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Improving Teaching Quality and Problem Solving Ability Through Contextual Teaching and Learning in Differential Equations: A Lesson Study Approach

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Abstract. *Differential equations is a branch of mathematics which is closely related to mathematical modeling that arises in real-world problems. Problem solving ability is an essential component to solve contextual problem of differential equations properly. The purposes of this study are to describe contextual teaching and learning (CTL) model in differential equations course, to improve lecturers' abilities in implementing CTL, and to improve students' problem solving ability in differential equations. The study was conducted in the fifth semester of 2015/2016 academic year with 34 students of mathematics education Universitas Muhammadiyah Surakarta as participants. The CTL model was applied by lesson study approach which involved three stages namely plan, do, and see in each cycle. This research was conducted in four cycles. The study results found that discovery-based CTL could be applied in differential equations course. The lecturer abilities to design discovery-based contextual learning plan, to present real-world problem in learning process, to design learning strategy and assessment instruments of problem solving improved significantly. Problem solving ability of students also improved during teaching and learning process.*

Keywords*: contextual learning, differential equations, lesson study, problem solving ability*

Abstrak. *Persamaan diferensial merupakan salah satu cabang matematika yang berkaitan dengan pemodelan matematika dari kejadian nyata dalam kehidupan. Kemampuan pemecahan masalah merupakan komponen penting untuk memecahkan masalah kontekstual pada persamaan diferensial. Tujuan penelitian ini adalah mendeskripsikan CTL pada pembelajaran persamaan diferensial, meningkatkan kemampuan dosen dalam mengimplementasikan pembelajaran CTL, serta meningkatkan kemampuan pemecahan masalah mahasiswa dalam persamaan diferensial. Penelitian ini dilakukan pada semester ganjil tahun ajaran 2015/2016 dengan 34 mahasiswa pendidikan matematika Universitas Muhammadiyah Surakarta sebagai partisipan. Pembelajaran CTL dilaksanakan dengan pendekatan lesson study yang meliputi tiga tahap yaitu perencanaan, pelaksanaan, dan refleksi untuk setiap siklus. Hasil penelitian menunjukkan bahwa model CTL berbasis penemuan dapat diterapkan pada pembelajaran persamaan diferensial. Kemampuan dosen dalam menyusun rencana pembelajaran kontekstual berbasis penemuan, menyajikan permasalahan nyata dalam pembelajaran, merencanakan strategi pembelajaran, serta menyusun instrumen penilaian kemampuan pemecahan masalah mengalami peningkatan. Kemampuan pemecahan masalah mahasiswa selama proses pembelajaran juga meningkat.*

Kata kunci*: kemampuan pemecahan masalah, lesson study, pembelajaran kontekstual, persamaan diferensial*

Introduction

Differential Equations (DE) is one of mathematics branches, which is commonly used in many fields, not only in mathematics. Other fields that also employ differential equations are physics, chemistry, biology, engineering, economy, social, and psychology. Differential equations is also used to formulate real world problems in mathematical form. Effective learning strategies of DE is a challenge for education practitioners. However, some researchers had tried to develop effective learning strategies of DE (Czocher, 2011; Czocher & Baker; 2010; Kwon, O.N, 2002; Selahattin, 2010; Slavit, et.al, 2002; Rasmussen & King, 2000). The ability to connect the concepts in differential and integral calculus is highly needed in order to accurately solve DE. The inability to connect the concepts in calculus will cause the lack mastery of DE concepts. The students will be trapped in solving DE, which is actually only procedural (Selahattin, 2010).

Contextual Teaching and Learning (CTL) is one of learning approaches that makes the use of everyday lives problems or problems surrounding the students as their learning objects. Contextual problems, or commonly called real-world problems, are defined as problems that portray the real world situation according to the students' experience (Gravemeijer & Doorman, 1999), in which in order to solve them, the students have to be able to interpret the problems, conduct symbolization, manipulate, and solve the problems by applying mathematical procedures or operations (Seifi, et al, 2012). According to Johnson (2002), CTL is a learning process that aims to help the students to see the meaning within the field that they are learning by connecting academic subjects and the real contexts in their everyday lives, which are the contexts of their private, social, and cultural condition. Johnson (2002) formulates eight important components to ensure the success of the purposes of contextual learning. They are: making meaningful connections, performing meaningful work, performing self-regulated learning, cooperating, thinking critically and creatively, helping individuals to develop and improve, aiming for high standard, and using authentic appraisal.

Muslich (2007) explains that contextual learning is a learning concept that helps the practitioners to connect between learning materials and the real world situation of the students, and encourage them to make the connection between they own knowledge and its application in their daily lives. The philosophical foundation of CTL is constructivism. Constructivism is a learning philosophy focusing on the fact that learning process is not merely by memorization; rather, it reconstructs or constructs new knowledge and skills through facts or proposition the students experienced in real life. Meanwhile, Hamruni (2012) explains seven principles in the development of contextual learning. They are 1) *constructivism*: the condition where the students' knowledge is constructed based on the experiences they encounter; 2) *inquiry:* a learning process based on seeking and discovering through systematical thinking process; 3) *questioning*: learning basically is a process of asking and answering questions; 4) *learning community:* an individual's knowledge and understanding is supported by communication with others; 5) *modeling*: in contextual learning, teacher is not the only model in the learning process; 6) *reflection*: a deposition process of experience the students have encountered by rearranging the learning events or occurrences they have experienced; 7) *authentic assessment*: the success of learning process is not determined solely on the development of intellectual ability, it should also include the development in all aspects as the criteria of learning success.

Problem solving ability is the most important goal in mathematics learning. According to MAA (1998), mathematic students are expected to solve real or contextual problems by applying learned knowledge, concepts, ideas, and procedures. The students have to be able to solve problems outside mathematics by using mathematic knowledge they own. Problem solving ability in mathematics is the ability to use knowledge or to connect mathematic concepts they own to solve problems arising in the real world. This means that "problems" in problem solving tend to be complex, non-routine, open-ended, and challenging.

Problem solving is not only understood as an activity to solely solve a problem; rather, it is also a complex activity including cognitive activity, behavior, and attitude (Foshay & Kirkley, 2003). Mayer (in Foshay & Kirkley, 2003) defines problem solving as some processes with phases that require problem solver to be able to find a connection between experience (schema) that he or she already own with the problem he or she faces, and is able to do something to solve the problem. Meanwhile, Gagne (in Foshay & Kirkley, 2003) defines problem solving as an activity to synthesize between knowledge, rules, concepts, schemes, or experiences they already own with the condition they face to find a solution. NCTM (2000) provides a definition of problem solving as an activity that requires critical and creative thinking because the problem solver needs to find the correct strategy, or even an alternative strategy, to be able to solve a problem.

If we are discussing about the strategy of problem solving, it cannot be separated from Polya (1973) who offers four steps to solve a problem, which are understanding the problem, devising a plan, carrying out the plan, and looking back on the obtained result. In the understanding the problem phase, the students should clearly understand the variables existing in the problem, the required data, and the conditions existing and non-existing in the problem. In devising a plan phase, the students are expected to make a connection between the existing concepts in the problem. Next, in the carrying out the plan phase, the students carry out step by step of the plan that they have already devised on the second phase. On this step the students have to focus on precision in order to properly carry out the steps. In the last phase, the students look back on the solution they obtained to evaluate the concepts they used, making sure that the plan they take is correct, and to minimize the chance of failure in solving problem.

Taking account on the researcher's teaching experience for almost ten years of teaching DE course, most students only focus on the procedural calculations in solving DE questions. However, the students are not able to understand the meaning behind the solution. Moreover, most students still cannot connect the concepts they have learned in differential and integral calculus to answer DE questions and are still weak on solving DE contextual questions (Khotimah & Masduki, 2015). Based on the above explanation, this research aims to improve problem solving ability of the students through contextual teaching and learning (CTL) model. Lesson study approach is also used in the implementation of contextual learning on differential equation.

Lesson Study is one of the models to improve professionalism of an education practitioner (teacher/lecturer) through collaborative and simultaneous learning study based on the principles of collegiality and mutual learning to build a learning community (Mulyana, 2007). According to Lewis (2002), the idea included in Lesson Study is actually succinct and simple, which is when a teacher/lecturer wants to improve their learning quality, one of the proper ways is to collaborate with other teachers/lecturers to design, monitor, and do a reflection on the conducted learning strategy. The implementation of *Lesson Study* by using cycle system, in which each cycle is conducted in three steps; they are *plan*, *do*, and *see*. The three steps can be illustrated in the following Figure 1:

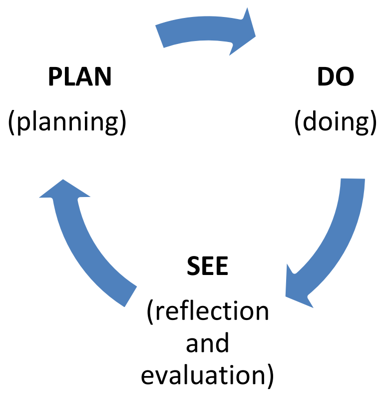

Figure 1. Lesson Study Cycle

The use of lesson study in this research aims to improve the learning ability of the lecturers in implementing contextual learning inside the class. As it is included in collegiality principle of lesson study, starts by composing learning instruments, performing learning process, and reflection and evaluation conducted collaboratively. Therefore, not only does lesson study approach encourage the lecturers in preparing the learning well, it also gives valuable input from other colleagues to do better improvement for the next learning process.

Research result conducted by Subadi, et al. (2013) showed that the implementation of lesson study on mathematics teachers showed a significant improvement of teachers' quality in preparing the lesson, improvement of teachers' collaborative work, improvement of the ability to apply learning strategies and the use of learning instruments especially information technology, and the ability to improve learning assessment instrument. Moreover, Lewis, et al. (2009) also concluded that lesson study was able to improve the teachers' knowledge and self-esteem, teachers' professional community, and the quality of learning sources. Therefore, this research aims to improve the problem solving ability of mathematics students in order to improve the lecturers' professional ability in learning, especially in the implementation of contextual learning.

Research Methods

This research was considered as an action research based lesson study approach. This research was conducted on the fifth semester students of Mathematics Education, Faculty of Teaching and Training Education, Universitas Muhammadiyah Surakarta, Indonesia, on 2015/2016 academic year. There were a total of 34 students served as the participants. In this case, the researcher as the actor collaborated with three other colleagues. The data were collected through observation method, field record, and interview. The data analysis was conducted through descriptive method by using three concurrent flows activity (Miles & Huberman, 1994), consisting of data reduction, data presentation, and conclusion. The data validation was done through technique, method, and sources triangulation.

The improvement of lecturer professionalism on the implementation of lesson study was monitored through observation method, field record, and interview. The data collected from observation, field record, and interview were presented descriptively and were analyzed by using Miles & Huberman method. The improvement of students' problem solving ability was calculated by using three indicators from Polya; they were: 1) understanding the problem, 2) devising a plan, and 3) carrying out the plan. The fourth indicator, which is evaluating the answer, was not used under the consideration that the indicator could not be seen only by using documentation of test result. The assessment of the three indicators used an assessment rubric, as presented in Table 1 as follows:

Table 1. Assessment Rubric of Problem Solving

Indicator	Score	Explanation
Understanding the problem	2	Write the question and answer correctly
	1	Write one of the above correctly
	0	Write nothing
Devising a plan	2	The formula/model/plan are correct, and if they are carried out, the answer will be correct.
	1	Part of the formula/model/plan is correct.
	0	Empty or there is no plan (formula/step), or there is a formula, but it is not correct.
Carrying out the plan	2	The plan and answer are correct.
	1	The plan is correct, but the answer is not correct, OR the plan is not correct.
	0	There is no answer.

Furthermore, to calculate the mean score of the students for each or all indicators, the researcher uses score scale between 0 – 4. The assessment criteria for mean score of problem solving ability are described in the following Table:

Table 2. Assessment Criteria

No.	Score	Criteria
1	Score $\leq$ 1.33	Low
2	1,33 <Score $\leq$ 2.33	Enough
3	2.33 <Score $\leq$ 3.33	Good
4	3.33 <Score $\leq$ 4.00	Very Good

Results and Discussion

The implementation of CTL in the classroom was conducted in four cycles, in which there are three steps of *plan, do,* and *see* on each cycle. On the *plan* phase, the activity was discussing the learning plan that was already made by model lecturer, the teaching material, the model or learning strategy, the learning instrument, and the assessment instrument that was relevant with the purposes of learning. Based on the discussion results, the lecturer revised the learning tools according to the suggestions and advices from her colleagues. The next step was the *do* phase, which was the implementation of learning plan that was already made in the class. On this step, the learning process conducted by the lecturer was observed by three colleagues as observers who functioned to monitor and record the learning process conducted by the lecturer and students. Both positive and negative moments occurred during the learning process were recorded by using the prepared instruments.

The last step of lesson study was the *see* phase, which is including the learning reflection and evaluation between lecturer and observers. The lecturer conducted self-reflection on the learning process they had done, presented some points that had or had not been conducted according to the model lecturer in accordance with the designed learning plan. Next, the observers presented their observation result about good learning process based on the lecturer's and students' learning actions. Based on the reflection between the lecturer and the observers, they discussed some ways to improve the learning plan for the next cycle. By using *plan, do,* and *see* steps on each cycle, simultaneous improvements of learning process were conducted collaboratively. The implementation of *plan, do,* and *see* steps on DE learning is presented in the following Figure:

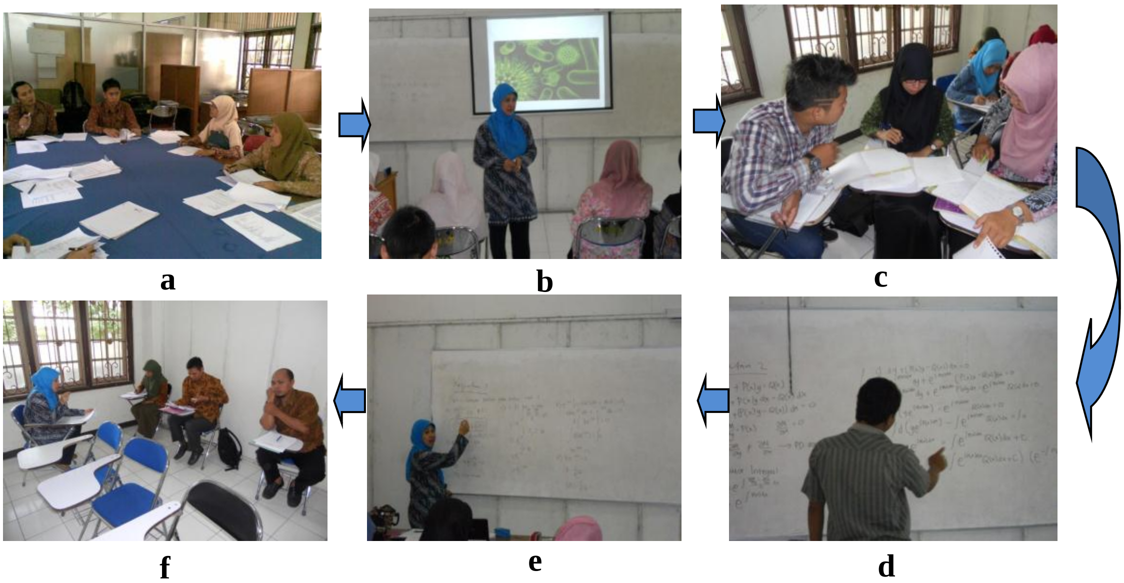

Figure 2. Implementation of Lesson Study

Notes:
a : *plan* activity
b – e : *do* activity
f : *see* activity

Contextual learning implemented in this research referred to discovery-based CTL with learning phases as presented in Table 3. For example, in *stimulation phase*, the lecturer gave a problem that might occur in daily lives related to the cooling process of coffee as follows:

> *"In a work meeting room, a cup of hot coffee will be cold as time goes by. During the meeting, the room temperature is 25º C, while the coffee temperature available in each desk is 70º C. After 15 minutes passes, the coffee temperature drops to 30º C. If the speed of coffee temperature change equals with the temperature difference between coffee and room temperature, what is the coffee temperature after the meeting goes for 30 minutes?"*

On the problem, the students were expected to be able to identify the data existing in the problem, which were room temperature, coffee temperature, and the coffee temperature change. The students should also be able to understand the connection between the speed of coffee temperature change and difference of coffee temperature and room temperature. This activity was conducted on problem orientation and data collection learning phase.

Afterwards, the students (in groups) were encouraged to connect or analyze the obtained data to come up with a solution from the given contextual problem. In this problem, the relation between both data could be presented as follows:

Table 3. Learning Phase of Discovery-based CTL

Learning Phase	Activity Description	Principles of Contextual Learning
Stimulation	Providing illustration of problems in daily lives related to the concepts of material they are learning.	Questioning
Problem Orientation	Organizing class into some groups of students. Giving them opportunity to cooperate in a group to identify or analyze the provided contextual problem.	learning community, questioning
Data Collection	Encouraging every group to find more information or collect needed data from various resources (books, internet, lecturer) in order to solve a problem.	Learning community, questioning, constructivism
Data Analysis	Supervising the students in groups to analyze information or data they acquired to solve a problem. Form of supervision is by using guided discovery model.	learning community, questioning, constructivism, inquiry
Verification	Facilitating the students to check the result of problem solving process by comparing the answer among groups and verification from the lecturers.	learning community, questioning, modeling
Generalization	Making conclusion and making generalization for similar problems or cases.	constructivism

For example T is the coffee temperature on t, and T_β *= room temperature; then, the relation between T and* T_β *can be presented in the following formula:*

$$\frac{dT}{dt} \approx \left(T - T_\beta\right)$$

or

$$\frac{dT}{dt} = k\left(T - T_\beta\right)$$, *with k as comparing constant.*

On this phase, students constructed the form of DE by using facts, information, or knowledge they had previously learned. The students are expected to understand the concept of differential in calculus in order to construct or formulate DE form accurately. After that, the knowledge of integral calculus was needed to solve DE form they had formulated. On verification phase, the answers of all groups were discussed or verified to acquire the most correct understanding regarding the solution of the problem. The last phase, which was generalization, was where the lecturer and the students make a conclusion of characteristics and the acquired DE solution procedures. The conclusion was then used to identify and solve other DE question forms.

This research was conducted in four cycle of learning with different materials. The learning topic of the first cycle was solving separate DE; the second cycle was identifying homogenous, non-homogenous, exact, non-exact DE; the third cycle was solving non-homogenous DE; and the last cycle was solving level one linear DE. Based on the learning observation result for four cycles and interview with the lecturers, it was clear that there was a significant improvement on the conducted learning quality. The improvements of lecturers' learning quality were shown through the improvement of these abilities: 1) designing learning plan following the steps of discovery-based contextual learning, 2) presenting real world problem in media and work sheet related to the learned DE materials, 3) designing learning strategy that would encourage students to have active discussion, able to voice their opinion, cooperate, and critical thinking, and 4) developing assessment instrument for problem solving ability. In addition, collaborative system in lesson study encouraged collegial lecturers to have mutual learning, discussion, and they were more open to any form of suggestions and critique regarding learning process they conducted. The research result complemented empirical evidence that lesson study approach serves as a model that could be used to improve educators' professionalism as it was reflected on a research conducted by Lewis, et al. (2009) and Subadi, et al. (2013).

One of the indicators of the success of the learning process was seen through the learning result, in which in this case the problem solving ability. In order to calculate problem solving ability, the research conducted a test for three times (Appendix). The first test was conducted after the performing of the first two cycles; second test was conducted after the third cycle; and the third test was conducted after the implementation of the last cycle. The improvement of problem solving ability could be seen through the indicators of problem solving, which were by understanding the problem, devising a plan, and carrying out the plan. The mean score of problem solving ability of each indicator and the mean score of problem solving ability was shown in Table 4.

Table 4. Mean Score of Problem Solving

Test	Indicator			Mean Score of Problem Solving Ability
	1	2	3	
I	2.91	3.44	2.1	2.81
II	3.47	3.47	3.29	3.41
III	3.9	3.53	3.35	3.59

Notes:
1 = Understanding the problem
2 = Devising a plan
3 = Carrying out the plan

The data on Table 4 showed that there was an increase of mean score of the students' problem solving ability on each indicator and all indicators from the first test to the third test. The ability to understand the problem (indicator 1) increased from mean score 2.91 on the first test to 3.47 on the second test, and it finally reached 3.9 on the third test with "Very Good" as its assessment criteria. Next, the score for first test of devising a plan (indicator 2) was 3.44 and it increased to 3.47 on the second test. On the third test, the mean score increased to 3.53 and categorized as "Very Good." The mean score for the last indicator (carrying out the plan) improved from 2.1 on the first test to 3.29 on the second test, and it kept improving to 3.35 on the third test. The assessment criterion for the third test was "very good." Overall, the mean score of problem solving ability from the first test to the third test increased from 2.8 to 3.41 and lastly to 3.59, under the criteria of "Very Good." The data showed that learning with discovery-based contextual approach could improve the students' problem solving ability in DE learning.

The assessment criterion for students' problem solving ability after the implementation of CTL was considered "very good."

The research results showed improvement of the students' problem solving ability seen through each indicator and all indicators of problem solving ability. The assessment category for three indicators and all indicators was "very good" after the implementation of contextual learning. In the learning process by applying discovery-based contextual approach, the students were given real world problems that required the students to look deeper on the existing information and data, retrieving needed information not included in the problem to help them solving the problem, and looking for possible conditions appearing in the problem. After they were able to solve the problems, the students formulated strategy for problem solving by establishing connection between acquired variables. The accuracy in establishing the connection among variables would determine the precision of the acquired solution. Next, the strategy they had formulated would be carried out by performing algebra manipulation or calculation.

The improvement of problem solving ability through contextual learning was in line with the research conducted by Suryawati, et al. (2010) who stated that groups with contextual learning had better problem solving ability compared to groups with conventional learning. Moreover, Widiati (2014) in her research to improve problem solving ability through contextual learning also showed that students with low level of problem solving ability experienced an increase on their problem solving ability after implementing learning with contextual approach. Meanwhile, the students with medium and high level of problem solving ability tended to be stable. This meant that learning with contextual approach could improve the students' problem solving ability.

This research also provided information that by using learning phases in discovery-based contextual learning model was accepted well by the students, shown through positive respond on the implementation of the learning model. The learning atmosphere was recorded to be dynamic by the discussion and opinions exchange among the students. Aside from positive respond, the students also showed improvement on some attitude aspects on learning such as responsibility, critical thinking, ability to express opinion, systematic thinking, keenness in finding more knowledge, cooperation, courage to ask questions, activity in learning process, independent, creativity, respecting other people's opinion, and inducing curiosity.

The improved attitudes after the implementation of contextual learning model is in accordance with a research by Sutama, et al. (2013), who concludes that contextual based learning would be able to improve the students' communication ability, seen through some aspects such as: 1) Presenting ideas verbally (expressing opinion), 2) Compiling ideas in mathematic model (systematic thinking), 3) Noting ideas visually (systematic thinking), and 4) Explaining mathematic concepts (expressing opinion). In addition, the research result conducted by Kurniati, et al. (2015) also showed that learning with contextual approach could also improve the students' critical thinking. In their research, Kurniati implemented two groups of students who used contextual approach learning as experiment class and traditional learning as control class. The research conducted by Kadir dan Mayjen (2013) also showed that learning with contextual approach improved students' communication ability, students' learning activity, expressing opinion ability, and the students' asking ability was better compared to learning with traditional approach.

Conclusion

Contextual learning model in differential equations to improve problem solving ability is regarded as discovery-based contextual learning. The phases of discovery-based contextual learning are: 1) *Stimulation*, which is by providing illustration of problems in daily lives related to the concepts of material they are learning; 2) *Problem orientation*, which is by giving students the opportunity to cooperate in a group to identify or analyze the provided contextual problem; 3) *Data collection*, which is by encouraging every group to find more information or collect needed data from various resources (books, internet, lecturer) in order to solve a problem; 4) *Data analysis*, which is by supervising the students in groups to analyze information or data they acquired to solve a problem; 5) *Verification*, which is by facilitating the students to check the result of problem solving process by comparing the answer among groups and verification from the lecturers; 6) *Generalization*, which is by making conclusion and making generalization for similar problems or cases.

Lesson study approach encouraged lecturer to prepare and conduct better learning process. The improvement of learning quality was shown through the lecturer's ability in: 1) preparing lesson plan following the steps of discovery-based contextual learning; 2) presenting real world problems in media and work sheet related to the DE materials the students were learning; 3) designing learning strategies that would encourage the students to be active in discussion, able to voice their opinions, cooperate with other students, and critical thinking; and 4) developing assessment instrument for problem solving ability.

It was recorded that the students' problem solving ability improved after the implementation of discovery-based contextual learning. By using score criteria from 0 – 4 from three times of tests, it was found that the indicator in understanding a problem rose from 2.91 on the first test to 3.9 on the third test. The indicator of planning problem solving strategy showed that the mean score increased from 3.44 to 3.53. Next, the mean score of the indicator of performing problem solving strategy showed an improvement from 2.1 to 3.35. Overall, the mean score of problem solving ability rose from 2.8 on the first test to 3.59 on the last test. The criteria of problem solving ability on the third test for each indicator and all indicators were in on "very good" criteria.

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Appendix

Contextual Problem of DE

Test 1:

1. Initially, a bacterial culture contains 500 bacteria and grows at a breeding rate proportional to the number of bacteria. After three hours, there are 8000 bacteria under the assumption that no bacteria dies.
   a. When will the bacteria grow into 30,000 bacteria?
   b. From the mathematic model that you obtain, explain which one is the separate DE? What is the Initial Value Problem?

   Note: For example N(t) = the number of bacteria on *t*

2. In a work meeting room, there is a cup of coffee that will be cold as time goes by. If the speed of temperature change of the coffee is proportional to the difference of temperature between the coffee and the room, determine whether the mathematic model obtain will be homogenous, non-homogenous, exact or non-exact differential equation? Give explanation!

Test 2:

In a bacterial culture, the number of bacteria will grow as time goes by. It is known that the breeding rate of the bacteria is proportional to the number of bacteria on *t*.

a. Explain that the equation model of bacteria breeding rate obtained is non-homogenous DE with $aq-bp=0$
b. By taking note that (a): the model obtained is non-homogenous DE with $aq-bp=0$, determine the number of bacteria on *t* under the assumption that no bacteria dies.

Test 3:

A bacterial culture grows with breeding rate equals to the number of bacteria. It is known that after 2 hours, there are 400 bacteria, and after 6 hours, it grows into 25.600 bacteria. By taking note that the equation of bacterial breeding rate obtained is level one linear DE, determine the initial number of bacteria in the culture