the success of learning in schools is supported by the effective and efficient use of educational facilities and infrastructure in schools (Megasari, Kibirige, Osodo & Mgiba, 2014). The results obtained by students during practicum activities are called practicum performance/performance in the laboratory. Performance in the laboratory is obtained by observing student activities during the practicum process. By doing practicum, students are able to solve problems. By doing practicum also means that students can improve performance in the laboratory (Susial, 2012).

In fact, most teachers have not conditioned science learning to allow students to acquire everyday science problem solving skills. The teacher begins learning by explaining a certain concept, followed by practice questions taken from the student handbook. These questions are very far from the problems that occur in the real world of students. It is also known that only 16.05% of students carried out practical activities in learning the separation of mixtures between liquids and solids and practicum carried out using filtration techniques. 83.95% of students do not do practicum on this material, because they do not have the facilities and infrastructure such as laboratories and practicum tools.

Based on the results of field studies, it was also found that many schools have inadequate and unfit for use laboratory equipment. The lack of equipment can be due to the purchase price of the equipment which is quite expensive and the desired tool is difficult to obtain so that practicum activities are not carried out. Even though the teacher expects a practicum to help teach the material for separating mixtures, especially with the centrifugation technique. Therefore, it is necessary to develop a centrifuge to improve performance in the laboratory and problem solving skills.

▪ METHOD

The research method used in this research is research and development or Research and Development (R & D), with the research design using a 4D development model (four-D). The 4D development model consists of 4 stages, namely define, design, develop and disseminate (Thiagarajan, Semmel, & Semmel, 1974). At stage define An activity is carried out to determine and define the conditions needed in the development of a centrifuge. The activity was an initial analysis conducted by interviewing four science teachers and giving questionnaires to 81 seventh grade students in three schools in Bandar Lampung, namely SMPN 24 Bandar Lampung, SMPN 31 Bandar Lampung and SMPN 36 Bandar Lampung. Then perform student analysis, task analysis, concept analysis and formulation of learning objectives. The instruments used in the define stage are interview guidelines and questionnaires that contain a question related to practicums that have been carried out and practicum tools that have been used in integrated science learning.

At the design, the design of the centrifugation device and students' worksheet is carried out. Because in its application, centrifugation equipment requires students' worksheet in the implementation of the practicum. Students' worksheet which is designed to contain practicum activities and problem solving process using an inquiry model with the stages of orientation, problem formulation, collecting data, hypotheses, testing hypotheses and formulating conclusions (Pedaste et al., 2015). At this stage the preparation of tests, media selection, format selection and initial design is carried out.

The develop aims to produce development products, namely centrifugation tools and students' worksheet to improve performance in the laboratory and problem solving skills. At this stage, expert validation was carried out by 2 validators and product trials to three science teachers and 28 seventh grade students at SMPN 1 Terbanggi Besar. The validation process is carried out to assess the readability aspect, the content suitability aspect and the construction aspect of the students' worksheet as well as to assess the feasibility aspect of the centrifugation tool which includes (1) the linkage with the material, (2) educational value, (3) tool resistance, (4) measurement accuracy, (5) efficiency of tool use and (6) safety for students. The instruments used were a readability aspect questionnaire, a content suitability aspect questionnaire, a construction aspect questionnaire, an attractiveness aspect questionnaire and a centrifugation instrument feasibility questionnaire.

The disseminate stage is the final stage in this research. At this stage, validation testing and packaging. The product that has been revised at the develop is then implemented on the real target, namely the 7th grade students of SMPN 1 Terbanggi Besar. Class 7A as the experimental class and class 7C as the control class. The determination of the experimental class and the control class was based on the results of the equations of two averages. The number of students from each class is 28 students. The implementation phase was carried out to determine the effectiveness of the students' worksheet using the experimental class and the control class. Before learning started, students in both classes were given a pretest and after finishing the lesson, they were given a posttest. The pretest and posttest questions are arranged based on indicators made with reference to the problem solving process according to Beyer (1995). Indicators (1) formulate the problem represented by questions number 1 and 6, (2) develop temporary answers represented by questions number 2 and 7, (3) test hypotheses represented by questions number 3 and 8, (4) develop and draw conclusions and (5) applying new data or experiences represented by questions no 5 and 10. Pretest and posttest questions that were given, they had previously been tested on 20 students of SMP N 1 Terbanggi Besar who had studied the material for separating mixtures. Testing of the test instrument was carried out with the SPSS 17.00 software

During the learning process, an assessment is carried out by direct observation of student performance during the practicum using a performance instrument that refers to the experimental procedure for separating mixtures using a developed centrifuge. The effectiveness of student's worksheet can be seen from the value of n-gain which is analyzed by prerequisite test, namely normality test and parametric test, namely by independent sample t-test and paired sample t-test, and effect size. The formula for calculating n-gain is as follows:

$$\text{n-Gain}= \frac{\text{the percentage of posttest scores} - \text{the percentage of pretest scores}}{100 - \text{the percentage of pretest scores}}$$

(Hake, 1999)

Then the last activity of the disseminate is packaging. Packaging is done by making boxes made of plastic as a container for the development tools.

▪ RESULT AND DISSCUSSION

In the define stage, the results of the initial analysis showed that there were no teachers who did practicum in learning the separation of mixtures. The practicum was not carried out due to the limited facilities and infrastructure available at the school, such as the absence of practicum and laboratory equipment. The unavailability of tools is a factor that causes the practicum is not carried out. In addition, it is also known that there are no students who have done the centrifugation technique mixture separation practicum, students only do the filtration technique and most students have difficulty understanding the material without any practicum.

In the student analysis, the data obtained in the experimental class consisted of 14 female students and 14 male students, while in the control class there were 15 female students and 13 male students. These two classes have almost the same abilities. Task analysis is formulated on indicators of competency achievement which are based on a problem-solving process that refers to the problem-solving process according to Beyer (1995). Indicators of competency achievement are written on the students' worksheet as a result of development. This concept analysis is based on basic competence 3.3, namely understanding the concepts of mixtures and single substances (elements and compounds), physical and chemical properties, physical and chemical changes in everyday life and basic competence 4.3 presents research data or works on solutions, physical changes and chemical changes or mixture separation.

At the design, the centrifugation device design and students' worksheet design were obtained. The design for the centrifuge can be seen in Figure 1. students' worksheet design consists of several parts, namely introduction, content and closing. The introductory section consists of cover front, inner cover, preface, table of contents and general instructions. The content section contains learning steps according to the syntax of the inquiry learning model. The closing section consists of a bibliography and cover. The results at the develop stage consist of research results at the expert validation stage and the product trial stage. Expert validation shows the average value of students' worksheet validation and centrifugation device design is 100% with very high criteria for all aspects of the assessment. This shows that the centrifuge and students' worksheet developed are suitable for improving performance in the laboratory and students' problem solving skills.

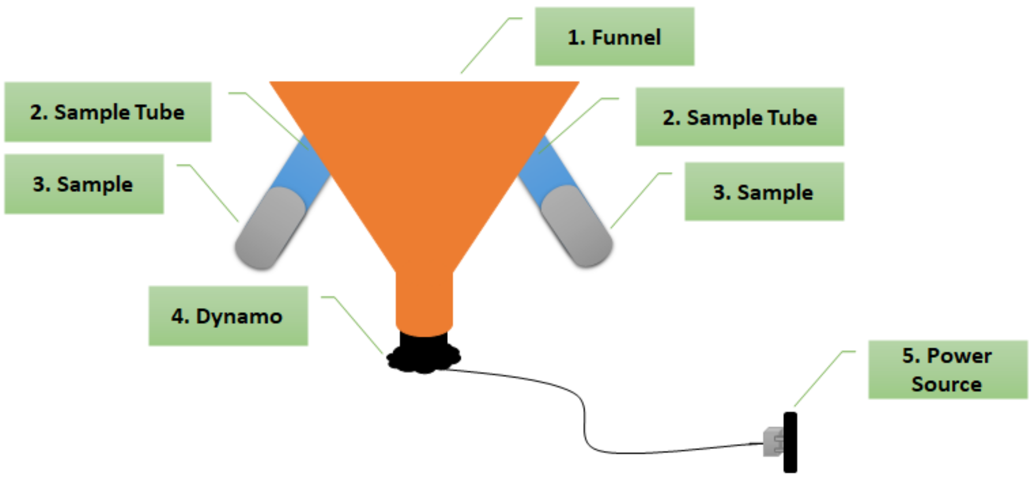
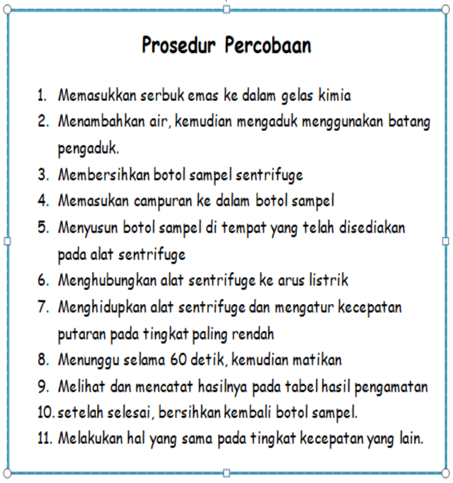


Figure 1. Centrifuge device design

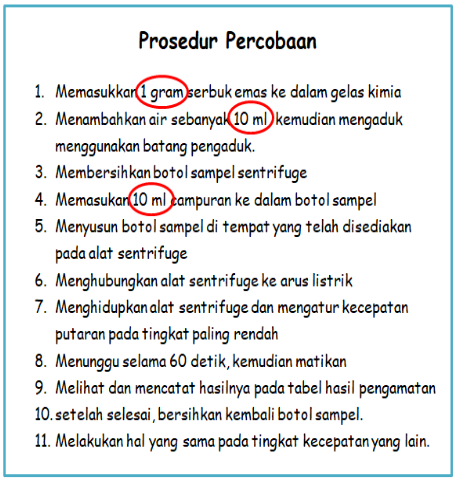
However, there are some suggestions given for improvement in the students' worksheet, such as adding sources to the picture, improving learning objectives containing ABCD components (audience, behavior, condition and degree) and adding a clear size to the experimental procedure. Examples of students' worksheet improvements before and after revision can be seen in Figure 2 and Figure 3.



Prosedur Percobaan

1. Memasukkan serbuk emas ke dalam gelas kimia
2. Menambahkan air, kemudian mengaduk menggunakan batang pengaduk.
3. Membersihkan botol sampel sentrifuge
4. Memasukan campuran ke dalam botol sampel
5. Menyusun botol sampel di tempat yang telah disediakan pada alat sentrifuge
6. Menghubungkan alat sentrifuge ke arus listrik
7. Menghidupkan alat sentrifuge dan mengatur kecepatan putaran pada tingkat paling rendah
8. Menunggu selama 60 detik, kemudian matikan
9. Melihat dan mencatat hasilnya pada tabel hasil pengamatan
10. setelah selesai, bersihkan kembali botol sampel.
11. Melakukan hal yang sama pada tingkat kecepatan yang lain.

Figure 2. (a) Before Revision



Prosedur Percobaan

1. Memasukkan 1 gram serbuk emas ke dalam gelas kimia
2. Menambahkan air sebanyak 10 ml kemudian mengaduk menggunakan batang pengaduk.
3. Membersihkan botol sampel sentrifuge
4. Memasukan 10 ml campuran ke dalam botol sampel
5. Menyusun botol sampel di tempat yang telah disediakan pada alat sentrifuge
6. Menghubungkan alat sentrifuge ke arus listrik
7. Menghidupkan alat sentrifuge dan mengatur kecepatan putaran pada tingkat paling rendah
8. Menunggu selama 60 detik, kemudian matikan
9. Melihat dan mencatat hasilnya pada tabel hasil pengamatan
10. setelah selesai, bersihkan kembali botol sampel.
11. Melakukan hal yang sama pada tingkat kecepatan yang lain.

Figure 2. (b) After Revision

Furthermore, the manufacture of a centrifuge is carried out by taking into account some of the suggestions given by experts. The suggestion is that the funnel is not recommended to be used on the tool, because it vibrates a lot when operated, it is recommended to use a dynamo that has a speed of > ± 1250 rpm and it is recommended to use a sample container measuring < 3 cm. The image of the developed centrifuge can be seen in Figure 4. This centrifuge developed for a lab scale, which can only accommodate 10 ml samples and has 7 levels of rotational speed up to ±7500 rpm, and uses an electric current source. This tool has manual time settings, so it can affect aspects of accuracy in measurement.

Figure 3. Developed centrifuge

After being validated by experts, a trial was conducted and the results of teacher and student responses related to the developed centrifuge and students' worksheet were obtained. The results of the responses of teachers and students regarding the developed centrifuge can be seen in Figure 4.

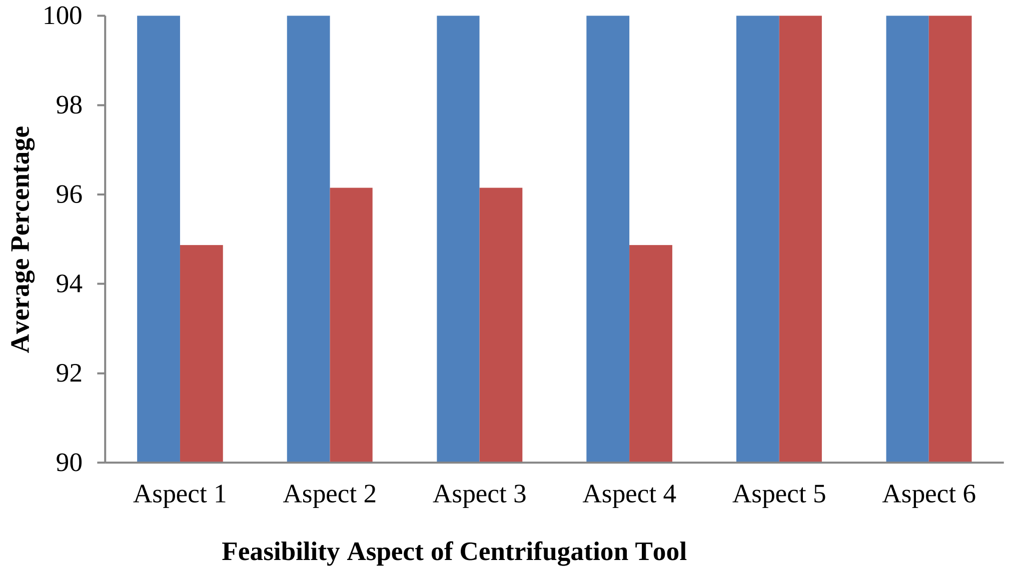


Figure 4. Results of teacher (blue) and student (red) responses to the centrifugation tool

There are improvements made at this stage is to put a mark on the scale of the rotation speed level regulator so that the scale is clearer. The results of the teacher's response to the students' worksheet on the aspects of the suitability of content, readability and construction are 100% each with very high criteria. The results of student responses to the worksheet developed on the readability aspect were 95.63% and the attractiveness aspect was 97.55% with very high criteria.

In the disseminate, the product is implemented on the actual target. Class VIIA as the experimental class and class VIIC as the control class. In the experimental class, researchers used students' worksheet and development tools in the learning process. And in the control class, the researcher taught with the conventional method. Before the learning was carried out, both classes were given a pretest and after the lesson was given a posttest. The questions given previously have been tested on 20 students who have studied the material for separating mixtures. Testing of the test instrument was carried out with the 17.00 software and the results of the test instrument were valid and reliable with very high reliability, so that the questions could be used to measure problem solving skills.

The results of the assessment of the implementation of the Lesson Plan conducted by two science teachers during the implementation of the centrifugation device and the students' worksheet developed were 84.38% with very high criteria. The effectiveness of the students' worksheet and the centrifugation tool is seen from the calculation of the mean n-gain and the size effect size from the results of the pretest and posttest scores for the control class and the experimental class. The first step in this test is the prerequisite test, namely the normality test. Based on the normality test using SPSS 17.00, the research data obtained were normally distributed, so the next test was parametric test.

Then proceed with calculating the value of n-gain and effect size. The n-gain conducted to determine the increase in the pretest and posttest scores on problem solving skills. The average value of the n-gain in the control class and experimental class is shown in Figure 4.

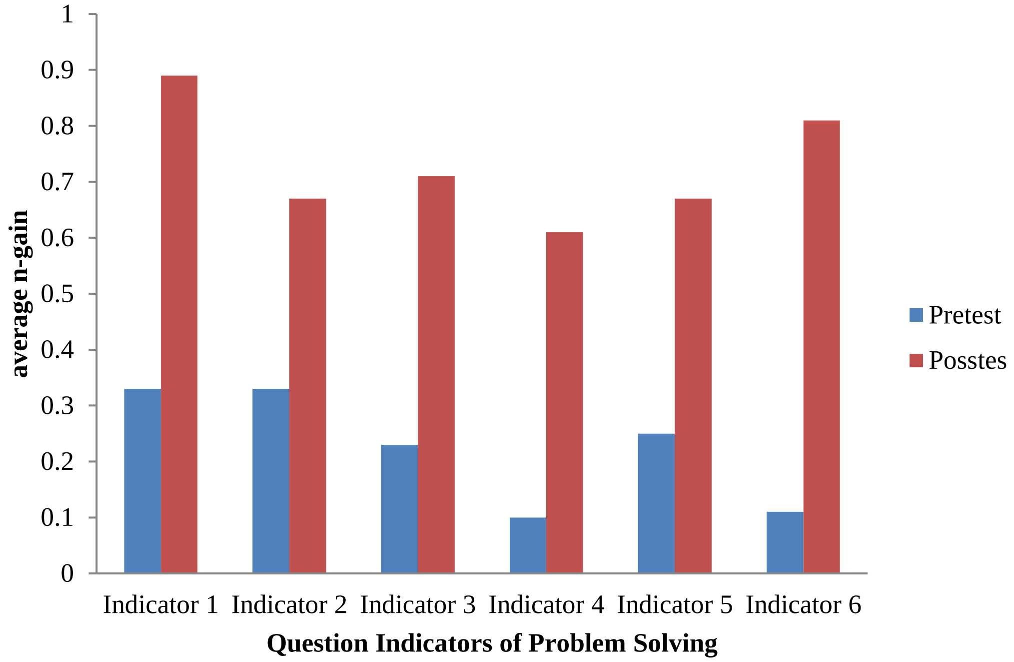


Figure 4. The average n-gain of problem solving question indicator

Based on Figure 4 it is known that the average value of n-gain problem solving skills in the control class is lower than the experimental class for all indicators. This shows that problem solving skills were successfully grown in the experimental class which in the learning process used LKPD and centrifugation tools. This is caused by several factors, including each stage of learning in the learning syntax contained in the LKPD, problem solving skills are trained. The LKPD developed using the inquiry model, where the learning syntax of the inquiry model contains a problem solving process that refers to the problem solving process according to Beyer (1995).

Furthermore, the difference between the two averages was tested using the Independent Sample T Test and Paired Sample T Test. The results of the test of the difference between the two averages obtained the value of Sig. (2 tailed) < 0.05, i.e. 0.00 for both tests, this means that H0 rejected. In the Independent Sample T Test, H0 is rejected, meaning that the average n-gain problem solving skills in the control class is significantly different from the average n-gain problem solving skills in the experimental class, with higher n-gains in the experimental class. And in the Paired Sample T Test, H0 is rejected, meaning that the average posttest value is not the same as the average pretest value, namely the average posttest value is higher than the average pretest value. In the tests conducted before the learning took place, the results showed that there was no significant difference in the test results of the two classes. After learning is complete, the test is carried out again by giving different problem-solving skills test questions from the previous test. From the test results with independent sample t-test, the results were significantly different between the average n-gain of the experimental class and the average n-gain of the control class, where the experimental class had a higher value than the control class.

Based on Paired Sample T-test analysis, the average posttest value was higher than the average pretest value in the experimental class, meaning that there was an increase in both values. This proves that the use of the developed students’ worksheet can improve students' problem solving skills. This result is also supported by facts in the field, where in the control class students seem to have difficulty solving test questions, while in the experimental class students seem to find it easier to work on test questions because problem solving skills have previously been trained. Then the effect size is carried out to find out how much influence the students’ worksheet results have in development. Based on the calculation results, the effect size is 0.32 with moderate criteria. The calculation provides information that the impact of the developed students’ worksheet has a moderate impact in improving students' problem solving skills.

In the students’ worksheet developed, there are stages that contain experimental procedures, namely the stage of testing the hypothesis. This stage allows students to perform performance to test the hypothesis that students have made before. Performance assessment is carried out by observing directly the experimental activities in the laboratory carried out by students. From this assessment, the average student performance score was 91.52 and the standard deviation was 5.945. This calculation is carried out to determine the distribution of data in a sample and see how close the data is to the mean value (Sekaran and Bogie, 2016). The results of the calculation of the mean and standard deviation on student performance in the laboratory show that the standard deviation value<mean. This proves that the students' performance scores in the laboratory have a distribution close to the average value. The lower the standard deviation value, the closer to the average (Ghozali, 2016). In the control class which does not use students’ worksheet in the learning process, of course, the practicum process facilitated by centrifugation also does not occur, so students do not have performance scores in the laboratory. This means that with the presence of a centrifuge, practicum can be carried out and the value of student performance in the laboratory can be measured. After implementing the product, students in the experimental class and partner teachers were asked to fill out a response questionnaire regarding the use of students’ worksheet and centrifugation equipment.

The results of the teacher's response to learning that apply centrifugation tools and students’ worksheet to improve problem solving skills and performance in the laboratory are 100% with very high criteria. The same thing is also seen from the overall student responses to the centrifuge and students’ worksheet, which is 95.77% with very high criteria. Based on the results of student responses, it is known that the learning is fun and students are familiar with the stages of problem solving skills. The obstacles to the implementation of the students’ worksheet and the developed centrifuge are the unavailability of an adequate science laboratory in schools, the laboratory building has not been used for a long time so that some parts of the room are damaged and unfit for use. The solution is practical activities carried out in class.

▪ CONCLUSION

Learning that applies centrifugation tools and students' worksheet to improve performance in the laboratory and students' problem solving skills as a result of development get good responses from teachers and students. This can be seen from the responses of teachers and students to learning by 100% and 95.77%, respectively. Student performance scores in the laboratory have a distribution close to the average score, with a mean score of 91.52 and a standard deviation of 5.945. Students' worksheet development results declared effective in improving problem solving skills. This can be seen from the significant difference between the average value of n-gain in the experimental class and the control class, where the average value of n-gain in the experimental class is greater than that in the control class. And in the experimental class, the average posttest score is higher than the average pretest value which indicates that there is an increase. In addition, the effect size is 0.42 in the medium category which indicates that the students' Worksheet developed has a moderate impact in improving problem solving skills.

The obstacles in this study were the unavailability of an adequate science laboratory in schools, the laboratory building had not been used for a long time so that some parts of the room were damaged and unfit for use.

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