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Development of PjBL-based science student worksheets to improve the engineering design process and learning outcomes of elementary school students

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ABSTRACT

Student's 4C (Critical Thinking, Creativity, Communication, and Collaboration) skills need to be facilitated in 21st century learning. It can be trained with various learning resources. However, the books is still the majority of learning resources in the classroom. One solution is to compile the student worksheets as a learning resource combined with the PjBL learning model. The student worksheets developed must be valid, practical, and effective in use. The student worksheets needs to be tested to measure the value of its validity, practicality, and effectiveness. It uses the 4D model and this development process is discussed sufficiently at the develop stage. The research instruments used are student worksheets validation sheets, student worksheets implementation sheets, learning outcome tests, and student response questionnaires. The trial was conducted at SD Negeri Kedungrejo 02, Lumajang with 16 students. Before it used, the student worksheets was validated by 2 experts and 1 certified ASN teacher who obtained an average validation score of 81.3 with a very valid category. After it was declared valid, it was tested in the classroom and the practicality score obtained an average of 97.2% with a very practical category. Meanwhile, the effectiveness in terms of n-gain was obtained with an average of 0.73 with details of 0.75 for learning outcomes and 0.70 for EDP, both of which are included in the high value with the effective category. The results of this trial indicate that the student worksheets developed meets the validity, practicality, and effectiveness values for use in classroom learning.

Keywords: *EDP Student worksheets; Engineering Design Process; Learning Outcomes; Student worksheets; PjBL Student worksheets*

ABSTRAK

Keterampilan 4C (*Critical Thinking*, *Creativity*, *Communication*, dan *Collaboration*) siswa perlu difasilitasi dalam pembelajaran abad 21. Keterampilan 4C dapat dilatih dengan berbagai sumber belajar. Namun kecenderungan sumber belajar berupa buku masih menjadi mayoritas pembelajaran di kelas. Diera yang modern ini perlu adanya pemanfaatan sumber belajar lain untuk mendukung keberhasilan pembelajaran. Salah satu solusinya adalah dengan menyusun LKPD sebagai sumber belajar yang dipadukan dengan model pembelajaran inovatif PjBL. LKPD yang dikembangkan harus bernilai

valid, praktis, dan efektif untuk digunakan dalam pembelajaran. LKPD yang dikembangkan perlu diuji coba untuk mengukur nilai kevalidan, kepraktisan, dan keefektifannya. Pengembangan LKPD ini menggunakan model 4D dan proses pengembangan ini dibahas cukup pada tahap *develop*. Instrumen penelitian yang digunakan adalah lembar validasi LKPD, lembar keterlaksanaan LKPD, tes hasil belajar, dan angket respon siswa. Uji coba yang dilaksanakan di SD Negeri Kedungrejo 02 kabupaten Lumajang dengan jumlah responden sebanyak 16 siswa selama 1 minggu. Sebelum LKPD digunakan, LKPD divalidasi oleh 2 orang ahli dan 1 guru ASN bersertifikat pendidik yang mendapat hasil rata-rata nilai validasi sebesar 81,3 dengan kategori sangat valid. Setelah LKPD dinyatakan valid maka LKPD diuji coba ke dalam kelas dan nilai kepraktisan didapatkan rata-rata sebesar 97,2% dengan kategori sangat praktis. Sedangkan keefektifan dari segi *n-gain* diperoleh rata-rata sebesar 0,73 dengan rincian 0,75 pada hasil belajar dan 0,70 pada EDP yang keduanya masuk dalam nilai tinggi dengan kategori efektif. Hasil uji coba ini menunjukkan bahwa LKPD yang dikembangkan memenuhi nilai kevalidan, kepraktisan, dan keefektifan untuk digunakan dalam pembelajaran di kelas.
Kata Kunci: Engineering Design Process; Hasil Belajar; Lembar Kerja Peserta Didik; LKPD EDP; LKPD PjBL

INTRODUCTION

The demands of 21st century learning are that students can master the 4C skills (Critical Thinking, Creativity, Communication, and Collaboration). Septikasari & Frasandy (2018) states that learning needs to develop and adapt to adjust to circumstances, especially in the demands of the times that require students to master 4C skills. The results of observations in several elementary schools in 3 sub-districts found that students' 4C skills were not facilitated properly because of the difficulty of implementing them in learning. The achievement of 4C skills in students in learning, especially in science subjects in schools, can be facilitated by one of them, the Engineering Design Process (EDP). EDP is a process that emphasizes engineering with activities that encourage students to think critically for problem solving, decision making, assumption analysis, evaluation, and investigation (Artobatama et al., 2020). Engineering skills in STEM can be used in science or science learning as an alternative (Muttaqiin, 2023). EDP implementation does not achieve maximum results due to lack of knowledge and lack of training (Wardani & Ardhyantama, 2021).

The 2016 Minister of Education and Culture Regulation requires collaborative and creative learning, one of which can be done by improving student's 4C skills (Ardiansyah et al., 2020). These 4C skills can also be developed in various ways, including using the Project Based Learning model in elementary schools (Azizah et al., 2024). Science learning is also more focused on PjBL (Project Based Learning) learning so that students can be more independent, critical, and develop their curiosity (Ikhsani & Alfiansyah, 2023). Project Based Learning can be integrated into learning through student worksheets. Project based learning can be integrated into teaching materials and has the feasibility so that innovative and creative learning is created through student worksheets (LKPD) (Arsana & Sujan, 2021). The results of observations in several elementary schools in 3 sub-districts found that many schools were not optimal in implementing learning due to the lack of learning resources in the form of books available at school. Learning resources do not only use books, student worksheets compiled by teachers are one form of learning resources (Rahayu & Budiyono, 2018). This student worksheets was developed with the integration of Project Based Learning as an innovation and

solution to the limited number of books owned by schools as learning resources (Kurino et al., 2023).

Student learning outcomes can be improved through teacher innovation in learning by developing student worksheets. Learning outcomes can be influenced by teacher innovation in learning (Wulandari & Nisrina, 2023). Observations in several Public Elementary Schools in Tempeh District show that learning outcomes obtained in learning often do not meet the learning objective achievement criteria (KKTP). Learning outcomes that meet KKTP can be achieved if the three important aspects can be facilitated through innovative learning. Learning outcomes in the cognitive aspect can be improved through student activity through innovation in learning using PjBL in the classroom (Setiawan et al., 2021).

Based on the description above, PjBL-based student worksheets in improving engineering design process and students' cognitive learning outcomes needs to be studied in a solution to overcome learning problems in limited learning resources or dependence on learning resources on books and as a means of adjusting learning to the demands of the times in today's education world. This study will answer how the validity, practicality, and effectiveness of PjBL-based IPAS student worksheets are to improve engineering design process and learning outcomes of elementary school students that are developed.

METHODS

Type and Design

This research is a development research. The development used is the 4D model (define, design, develop, disseminate) owned by Thiagarajan, Semmel, and Semmel (Saputri et al., 2019). The 4D development model is very suitable for developing learning devices. The 4D development model is very suitable for use in developing teaching devices because of the analysis of materials and tasks (Agustina & Vahlia, 2016). The research procedures implemented in developing student worksheets are shown in Figure 1.

Figure 1. Student Worksheets Development Procedure

The discussion of this research is limited to the development stage, which is tested on students who have received the material using the developed student worksheets.

Data and Data Sources

The data processed is quantitative data. The research data was taken since January 7, 2025 and was carried out for one week at Kedungrejo 02 Elementary School, Kedungrejo Village,

Rowokangkung District, Lumajang Regency with the subjects/targets of the research being 16 fifth grade students in 3 face-to-face learning meetings. The results of the data obtained were used to test the student worksheets in terms of validity, practicality, and effectiveness so that it was suitable for use.

Data collection technique

The validity, practicality, and effectiveness of the developed student worksheets will be collected data through several research instruments. The student worksheets validation sheet will be used to validate the student worksheets. 2 expert lecturers and 1 ASN certified teacher will be the validators. The aspects that need to be tested in the teaching module or student worksheets to be included in the feasible category are: (a) presentation, (b) content, (c) language, and (c) suitability (Wati & Yuliani, 2020). The practicality of student worksheets will use the student worksheets implementation observation sheet. Student activities carried out in using student worksheets can show that student worksheets is practical to use in classroom learning (Rahayuningsih et al., 2018). Meanwhile, for the effectiveness of student worksheets, 2 instruments will be used, namely learning outcome tests and student response questionnaires. The cognitive domain learning outcome test is carried out on the cognitive process dimension aspect which contains 6 categories of Bloom's Taxonomy (Ndiung & Jediut, 2020). Student response questionnaires will be given after the learning is completed at each meeting. Aspects contained in the student response questionnaire include: appearance aspects, material aspects, presentation component aspects, language aspects, and learning objective aspects (Maharani & Hakim, 2022).

Data analysis

The validity of the student worksheets will be measured using the instrument on the student worksheets validation sheet. The results of the filling by the validator will be used as the basis for the revision of the student worksheets. The data obtained is in the form of a percentage from each validator which is then averaged. The score calculation uses the Likert Scale (Efendi et al., 2021) shown in table 1 below

Table 1. Likert Scale Categories

Rating Scale	Categories
1	Very Accordance
2	Less Accordance
3	Accordance
4	Not Accordance

(Source: adopted from Efendi et al. (2021))

The calculation used to obtain the student worksheets validity score from the three validators uses the equation,

$$\text{Validity Score} = \frac{\sum score\ for\ each\ indicator}{\sum maximum\ score\ of\ the\ indicator} \text{ x } 100$$

The results of the validator filling will be taken as an average in the form of numbers which will then be entered into the criteria in table 2.

Table 2. Percentage Classification of Validity Indicators

Validity Criteria	Validity Score
Very valid or can be used without revision	$76 < X \leq 100$

Quite valid or can be used with minor revisions	51 < X ≤ 75
Less valid and recommended not to be used because it needs major revision	26 < X ≤ 50
Invalid or may not be used	X ≤ 25

The practicality of student worksheets is measured using an observation sheet in the form of an student worksheets implementation sheet during learning. This sheet will be filled in by the teacher as an observer in the use of student worksheets by students during learning. The practicality of student worksheets can be seen from student activities in using and working on student worksheets during learning in class (Rahayuningsih et al., 2018). This sheet also uses the Likert Scale (Efendi et al., 2021). The calculation used to obtain the percentage of learning practicality through the use of student worksheets filled in by observers uses the following equation,

$$\text{The Value of Practicality} = \frac{\sum score\ obtained}{\sum highest\ score} \text{ x } 100\%$$

The results of the observer's filling will be taken as an average in the form of a percentage which will then be interpreted in table 3.

Table 3. Practicality Score Criteria

No.	Percentage	Criteria
1	P > 75%	Very Practical
2	50% < P ≤ 75%	Practical
3	25% < P ≤ 50%	Less Practical
4	P ≤ 25%	Very Impractical

(Source: adopted from Lestari et al. (2018))

Based on the interpretation that has been produced, the student worksheets is declared practical if it gets a value of ≥ 75%.

The effectiveness of student worksheets is measured using student response questionnaires and cognitive domain learning outcome tests. Student response questionnaires are given and filled out by students at each meeting in the learning process. This sheet also uses a Likert Scale (Efendi et al., 2021). The calculation used to obtain the percentage of learning effectiveness through the use of student worksheets filled in by students uses the following equation,

$$\text{Percentage of Student Responses} = \frac{\sum score\ obtained}{\sum maximum\ score} \text{ x } 100\%$$

The results of the students' questionnaire will be taken as an average in the form of a percentage which will then be interpreted in Table 4.

Table 4. Category of Student Response Result Interpretation

Percentage	Criteria
75% < P ≤ 100%	Very Effective
50% < P ≤ 75%	Effective
25% < P ≤ 50%	Less Effective
P ≤ 25%	Not Effective

(Source: adopted from Rizkika et al. (2022))

The effectiveness of student worksheets was also measured through pretest and posttest in learning outcomes of cognitive domains and EDP abilities. Pretest and posttest were analyzed using the N-gain score calculation (Amalia & Novita, 2022). The equation used,

$$N - gain = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score}$$

The results of the N-gain calculation will be interpreted in categories that can be seen in table 5.

Table 5. N-gain score interpretation categories

Score	Categories
$g \geq 0{,}7$	High
$0{,}3 \leq g < 0{,}7$	Medium
$0 \leq g < 0{,}3$	Low
$g < 0$	Fail

(Source: adopted from Wahab et al. (2021))

tudent worksheets are declared effective if they get an N-gain score ≥ 0.7. Obtaining an N-gain score ≥ 0.7 also indicates an increase in learning outcomes in the cognitive domain and the EDP domain.

RESULTS AND DISCUSSION

Student worksheets developed using PjBL refer to research Sari et al. (2020) states that student worksheets PjBL provide effectiveness in classroom learning which has an impact on improving student learning outcomes. The application of project based learning in classroom learning has an effect on improving student activity and learning outcomes (Fatmawati, 2023). The use of PjBL in classroom learning can improve student learning outcomes (Desi et al., 2023). Not only learning outcomes can be improved through PjBL, students' EDP can also be improved. Project-based learning improves students' EDP (Nurbayani et al., 2023). Angelina et al. (2023) concluded that the PJBL model can improve engineering skills in finding and determining solutions to a problem through the application of science concepts, designing, making prototypes, and testing and analyzing them to find alternative solutions. This EDP is important for elementary school students to master to face problems in everyday life. EDP integration can encourage students to understand science concepts and find relationships between these concepts to solve real-world problems (Fitri & Zhaza, 2021).

The developed student worksheets will be used after their feasibility has been tested first. The developed student worksheets are said to be feasible if they meet three aspects, namely: validity, practicality, and effectiveness (Dewi & Azizah, 2019). The student worksheets that will be tested for their eligibility have previously been reviewed by FKIP UNEJ lecturers to provide input before being submitted to the validator. The appearance of the student worksheets cover is designed with bright colors to attract students' attention. Student worksheets display several writings and images that show learning materials. An example of a student worksheets cover is in Figure 2.

Figure 2. Main cover of student worksheets

The content in the student worksheets contains the flow that students will go through in using the displayed student worksheets, while the PjBL phase and EDP indicators are also integrated into the student worksheets. This aims to introduce and improve EDP to elementary school students. Figure 3 is the design of the student worksheets that were developed.

a. Student worksheets processing flow b. Display of assignment content in student worksheets

Figure 3. Design of student worksheets

The EDP indicators used in this study adopt the property of Ulum et al. (2021) which includes 6 aspects consisting of (1) problem identification, (2) knowledge in problem solving, (3) creating products based on ideas and concepts, (4) conducting product trials and development, (5) evaluating products, and (6) determining products that are appropriate to the problem. The researcher adjusted these six aspects to make them easier to apply with the PjBL model.

EDP was chosen to be integrated into PjBL because it has similarities in terms of project creation. EDP is a process in creating user-centered designs with a prototype as a solution to problems that are in accordance with community needs (Nusyirwan et al., 2020). The integration of EDP indicators applied to PjBL can be seen in the following table 6.

Table 6. Integration of EDP indicators into PjBL

PjBL Steps	Student Activities	EDP Indicators

Fundamental Questions	Asking fundamental questions about what students should do with the topic/problem solving	Identification of problems
Designing Project Planning	Students hold discussions to determine a project creation plan as a solution to the problems that have been put forward	1. Knowledge in problem solving 2. Create products based on ideas and concepts
Creating a Production Schedule	Students prepare and agree together on a schedule for completing the project and the time for submission	
Monitoring Project Activity and Progress	Students create agreed projects by implementing them according to schedule, recording each development, and discussing with the teacher if they encounter difficulties	Creating products based on ideas and concepts
Testing Project Results	Discuss the feasibility of the project that has been created by creating a product report for presentation material	Conducting product testing and development
Evaluation of Learning Experiences	Each student presents a report that has been made and responded to by other students who then conclude the results of the project together with the teacher	Evaluate and determine products that are appropriate to the problem

The improvement of cognitive learning outcomes will also be trained in student worksheets through several examples of exercises. The ability to remember (C1) will be trained using exercises in the form of puzzles about identifying the stages of the water cycle. The ability to analyze (C4) will be trained by forming groups which then hold discussions in solving problems by creating appropriate project designs. Meanwhile, the ability to create (C6) will be trained by realizing the project design into a product in the form of a water cycle diorama and presenting the results of the project as a solution to the problem.

Validity of student worksheets

The validity of the developed student worksheets is validated by the validator covering several aspects. Several aspects that are validated in measuring the validity of student worksheets are presentation, content, language, and suitability (Wati & Yuliani, 2020). Researchers will use 3 aspects, including: presentation, content, and language. The validators are 2 lecturers from FKIP Universitas Jember and 1 ASN teacher who has a teacher certificate. The validation process takes approximately 1 month, followed by revisions according to input from the validators. This input provides a reference for further developing student worksheets before being used by students.

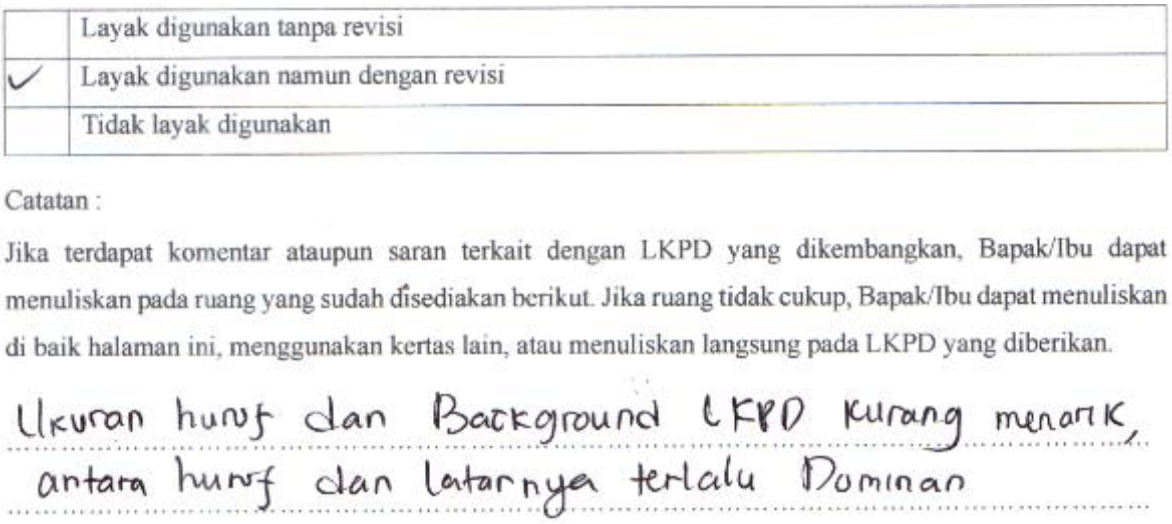
The validation results from the 3 validators are then processed and a recapitulation of the validation of student worksheets can be displayed as shown in table 7.

Table 7. Recapitulation of student worksheet validation results

No	Indicator	Score		
		Validator 1	Validator 2	Validator 3
1	Content	44	33	37
2	Presentation	8	6	12
3	Language	5	6	5
Total Score			45	54

Validity Score Average	70,3	84,4

Based on the recapitulation table of the validation sheet results, an average validity score of 81.3 was obtained. The magnitude of the validity score produced shows that the developed student worksheets fall into the very valid criteria. However, the validator noted that there needs to be a revision in the presentation of the student worksheets that were made because the size is not proportional and needs to be adjusted to be more balanced. The student worksheet notes are shown in Figure 4.



	Layak digunakan tanpa revisi
✓	Layak digunakan namun dengan revisi
	Tidak layak digunakan

Catatan :

Jika terdapat komentar ataupun saran terkait dengan LKPD yang dikembangkan, Bapak/Ibu dapat menuliskan pada ruang yang sudah disediakan berikut. Jika ruang tidak cukup, Bapak/Ibu dapat menuliskan di baik halaman ini, menggunakan kertas lain, atau menuliskan langsung pada LKPD yang diberikan.

Ukuran huruf dan Background LKPD kurang menarik, antara huruf dan latarnya terlalu Dominan

Figure 4. Notes from one of the validators for revising the adjustments to the appearance of student worksheets.

Based on this input, several points that need to be revised based on input from the validator can be seen in Figure 5.

Figure 5. Presentation of student worksheets which are the validator's notes.

In addition to the work steps and assignments, the revision of the presentation of the student worksheets display also needs to add additional information regarding the work step code, pages, PjBL syntax, and EDP indicators to facilitate the use of student worksheets. It is important to make revisions so that the resulting learning products are appropriate and useful

in classroom learning (Kurniawan et al., 2018). Changes in the appearance of student worksheets after revision can be seen in Figure 6.

a. Initial view before revision b. View after revision

Figure 6. Changes in the appearance of student worksheets after revision

Practicality of student worksheets

The practicality of student worksheets that have been developed by researchers will be measured through the learning implementation observation sheet. The implementation of observed learning will focus on student activities in using the student worksheets that have been developed. Observers are teachers at the school with the number adjusted to the groups formed and at this trial stage using 3 observers.

Observations were conducted during the learning process for 3 meetings to 3 groups that were formed. The results of the observations obtained the percentages shown in table 8.

Table 8. Recapitulation of the results of observations of the implementation of student worksheets

No	Observer	Learning to- (%)		
		1	2	3
1	Observer 1	96,4	92,9	100,0
2	Observer 2	100,0	96,4	100,0
3	Observer 3	96,4	92,9	100,0
Average each learning (%)		97,6	94,0	100
Total average (%)			**97,2**	

The average result obtained from the observation sheet of learning implementation using student worksheets developed was 97.2%. The percentage obtained was included in the very practical category. The EDP process carried out in class can be seen in Figure 7.

Figure 7. Students make sketches for the projects they are working on

Effectiveness of student worksheets

The effectiveness of student worksheets will measure the improvement of learning outcomes and EDP as well as student response questionnaires which will be described as follows,

a. Learning Outcomes and EDP

Pretest and posttest will be used to measure learning outcomes. Learning outcome tests can be measured using questions in the form of questions consisting of pretest and posttest stages (Nomor et al., 2022). Pretest and posttest will be used to measure learning outcomes. Learning outcome testPretest was conducted before the research was conducted. Furthermore, the posttest was conducted at the end of the learning after using student worksheets developed by the researcher. The questions given are divided into 2 types, namely: multiple choice and essay. Measuring cognitive domain learning outcomes will use multiple choice questions while essays are used to measure students' EDP abilities. The results of the pretest and posttest will be analyzed using data in the form of N-gain score calculations. Analysis of learning outcomes can be calculated using N-gain score calculations which can be measured using questions in the form of questions consisting of pretest and posttest stages (Amalia & Novita, 2022).

The cognitive domain learning outcome test uses multiple choice questions. Multiple choice questions are chosen because they are suitable and easy for students to understand. Qura et al. (2024) states that students' cognitive levels can be measured by multiple choice questions with more consistent assessments. Pretest and posttest are suitable for use in assessing improvements in student learning outcomes in the implementation of PjBL. Previous research by (Wardani et al., 2019) conclude that pretest and posttest can be used to measure the effectiveness of improving student learning outcomes in PjBL.

The assessment of EDP indicators will be measured using essay questions. Essay questions are chosen for EDP indicators because they have appropriate criteria in knowing the processes that students have gone through and obtained during learning. According to Aristiawan (2022) essay questions applied in assessments are not only summative assessments, but can also be used as formative assessments because the problem-solving process chosen by students is not only limited to one solution.

The value of data analysis obtained from learning outcomes and EDP shows that there is an increase after using student worksheets compiled and developed by researchers. In the small class trial, an n-gain was obtained with an average of 0.73, as a breakdown of 0.75 in learning outcomes and 0.70 in EDP abilities. Based on the results of the student worksheets developed are included in the high value with the effective category. The following is an example of the results of the EDP capabilities facilitated in student worksheets can be seen in Figure 8

a. Diorama design sketch by group 1 b. Diorama results by group 1

Figure 8. Results of group projects that facilitate student's EDP skills

Thus, it can be concluded that these student worksheets are very effective to use in learning to improve cognitive learning outcomes and students' EDP abilities. Similar results were also obtained in previous research by Amar (2018) concluded that the integration of PjBL with EDP in science subjects had a positive impact on students' learning outcomes, creative thinking, critical thinking, and communication.

b. Student Response Questionnaire

The student response questionnaire was filled out by students to provide researchers with an overview of the conditions of students when using student worksheets in the ongoing learning process. This also has an influence on the effectiveness of student worksheets in learning. The ease of students in using student worksheets has a significant impact. The student responses obtained when filling out the questionnaire are an overview of the ease of use of student worksheets by students in the classroom which can show effectiveness in learning (Dermawati et al., 2019). Students seemed enthusiastic in using the student worksheets that were compiled and developed. The completed student response questionnaires obtained results of 85.4% during the small class trial and were categorized as very effective.

Effectiveness gets 2 categories that are both included in the effective category. Learning outcomes and EDP are included in the effective category which gets an average of n-gain 0.73, while in the student response questionnaire it is categorized as very effective with an average percentage of 85.4%.

CONCLUSION

Based on the results obtained in the study, the developed student worksheets were declared valid which was categorized as very valid with an average score of 81.3. The practicality level of student worksheets was declared practical which obtained an average of 97.2% in the very practical category. The effectiveness level of student worksheets was stated with 2 criteria, namely: learning outcomes and EDP obtained an average n-gain of 0.73 with details of 0.75 and on EDP of 0.70 which was a high criterion and entered the effective category while the results of the student response questionnaire obtained an average of 85.4% which was included in the very effective category. student worksheets developed based on PjBL were said to be feasible to use with student learning outcomes and EDP in the classroom at public elementary schools in science learning increasing. As a suggestion for further research, there

needs to be student worksheets in digital form to keep up with the times and minimize the risks that occur.

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