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Improving Contextualized Problem-Solving Skills among Grade 8 Students Through "Digestive System" Problem-Oriented Learning: A Study Intervention Findings in the Complex Domain

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ABSTRACT Indonesia needs more appropriate learning methods and educational policies to improve literacy and numeracy skills, including problem-solving competence. These two capabilities are fundamental in this era of Industrial Revolution 4.0. This research investigates whether Digestive System learning designed to be oriented toward contextual problems with direct SESD-based teaching encourages students' ability to solve contextual problems better than conventional learning in the classroom. Data collection included paper and pencil assessments of students' problem-solving skills through a quasi-experimental study using a pretest-posttest experiment control group design. The experimental group received learning about the digestive system based on the principles of education for sustainable development. The study sample comprised class VIII students at SMPN 4 Ponorogo. The result of this research shows that the ANCOVA analysis with pre-test scores as a covariate: F (6.860) indicates that the experimental group displayed more autonomy, independence, and openness in their approach to problem-solving due to the treatment they received. With a Cohen's d of 0.60, 72.4% of the "treatment" group will be above the mean of the "control" group (Cohen's U3), 76.6% of the two groups will overlap, and there is a 66.3% chance that a person picked at random from the experimental group will have a higher score than a person picked at random from the control group.

Keywords Contextual, Digestive system, Problem-oriented learning, Problem-solving ability, SESD

1. INTRODUCTION

The current focus of the Natural Sciences education curriculum in Indonesia is to equip students with sustainable competencies with student-centered learning and democratic, pluralistic learning synergies (Pradipta & Hariyono, 2021). These sustainable competencies include systems thinking skills, anticipatory skills, normative skills, strategic skills, collaboration skills, critical thinking skills, self-awareness skills, and integrated problem-solving skills. It is hoped that students can master the skills above to achieve the goals of sustainable development or sustainable development goals (SDGs) (Purnamasari & Hanifah, 2021).

To achieve the competencies expected in Natural Sciences education above, the Ministry of Education and Culture initiated a new curriculum policy, namely the independent learning policy, where teachers are free to carry out the teaching and learning process, which can create a conducive learning environment and can motivate students in their learning. As one of the consequences of freedom to learn, natural science teachers in Indonesia must improve science learning content and the science learning process to provide meaningful learning to students. One of the aims of science learning is to increase students' competence, including problem-solving.

The ability to solve problems is the ability to think by collaborating the skills of critical thinking, analytical thinking, and creative thinking in solving a problem. Problem-solving skills are higher-order thinking skills applied to real-world problems (Makrufi & Hidayat, 2018). Science learning must be able to answer problems relevant to natural symptoms or phenomena that change over time. One of the competencies that students are expected to master in science learning is the competency to solve

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problems. Dogru stated that in the science education environment, one of the main goals of education is to develop critical, logical thinking, and problem-solving competence (Prastiwi & Nurita, 2018). Science learning has achieved the learning objectives perfectly if the student's ability to solve science problems is considered good enough (Sulastri & Pertiwi, 2020).

Based on the results of the Program for International Student Assessment (PISA) in 2018, Indonesia was in 74th position out of a total of 79 countries with a relatively decreased score from 2015, namely a mathematics score of 379, a science score of 396, and a literacy score of 371. In 2015, Indonesia was in the 64th position of 75 countries, with a math score of 386, a science score of 403, and a literacy score of 397 (Hilda et al., 2022). The ability of Indonesian students to solve story problems related to non-routine questions still needs to improve because students still need to understand the problem and look for alternative solutions (Partayasa, Suharta, & Suparta, 2020). Based on this, Indonesia needs more appropriate learning methods and educational policies to improve literacy and numeracy skills. Meanwhile, these two capabilities are essential in this era of Industrial Revolution 4.0.

Teachers can measure students' problem-solving abilities by presenting contextual problems to students and seeing how they behave in analyzing and carrying out the problem-solving process. The purpose of raising students' problem-solving skills is to hone, surface, and improve problem-solving abilities in science learning so that they can apply them when facing problems in everyday life. Fun and innovative learning is needed to gain the ability to solve students' problems so that students can be more motivated in the problem-solving process.

Hudojo, in 2005, put forward the indicators for solving problems, namely identifying problems, planning problem-solving, resolving problems, and interpreting results (Mamin, Yunus & Ariska, 2018). According to George Polya, 4 steps need to be taken to solve problems, namely the problem identification stage, the problem-solving planning stage, the problem-solving implementation stage, and the re-examination stage of the findings. Meanwhile, according to Dewey's theory, indicators in solving problems include recognizing problems, defining problems, developing hypotheses, testing hypotheses, and implementing the best hypothesis (Zulqarnain & Fatmahanik, 2022). Based on the opinions above, the ability to solve problems can be classified into the following indicators.

a. Identifying the problem is recognizing and understanding students' challenges or problems.
b. Plan problem resolution is a further step from problem identification, where students begin to plan how the problem will be resolved.
c. Solving the problem is the implementation and planning stage made in the previous stage.
d. Interpreting the results reflects the process and results of problem-solving designed by students.

Based on observations and brief interviews with science subject teachers and several students, it is known that science learning at SMPN 4 Ponorogo is still teacher-centered (teacher center), where the teacher explains the material in front of the class, and the students listen. Apart from that, sometimes learning is also carried out through discussions and presentations by students, and occasionally, practical learning is carried out in the laboratory. However, this learning still needs to be implemented. The impact of the learning teacher centers what students have done becomes dependent on the teacher's explanation and less able to analyze contextual problems in the test questions they face.

Judging from the results of preliminary studies that have been carried out, it is found that the ability of students to solve problems still needs to improve, and teaching and learning activities are often teacher-centered. The expected situation from science learning is that students are competent in solving contextual problems that involve understanding scientific concepts and critical and analytical thinking skills. Conditions in the field show that most students experience difficulty in solving contextual problems involving the application of science concepts in real-world situations. This condition shows the need for effective learning models and approaches to overcome the gaps. This condition is also the basis for developing a problem-oriented learning (PBL) model based on Science Education for Sustainable Development (SESD).

Problem-oriented learning, commonly known as Problem-Based Learning (PBL), is offered as one of the teaching models that can enhance students' problem-solving skills. The problem-oriented learning model is one of the learning models that relate problems in everyday life to become issues for students and can be used to hone problem-solving skills, critical thinking, and analytical thinking. Science learning with PBL models is considered suitable for improving the ability to solve science problems in class VIII middle school students. The increase in the ability to solve problems occurs because PBL students are always encouraged to think critically in gathering information that can be used to solve science problems given by the teacher.

There are 5 stages in the PBL model, namely from the student orientation stage to the problem, the stage of organizing students to learn, the investigation guidance stage (can be individual or group), the stage of presenting the results of the investigation, and the evaluation stage of the student's problem-solving process. Through the PBL stages, it is hoped that students' problem-solving abilities can increase, especially in the investigation stage, individually and through study groups.

The PBL model is considered to have several advantages, including being able to encourage students to develop competence in solving real-world problems, having the opportunity to construct their understanding through the learning process, students experiencing scientific activities when conducting group activities, familiar with accessing various sources of information, have the competence to assess their learning abilities, students are familiar with scientific communication activities through discussion activities and presentation of discussion results, and individual learning difficulties of students can be resolved through group discussions (Agustina, 2015).

Several previous studies that discussed increasing students' problem-solving abilities through several innovations in learning activities, including Sulastri & Pertiwi (2020), found that the Problem-Based Learning learning model with a contextual approach can improve the science problem-solving abilities of junior high school students. Roesch, Nerb & Riess, (2015) found that ecological learning in complex domains through problem-oriented learning can improve experimental problem-solving abilities and allow for more autonomous students' rights. Partayasa, Suharta, & Suparta (2020) showed the findings of their research, namely that students' problem-solving skills in mathematics can be improved through the video-assisted creative problem-solving learning model rather than conventional learning.

However, many studies show an increase in students' problem-solving abilities through various learning models, for example, project-based learning (Gao, Xiao, Jia & Wang, 2021; Makrufi & Hidayat, 2018), TTW learning model (Think, Talk, Write) assisted by web live worksheet (Hidayah & Arif, 2022), Discovery Learning model integrated Reading, Questioning, and Answering (RQA) (Hariyanto, Hikamah & Maghfiroh, 2023), as well as through approaches Concrete Representational Abstract (Malik, Fanka, Rachman & Kuntadi, 2022). Daryanes developed a form of interactive learning media, Articulate Storyline, which can improve students' problem-solving abilities (Daryanes, Darmadi, Fikri & Sayuti, 2023). Similar research was also carried out by Fitriah & Ita (2022), who developed BioPhy magazine, which was proven to improve problem-solving skills and increase environmental awareness.

Solving problems independently by students with high problem complexity can also cause a heavy cognitive demand on students' work memories (Roesch, Nerb & Riess, 2015). These conditions can arise depending on the type of student activity and the level of openness of learning activities. Next, the researcher will discuss the factors related to high cognitive load in learning, the complexity of the learning material provided by the teacher, and its influence on student's ability to solve problems in more detail.

Some research demonstrates the fundamentals of instructional support during learning for successful self-guided problem-solving; the guided instruction and training of scientific reasoning appear to improve the cognitive and metacognitive dimensions of problem-solving skills more efficiently than the guided discovery lessons of constructivists (Roesch, Nerb & Riess, 2015). A variety of support methodologies have been experimented with like (a) procedural guidance during a teacher-led conversation (Socratic method), (b) examples to familiarize oneself with the process of problem-solving and problem-decision examples, (c) worked examples to familiarize oneself with the steps of the problem-solving process and examples of problem decisions, (d) process worksheets that can help organize the problem-solving process, (e) instruction in a computer-based learning environment with a variety model system, and (f) providing basic questions as structural training support for producing practical research problems. Typically, these procedural tools only succeed after extensive orientation and training activities.

Efficient intervention research has primarily focused on the fields of ecology (Roesch, Nerb & Riess, 2015), thermodynamics (Malik, Fanka, Rachman & Kuntadi, 2022), environmental awareness (Fitriah & Ita, 2022), and fluid dynamics (Makrufi & Hidayat, 2018). Less complex systems categorize some of those science subjects compared to the continuous learning systems used by the researchers. The benefit of subjects with a low level of complexity is that basic learning techniques and sufficient conceptions can be acquired relatively easily. However, some crucial dimensions of experimentation need to be included and thus cannot be improved.

Because of this reason, we selected the contextual problem-oriented Food and Digestive System subject to be a trial case for a learning context in which different components of problem-solving ability can be improved. The Food and digestive system domains are complex because they cannot be observed directly (by the senses) by students and are influenced by several factors that are not simple. Students are only often given explanations of concepts related to this domain and are not linked to daily lifestyle patterns. Because of this, researchers want to know the impact or influence of a contextual problem-based learning model in Food and the Digestive System material to support science learning for sustainable development (SESD), which has never been raised in previous research.

Therefore, measuring competence in solving contextual problems in Food and the Digestive System material not only requires measurement strategies to control variables, generate a hypothesis on the causality of the variables, and conclusions on the appropriateness of the research design (all of these are internal validity questions) and yet must also consider reliability aspects like the use of suitable sample sizes and also long-term effects of the treatment. Only now are some instruments still available to assess competency in solving problems in the Food and Digestive System material.

Various research has demonstrated a significant impact of context- and application-based science teaching. The researchers have found improvements in students' generic attitudes toward natural and applied science, motivation to learn, ability to argue, comprehension of natural science, and mediation of competencies in transfer and implementation. Studying this kind of science principles and concepts with problem-based treatment demonstrates results that are at least compatible with conventional teaching, even sometimes providing much more favorable outcomes than traditional teaching (Sulastri & Pertiwi, 2020). These arguments support contextualizing learning materials to improve students' science problem-solving abilities.

Contextualized science education, however, encompasses various teaching and learning objectives, thus placing challenging requirements on both the instructional and learning processes. Several researchers have pointed out the challenges of high-complexity content (Roesch, Nerb & Riess, 2015). Such a learning environment can discourage students and reduce the learning effect due to the high cognitive load. However, the problem-solving process in learning requires reduced didactically plausible complexities of both phenomenon and learning environment and concentration and specialization on crucial items and skills.

Considering that contextual problem-based learning with the SESD approach is a complex learning activity, the question arises as to whether students' ability to solve science problems can be increased through learning models and approaches taken based on previous research suggestions. After evaluating the theoretical and empirical foundation that is being presented, I will provide a review. Various issues emerge that researchers want to investigate in their research.

Therefore, researchers focused on the following issues:

a) Can the Problem-Based Learning learning model using the Science Education for Sustainable Development (SESD) approach improve the ability to solve contextual problems for class VIII SMP students, which includes an understanding or analyzing problems, planning to problem-solve, and carrying out problem-solving that has been planned in the material Food and the Digestive System?
b) Can the teacher's treatment in learning influence students' feelings of autonomy?

For the research conducted, researchers expect a moderate effect from the learning carried out in developing students' specific science problem-solving abilities. The treatment provided includes learning models and approaches that are well demonstrated. Researchers consider that class VIII junior high school students are still early enough to be encouraged to learn about Food and the digestive system and integrate them into everyday problems (contextual) and sustainable development (food suitability). Thus, the researcher hypothesizes that students will differentiate between good and bad designs when solving the issue raised.

On the other hand, researchers suspect that the complexity of contextual problems related to Food and digestive system learning content will provide a more meaningful learning effect than conventional classroom learning and increase students' sense of autonomy in the learning process. The researcher then also raised the assumption that students who took part in the experimental class would gain more independence than students from the control group. This assumption is considered reasonable because the structure of the learning model in the experimental class allows students to develop their cognitive abilities further compared to the control class with conventional learning.

2. METHOD

2.1 Research Design

Researchers conducted field studies in a classroom environment that students can use in daily learning activities to obtain valid results in this research. This design ensures no random assignment of students or teachers to certain learning conditions. Therefore, in the research, the researchers chose the classes to be used through several considerations, including choosing classes with experimental group and control group conditions that were as close as reasonable regarding class size, male-female student ratio, class level, and school location. Other variables, such as students' common cognitive ability, level of skill, familial and environmental conditions, institutional-like teacher qualities, and external support to students, were not monitored. However, the researcher selected a research location in a school with parallel classes to minimize the influence of other uncontrollable variables. The researcher chose an active involvement in learning in the experimental class, and for the control class, it was left to the subject teacher, who usually handles learning in the class.

The study's research questions were examined using a pre-test/post-test quasi-experimental design. This study uses a control group to compare students' problem-solving ability levels in conventional learning with the treatment given to the experimental class. The researcher implemented a pre-test to statistically regulate relevant factors, such as pre-test scores and attainment in multiple school subjects, which were vital to the research questions. These measures boosted the study's internal validity and eliminated other explanations for the post-treatment effect between conditions. Thus, the researcher endeavored to balance the methodological and practical necessities in accomplishing their research goals.

2.2 Experimental Conditions

In the experimental class, students receive learning that is developed and structured appropriately oriented to contextual problems (Problem-Based Learning) to create science learning that supports Science Education for Sustainable Development (SESD), validated and approved by previous science teachers. Implementing learning treatments in experimental classes includes variations in learning media, methods, approaches, and selected learning activities. Meanwhile, in the control class, students receive conventional model learning activities from teachers who usually teach science subjects in selected classes. Learning in the control class is not tied to learning media, methods, and learning activities like in the experiment class. The duration of the learning treatment in both experimental and control classes was identical.

The researcher felt that hiding the concept of the specific promotion given to the experimental group from the control group during the research was the most appropriate; with the first consideration, the 'conventional' feeling in science learning in the control group will be more pronounced. Second, we conveyed the learning mechanism in the experimental group to the control group teacher after the learning activity ended. As an additional basis for researchers to report results, preliminary study (pre-test results) and control class are to be considered for the material given when learning.

2.3 Research Sample

The research was conducted in two parallel VIII classes at SMPN 4 Ponorogo. The total sample consisted of 64 students in two predetermined courses. The average age of students is 11-13 years, with the percentage of male students at 56%, slightly higher than that of female students at 44%. Javanese is the native language for 95% of the surveyed students' mothers and fathers. The percentage of students' gender and mother tongue was similar for both research classes. Research class conditions can be seen in Table 1.

Table 1 Experimental conditions

Aspect		Experimental conditions	
		Experiment	Control
Specific treatment to increase problem-solving ability		Yes	No
Food and Digestive System topics		Yes	Yes
Sample size (n)		32	32
Age	M	12	12
	SD	0.56	0.58

Note: n, number of test subjects in the partial sample; M, mean value; and SD, standard deviation.

Researchers chose class VIII junior high school students as participants or subjects in the research, which was carried out with the following considerations: the learning material for Food and the Digestive System is contained in the content of the Phase D Natural Sciences independent curriculum, specifically in class VIII of Junior High Schools in the Indonesian education curriculum. Therefore, selecting class VIII junior high school students as research samples is a valid context in terms of curriculum. Even though Food and the digestive system were also studied more deeply at the senior high school level, the researchers still chose class VIII of junior high school as the research sample. With that in mind, researchers realize that mastery of science concepts is essential for achieving aspects of validity at a higher level.

It is necessary to explain further regarding the selection of students. Education in Indonesia has a system of grouping educational phases through an independent curriculum. Phases A through F correspond to different levels of schooling, starting with grades 1 and 2 of elementary school and ending with class 10 of high school. Students who are in middle school, both middle school and high school, tend to need instructional support that is more intensive than other levels. Middle school students generally achieve in the middle of the achievement spectrum. Therefore, researchers seek to mitigate the impact of exceptional student abilities that could skew research results or contribute to more significant data variance (due to the inclusion of students with either low or high levels of achievement).

2.4 Learning Treatment

Researchers chose contextual problems as issues that students would analyze because these problems were considered to be 'closer' to the environment and students' lives. The researcher's treatment is intended to encourage students' ability to solve contextual problems and realize sustainable learning. This treatment is designed based on moderate constructivist principles. Researchers design learning units to be structured, sequenced, and explicable, accounting for students' understandings, misunderstandings, and levels of competence. The purpose is to establish a pattern of problem-based learning experiences with multiple levels of teacher-directed instruction and open-ended, guided problem-solving phases. By applying a contextual problem-based learning model with the SESD approach, students are expected to gain knowledge of food content and the digestive system, scientific reasoning, and competence in solving contextual problems.

Issues related to a healthy lifestyle, problems or disorders in the digestive organs that often occur in everyday life, and food suitability issues are the main issues that students will analyze. Through this issue, students can feel and experience awareness of the importance of conducting scientific investigations to investigate the causes and effects of human activities and food choices for the health of the digestive system and for multi-perspectivity and responsibility in making decisions in sustainable development.

2.5 Test Performance of Dependent Variable Operationalization

Researchers have created and applied written performance tests grounded in traditional test theory to determine competence in solving contextual problems. Compared with performance performances, interviews about conceptions and problem-solving strategies, and data-based computer-based tools, paper-and-pencil-based tests present a lower level of validity (Roesch, Nerb & Riess, 2015) due to their lack of objectivity. Correlations with the process are limited and cannot fully depict the problem-solving process, including all required competencies and interactions. However, researchers used paper and pencil tests because the sample size was quite large and resources were limited.

The test developed by the researchers consisted of contextual problem-oriented Food and digestive system questions consisting of 9 questions with the following details:

a) The socio-emotional test on Food and the digestive system consists of 6 questions (item numbers 1-6) to measure indicators for identifying problems in the aspects of preventing problems from arising and analyzing the causes of problems; planning problem-solving in the aspects of strategy selection and priority scale determination; as well as carrying out problem-solving in the aspects of implementing steps and complying with the plans developed. This socio-emotional test uses a 1-4 point rating scale to measure students' problem-solving abilities. In this test, students are asked to choose one answer they think is the most correct from the 4 answer choices available. Each answer choice will get a score of 1-4 according to the answer's correctness level.

b) The contextual problem-based description test in Food and the digestive system consists of 3 questions, each of which assesses two aspects of the indicator of solving the problem. The indicators measured in the description questions are indicators of analyzing the problem in the aspect of describing the problem and realizing the urgency of the problem, indicators of planning problem-solving in the elements of plan formulation and strategy selection, well as indicators for implementing problem-solving in the elements of effective communication and reflection and learning. Each description test item will be given 1-4 points for each aspect according to the suitability of the student's answer to the problem presented.

We then asked participants to rate their gained level of openness, independence, and autonomy on a 4-point Likert scale in both the control and experimental groups. Furthermore, those in the experimental group elaborated on how the learning environment affected their attitudes and motivation towards learning.

2.6 Research Procedure

An instrument for assessing students' ability to solve science problems on Food and the digestive system was developed by researchers by presenting 9 contextual problem-oriented questions. After creating the test instrument, it was administered to the experimental and control class students as a pre-test to measure value. Afterward, the experimental class underwent contextual problem-oriented learning utilizing the SESD approach, while the control class engaged in conventional learning with the subject teacher. After the lesson, the experimental and control groups underwent a post-test to assess their problem-solving abilities. They completed a questionnaire to determine the level of autonomy achieved by the students.

In general, the procedure of this research is divided into three stages, namely the preparation stage, the implementation stage, and the final stage. Each stage is outlined in the research procedure shown in Figure 1.

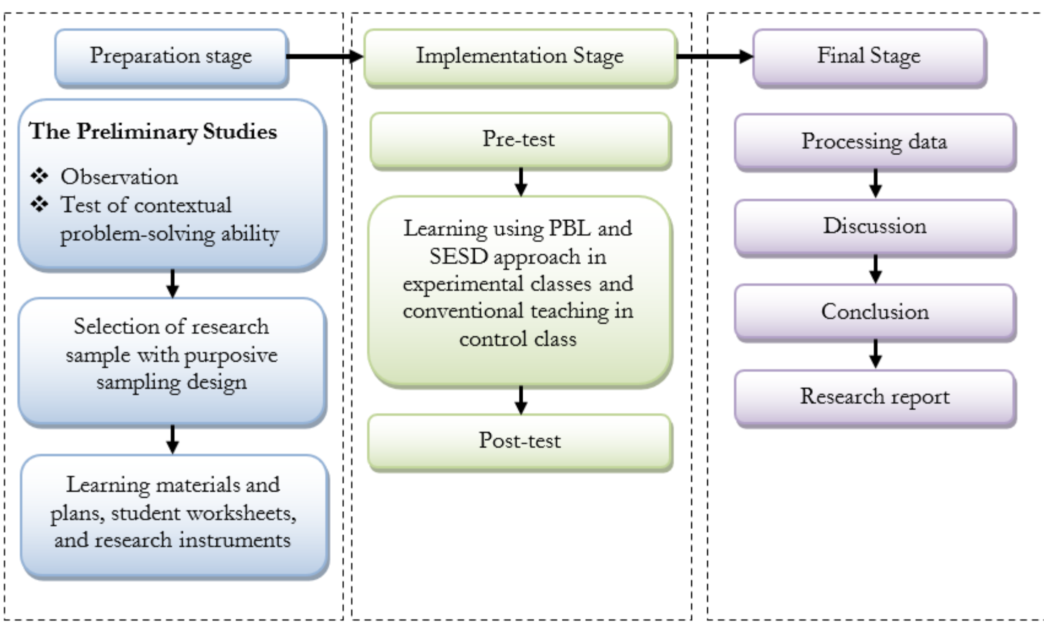

Figure 1 Research procedure

2.7 Data Analysis

The research data was statistically processed using PASW Statistics 18 software and evaluated using parametric tests according to the per-fiat principle.

3. RESULT AND DISCUSSION

3.1 Result

3.1.1 Test Instruments

Based on the instrument validity test, it is known that the Pearson correlation score for each item is greater than the r table (0.264), so it can be concluded that each item developed is valid. Moreover, the Cronbach Alpha value is more than 0.8, so the test items are declared reliable. It is shown in Table 2.

Table 2 Instrument validity and reliability

Indicator	No. Item	Pearson Correlation	Cr. α
Identify the problem	1	.726	.900
	2	.734	.899
	7	.701	.901
Plan problem solution	3	.605	.905
	4	.698	.901
	8	.769	.897
Solve the problem	5	.695	.902
	6	.620	.905
	9	.764	.898

The reliability value was unexpectedly higher in the pre-test when compared to the post-test (refer to Table 3). The internal consistency of the problem-solving ability test subscale is adequate for group comparisons. The moderate internal consistency of specific scales may be attributed to limitations on the number of items per subtest scale.

Table 3 Property scale (page 18, row 10)

Indicator	No. Items	Measuring time			
		Pre-test		Post-test	
		n	Cr.α	n	Cr.α
Identify the problem	1	190	.900	205	.886
	2	186	.899	203	.889
	7	193	.901	200	.884
	7	192	.901	198	.888
Plan problem solution	3	190	.905	197	.891
	4	200	.901	210	.884
	8	191	.897	197	.883
	8	189	.898	201	.881
Solve the problem	5	189	.902	199	.883
	6	191	.905	199	.889
	9	184	.898	189	.885
	9	190	.902	197	.885

Note: n, total score per question items; and Cr.α, Cronbach's alpha.

Based on Table 3, it is not evident what the value was obtained from items per indicator of problem-solving ability increases from pre-test to post-test. The indicator score for identifying problems in the post-test is higher than the pre-test score for each question item. However, the Cronbach alpha reliability value was higher in the pre-test than in the post-test. The description of the data in Table 3 above shows that the score on each question item during the post-test is higher than the pre-test. This score identifies that implementing learning affects students' abilities to solve contextual problems in Food and the digestive system.

Bivariate correlations between the ability to solve contextual problems, school grades in natural sciences, and general cognitive abilities were calculated to assess construct validity. The small coefficients indicate distinguishable dimensions representing more than technical achievement in the subject or general cognitive ability.

3.1.2 Lesson Implementation

Learning activities in the experimental and control classes were carried out simultaneously on Friday, September 22, 2023, during the fifth to sixth lesson hours. The learning material presented was Food and Digestive System material in the Functional Structure of Living Things Chapter.

Learning in the control class was carried out through conventional learning by the science subject teacher who

Tabel 4 Learning activities of the control group

Pha-ses	Learning Syntax	Teacher's Activity	Students' Activity
1	Conveys objectives and prepares students	The teacher explains the learning objectives, background information, and importance of the lesson to prepare students for learning.	Listen and carry out what the teacher says and instructs.
2	Demons-trating knowledge	The teacher presents the learning material step by step according to the textbooks.	Listening to the learning material presented by the teacher.
3	Guiding research	The teacher plans and guides the activities in the textbook.	Pay attention to the teacher's explanation and do the activities in the package book.
4	Checking understanding and providing feedback	The teacher checks whether the students can carry out the task well and gives feedback to the students.	Following the teacher's instructions during evaluation and reflection.

Figure 2 Lesson implementation in the experimental group

taught the control class. Djamarah argues that conventional learning methods are better known as the lecture method (in Kresma, 2014). The following describes the core learning activities, including teacher and student activities in the control group (see Table 4).

Learning in the experimental class was conducted using a problem-oriented learning model with the Science Education for Sustainable Development (SESD) approach integrated into the Learner Worksheet by raising the issue of "Health and Food Sustainability for the Future." The following are details of teacher and learner activities in the experimental class (see Table 5 and Figure 2).

In Figure 3, the learners present a sample of the worksheet. The sample shows the analysis done by learners in dealing with the issues raised in the lesson. It can be seen that learners can collect the desired information and can answer questions with a distinctive analysis style in each group.

3.1.3 Correlation Analysis Between Lesson Implementation and Result

The research results presented in Table 2 show that each indicator of problem-solving in the control and experimental classes has increased in value. Furthermore, the researcher will put forward each indicator based on its

Tabel 5 Learning activities of the experimental group

Phases	Learning Syntax	Teacher's Activity	Students' Activity
1	Orient students to the problem	Conveying learning objectives and achievements, grouping students into groups, making relevance between previous material and material to be presented, and showing authentic problems related to learning material.	Listening to what the teacher says, gathering according to the group formed, asking questions in apperception, reasoning / analyzing the problems raised by the teacher according to each learner's experience.
2	Organizing students to learn	Assist students in formulating problems and describing techniques to find solutions to problems.	Formulate a problem or limitation of the problem at hand.
3	Guided inquiry (can be individual or group)	Assist students in collecting information or data relevant to the problem and encourage students to carry out experiments to achieve problem-solving.	Collect data to support learning, conduct literacy, and discussion to conduct investigations.
4	Presentation of investigation results	Assist learners in planning and presenting the results of the investigation.	Make an investigation report and present it in front of the class.
5	Evaluate students' problem-solving process	Provide evaluation of the reflection on the results of students' investigations.	Follow the teacher's instructions in conducting evaluation and reflection.

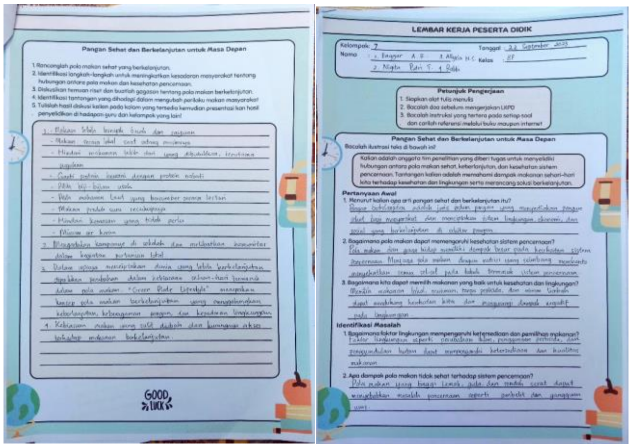

Figure 3 Working sample of student worksheet

gain score and analyze which learning syntax affects the increase.

Table 6 Gain score per indicator (page 20, row 6)

Indicator	Control Grup			Experimental Group		
	Pre-test	Post-Test	Gain Score	Pre-test	Post-Test	Gain Score
Identify the problem	377	382	5	384	424	40
Plan problem solution	385	383	-2	385	422	37
Solve the problem	372	375	3	382	409	27

Based on Table 6, it can be seen that the gain score of the experimental group is higher than the gain score of the control group. This result shows that the treatment given to the experimental group has a better impact than conventional learning on improving students' problem-solving skills.

In the experimental class, the indicator with the highest gain score is analyzing the problem, with a score of 40, followed by the indicator of planning problem solving, with a score of 37, and the lowest indicator of solving the problem, with a score of 27. These improvements are the impact of the learning carried out, especially in the phase of orienting students to the problem. In this phase, the teacher directs students to the problem at hand and guides them in reasoning and analyzing the problems that arise so that the ability of students to analyze problems can increase significantly.

3.1.4 Hypothesis Testing

A MANOVA analysis with subsequent univariate post hoc tests indicates no significant difference between the experimental and control groups of students in general cognitive abilities and Natural Sciences scores. If these variables significantly contributed to the explained variance in competency development, they were included as covariates in the analysis of covariance. The results of the MANOVA analysis showed no significant difference in the ability of the experimental and control groups to solve contextual problems as reported during the pre-test (F = 6.860).

Post-test scores for all groups, except for some variables in the control group, were higher on the post-test achievement test than the pre-test (refer to Table 7). These findings indicate that students experience a positive learning effect from taking the test. Additionally, the level of autonomy perceived by students increased following the learning process in both control and experimental classes.

To address our initial research query, we utilized ANCOVA with planned comparisons and considered pre-test scores as covariates to examine differences in learning effects between experimental groups based on the directional hypothesis. The experimental group's results were then compared with those of the control group, and we found that pre-test score covariates had moderate to strong effects on explaining the variance of all variables. The hypothesis that scores significantly differed between the experimental and the control groups was confirmed for all test question indicators, as shown in Table 8.

Table 8 Descriptive statistics of pre-test and post-test scores

			Pre-test		Post-test	
		n	M	SD	M	SD
Test scores	Eks	32	66.4	19.4	82.0	13.8
	Control	32	67.0	17.7	73.0	16.3
Degree of autonomy	Eks	32	2.6	0.9	3.1	1.0
	Control	32	2.2	1.0	2.6	1.4

Note: n, number of test subjects; M, average indicator; SD, standard deviation.

Table 7 Descriptive statistics and estimation of parameters for the learning achievement and personality tests

			Measuring time				ANCONA	
			Pretest		Posttest		Parameter estimates	
Indicator	**Class**	**n**	**M**	**SD**	**M**	**SD**	**M_b**	**SE**
Identify the problem	Exp	32	3.0	0.8	3.3	0.7	3.5	0.1
	Control	32	2.9	0.9	3.0	0.9	3.1	0.2
Plan problem solution	Exp	32	3.0	0.9	3.3	0.8	3,4	0.1
	Control	32	3.0	0.8	3.0	0.9	3,2	0.2
Solve the problem	Exp	32	3.0	0.9	3.2	0.8	3.4	0.1
	Control	32	2.9	1.0	2.9	1.0	3.0	0.2
Degree of autonomy	Exp	32	2.6	0.9	3.1	1.0	3.5	0.1
	Control	32	2.2	1.0	2.6	1.4	2.4	0.1

Note: n, number of test subjects; M, average indicator; SD, standard deviation; mb, adjusted (corrected) mean estimate; and SE, standard error.

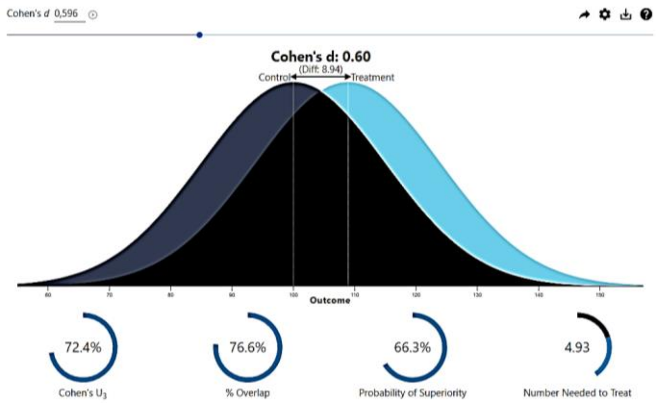

Figure 4 Cohen’s d effect size

According to Table 4, the pre-test scores for the experimental and control groups were similar, at 66.4 and 67.0, respectively. However, the experimental group had a higher post-test score of 82.0, while the control group had an average score of 73.0. This analysis indicates that problem-based learning (PBL) with the SESD approach is more effective than conventional learning in enhancing students' problem-solving skills. Based on the Cohen’s d effect size, the Cohen's d result is 0. 596 or can be rounded to 0.6 (see Figure 2).

With a Cohen's d of 0.60, 72.4% of the "treatment" group will be above the mean of the "control" group (Cohen's U3), 76.6% of the two groups will overlap, and there is a 66.3% chance that a person picked at random from the "treatment" group will have a higher score than a person picked at random from the "control" group (probability of superiority) (Figure 4). Moreover, to have one more favorable outcome in the "treatment" group than the "control" group, we need to treat 4.9 people on average. This result means that there are 100 people in each group, and we assume that 20 people have favorable outcomes in the "control" group, then 20 + 20.3 people in the "treatment" group will have favorable outcomes here.

The results of the questionnaire for our second research question indicate that the experimental group students displayed more autonomy, independence, and openness in their approach to problem-solving due to the treatment they received compared to the control group participants.

Table 9 Tests of Between-Subjects Effects

Dependent Variable: Post-Test			
Source	**df**	**F**	**Sig.**
Corrected Model	3	69.072	<.001
Intercept	1	69.910	<.001
Class	1	14.433	<.001
Pre-test	1	181.017	<.001
Class * Pre-test	1	6.860	.011
Error	60		
Total	64		
Corrected Total	63		

These results are supported by the ANCOVA analysis with pre-test scores as a covariate: F (6.860) (see Table 9). Although the results only reveal moderate effect sizes, they indicate that experimental group members faced higher cognitive challenges than conventional teaching and learning in natural sciences work. Furthermore, students in this group reported a solid motivation to engage in learning activities through independent investigation of contextual problems.

Post hoc analysis indicated significant differences in problem-solving ability indicators between the experimental and control groups, resulting in more substantial competencies among girls. In the experimental group, girls outperformed the average performance of the control group, with small to medium effect sizes (See Table 10). Additionally, girls' performance in the experimental group was above average for boys, with a medium effect size.

Table 10 Descriptive Statistics

	Group	Gender	Mean	Std. Deviation	N
Pre-Test	Experiment (PBL)	Male	62.33	12.902	18
		Female	72.14	14.522	14
		Total	66.63	14.289	32
	Control (Conventional)	Male	64.06	13.588	18
		Female	67.50	15.366	14
		Total	65.56	14.258	32
	Total	Male	63.19	13.088	36
		Female	69.82	14.860	28
		Total	66.09	14.170	64
Post-Test	Experiment (PBL)	Male	77.89	12.428	18
		Female	86.86	10.494	14
		Total	81.81	12.301	32
	Control (Conventional)	Male	72.78	14.256	18
		Female	76.21	17.295	14
		Total	74.28	15.488	32
	Total	Male	75.33	13.433	36
		Female	81.54	15.047	28
		Total	78.05	14.384	64

3.2 Discussion

Regarding our initial research inquiry, we discovered that the treatment offered was predominantly effective in most contextual problem-solving capabilities, consistent with Sulastri and Pertiwi's (2020) discoveries. Specifically, this approach enhances the skillset required for analyzing problems, devising practical solutions, and executing suitable problem-solving strategies. Additionally, concerning our second research question, a moderate constructivist learning environment incorporating problem-based learning phases resulted in an anticipated enhancement of students' sense of autonomy.

Given the limited number of students and teachers included in this study and the utilization of written paper-and-pencil tests for learning evaluation, caution must be exercised when interpreting the efficacy of the experimental group's treatment for improving competency. It is important to note that factors impacting learning outcomes inherent to the participating students and teachers cannot be fully controlled. Because the sample of junior high school students was limited to the Ponorogo area, this study cannot ascertain the effectiveness of the promotion concept in other regions – see (Sulastri & Pertiwi, 2020; Zulqarnain & Fatmahanik, 2022). We also lack evidence regarding the impacts on upper middle and elementary school grades. We did not have a control group with a specific promotional concept for contextual problem-solving abilities in other domains or less challenging contexts. Consequently, our study could not investigate the treatments' effectiveness and their effects on other learning domains or contexts.

The detected differences in achievement levels between girls and boys are exploratory findings. Therefore, our procedure does not permit the interpretation of possible causes related to the gender aspects' impact on problem-solving abilities during learning activities (see, for example, Dorisno, 2019).

However, based on our research compared to previous studies, it is reasonable to assume that acquiring the fundamental elements of problem-solving skills may be more attainable in less demanding educational environments and simpler domains (e.g., Malik, Fanka, Rachman & Kuntadi, 2022).

The findings are similar to Amir, Tati & Sarinikmah, 2021; and Rachmawati, Dewi & Prakoso, 2022, students in the experimental group in the research conducted showed an increase in their curiosity in several ways (for example, identifying problems, formulating problem-solving plans and carrying out problem-solving). This finding differs from the results of Prokop, Tuncer & Kvasnicak (2007), who found no differences in perceived curiosity (considering the preferred motivational orientation) under the same experimental conditions among sixth-grade elementary school students in Slovakia—who participated in courses in the field - compared to a control group who took lessons in a conventional classroom.

4. CONCLUSION

Considering previous research that used less complex domains (e.g., Malik, Fanka, Rachman & Kuntadi, 2022), the data obtained shows that the ability to solve experimental problems can be improved even in complex digestive system material since education is intermediate in challenging contexts and oriented to contextual problems. We discovered that average middle school students could tackle more challenging, interconnected settings and complex domains, contrary to other research that suggests otherwise (Malik, Fanka, Rachman & Kuntadi, 2022; Zulqarnain & Fatmahanik, 2022)).

The learning environment is quite constructivist, which is very interesting and motivating for students. In addition, this encourages students' ability to solve contextual problems at least as much as conventional competency-oriented natural science lessons and allows more autonomy. Furthermore, the ability to formulate epistemic questions can be stimulated earlier than anticipated. However, the increase in contextual problem-solving skills found by researchers in this study was slight compared to that observed in other studies (e.g., Sulastri & Pertiwi, (2020). Finally, particular components of validity and reliability in resolving contextual problems are beyond the grasp of eighth-grade middle school students.

The context for studying problem-solving ability involves three indicators: problem identification, problem-solving planning, and problem-solving. This context produces significant cognitive load and may challenge promoting contextual problem-solving skills in problem-based learning (PBL) classes with low or average performance. It is suggested that to develop the fundamental ability to solve contextual problems across different domains, it would be more appropriate to use a more straightforward domain, such as the digestive system, in a less complex learning environment, especially for students in grades 7 to 9., taking into account the findings from (Damayanti & Surjanti, 2022; Fibonacci, Azizati & Wahyudi, 2020; Kurnia, 2023; Pradipta & Hariyono, 2021; Pratiwi, Wijaya & Ramalis, 2019; Rahman, Heryanti & Ekanara, 2019; Sulastri & Pertiwi, 2020) and also from this study, Researchers believe that reducing irrelevant cognitive load to the necessary extent is crucial for promoting the ability to solve contextual problems that require attention. This idea concerns ambitious goals and complex approaches in sustainable development education.

While the researcher noted that the study sample did not demonstrate improved awareness of contextual issues in digestive system problems or disorders, the researcher maintains that utilizing a contextual problem-based learning model to teach the digestive system is crucial in enhancing students' proficiency in solving real-life contextual problems. Therefore, it is recommended by researchers that the incorporation of contextualization in the spiral curriculum takes place when students have a basic competency in problem-solving skills. The findings suggest that concepts related to long-term observations and random sample sizes in biological systems are highly complex and abstract (see research results Roesch et al., 2015). Teachers should allocate more instructional time to enhancing student competency in this area. For instance, they could develop contextual problem-based learning strategies, create live environments, or utilize field learning or computer-based simulations. Additionally, metacognitive reflection and explicit training in methodological criticism are essential components to consider.

In the end, overall, the research results show that didactic research in areas that can improve indicator components of the ability to solve specifically challenging contextual problems must clarify optimum methods, educational levels, and the application of suitable learning contexts and domains with appropriate cognitive strain-especially for average or low-achieving student groups. In addition, findings from research interventions indicate the need to create a spiral curriculum to promote/improve the construct of comprehensive contextual problem-solving abilities.

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