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Student's Physics Achievement in Problem-based Learning: A Quantitative Study

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Abstract: Low physics learning outcomes are still a problem in physics learning. Teachers need to think about what strategies could improve student learning outcomes. One of the learning models that could be used is the problem-based learning model. This study aims to describe the differences in learning outcomes of students in the application of problem-based learning models compared to the scientific approach at SMA Negeri 3 Padang. The type of research conducted was a quasi-experiment using the Randomized Posttest Only Control Group Design. The research instrument was a learning outcome test in the form of multiple-choice questions. The data analysis technique used is the Lilliefors test, F-test, and t-test with a significance of 0.05. Based on data analysis, it is obtained that the average physics learning outcomes of student in the knowledge aspect of the experimental class is 82, which is better than the control class, 71. Hypothesis testing showed that $t_{count} > t_{table}$ is 3.589> 1.667, which means H_1 is accepted and H_0 is rejected. It can be concluded that the implementation of the problem-based learning model has a significant effect on the physics learning outcomes of students in class X Phase E SMA Negeri 3 Padang.

Keywords: Problem-based learning model; Physics learning outcomes

Introduction

Education is one form of effort to improve the quality of human resources. Education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have religious spiritual strength, self-control, personality, intelligence, noble character, and skills needed by themselves, society, nation, and state (Nurkholis, 2019). Education needs to prepare and create graduates with the required abilities (Asrizal et al., 2018). Education is also defined as the process of influencing students both physically and mentally so that they can adapt well to the environment, so from this statement, education can instill positive values in students (Hidayat et al., 2019). Thus education should be able to develop the skills of graduates so that they can compete and solve the problem in this century (Amran et al., 2018).

In the teaching process of natural science, instructional materials play an important role both for teachers and for students (Asrizal et al., 2019). Physics is one of the subjects taught at the High School education level. Physics is part of the natural sciences. In the process of learning physics, students certainly need to have basic skills that must be built. Physics is a subject that can foster students' thinking skills that are useful for solving problems in everyday life (Aristawati, 2018). Physics also discusses the concepts and laws of physics as a product and makes observations, experiments, and investigations as a process (Hastuti et al., 2017). There are some abstract physics concepts. If the teacher is not able to concretize the abstract material well, the students will have difficulty understanding it (S. Y. Sari et al., 2022). Learning physics is not only finding a way to solve

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equations but also describing learning about a phenomenon (Sawitri et al., 2016). Prepared learning activities to aid students in mastering particular learning objectives (Habibah et al., 2023). The purpose of learning physics is to master the concepts and principles as well as master the skills to develop knowledge and a confident attitude as a provision to continue education at a higher level and develop science and technology.

Physics learning is a process between teachers and students that involves developing patterns of thinking and managing logic in a learning environment that is deliberately created by the teacher with various methods so that the physics learning program grows and develops optimally and students can carry out learning activities effectively and efficiently (Miswati et al., 2020). In learning physics, students are expected to be able to master concepts and scientific attitudes well to achieve learning objectives and learning outcomes well (Azmi et al., 2017). The process of teaching and learning activities of physics is often faced with abstract material. Physics lessons still seem difficult to understand because they have abstract concepts and are not easily connected to everyday events in human life. In the learning activities at school, teachers are not only required to master the teaching materials, but also expected to know the characteristics of the students because each student has a difference in learning activities and problem solving (Hamid & Nofiza, 2018). This requires educators to be creative in creating and developing learning media so that students can be more interested in learning physics and the material presented can be truly understood by students (Maryam & Fahrudin, 2020). In the physics process of learning, the use of innovative model of learning is very important to support the success of the model of learning used to improve student outcomes of learning (Putri et al., 2024).

Learning outcomes are a level of student success in learning that will be expressed by the value obtained through a test of the subject matter. Learning outcomes are learning achievements owned by students after receiving knowledge from learning (Sundari et al., 2024). Learning outcomes are one indicator of the learning process which includes three aspects, namely: attitudes, knowledge, and skills (Bistari, 2018). Learning outcomes are abilities that can be seen in a person after carrying out the learning process (Najwa et al., 2022). These learning outcomes can be in the form of verbal information, namely the ability to express knowledge in oral and written form, intellectual skills, namely the ability to present concepts and symbols, cognitive strategies, namely the ability to channel and direct their cognitive activities, motor skills, namely the ability to perform a series of physical movements in matters and coordination, attitude, namely the ability to accept or reject objects based on an assessment of these objects (Paradina et al., 2019). Learning outcomes as the achievement of competencies that include aspects of knowledge, skills, attitudes, and values that are manifested in habits of thought and action (Azmi et al., 2017).

Learning outcomes are changes in individuals in terms of cognitive, affective, and psychomotor aspects that they get as a result of a learning process (Azmi et al., 2017). Learning outcomes are a level of student success in learning that will be expressed by the value obtained through the subject matter test. Learning outcomes are not only based on the numbers listed on the score list or products but also involve the process and attitude of students in the learning process (Paradina et al., 2019). Learning outcomes are also in the form of changes in behavior after students learn which shows student attitudes. This attitude problem also occurs in the learning process. Most students are less enthusiastic about reading and studying the material taught, shy to ask about the material they do not understand and do not dare to express their opinions (Janah et al., 2018). Learning outcomes are very important because the success of learning is based on teaching and learning activities (Suliyanah et al., 2021).

Based on the results of observations made at SMAN 3 Padang, it was found that the learning outcomes of high school students in physics subjects were still relatively low. This can be seen from the diagnostic test scores of physics subjects in the odd semester of class X phase E in the 2023/2024 school year. Student learning outcomes have not reached the Learning Objective Achievement Criteria (KKTP) value set by the school of 80. Because the teacher has not used a learning model that is by the characteristics of the material so that students are passive in participating in the learning process. In addition, since the beginning of learning, students perceive physics material as difficult to understand and the scope of the material is too much. Physics is often considered a difficult subject by some students who are only oriented toward counting numbers. This paradigm is often reinforced by physics learning strategies that are not appropriate and are not accompanied by a complete understanding and skills in the learning process (Rohimat et al., 2022).

These difficulties can have an unfavorable impact on students' understanding of various physics concepts. The results of research by Janah et al. (2018) said that science concepts are skills that can activate, develop curiosity, responsibility, and independent learning, and help students in conducting research. Students must be able to develop their knowledge to bring up a deep understanding of physics concepts.

One needs skills to solve problems, cooperate and communicate with others, acquire new information and skills, and adapt to rapidly changing conditions. Based on this, a learning model that involves the role of students in the learning process is needed. One of the learning models that can be applied is the problem-based learning model. Learning with problem-based learning can occur if the teacher designs and implements learning activities that begin by giving problems to student. The PBL learning model is designed as one of the learning models that direct students to learn in groups and gain knowledge from constructing various knowledge and learning experiences they have and connecting them to learning problems given by the teacher. The teacher's role in problem-based learning is to present problems, ask questions, and facilitate investigation and dialog (Maryati, 2018). In addition, the Problem-Based Learning model is a learning model based on many problems that require authentic investigation, namely investigations that require real solutions to real problems (Azmi et al., 2017).

Choosing the right learning model can increase student interest in learning and be able to increase student activeness in the classroom (Ana, 2019). The PBL model is a model that can be used in learning with the characteristics of providing students to learn to prioritize the use of scientific methods in solving problems so that they know problems and skills in solving problems (Siregar et al., 2023). problem-based learning aims to help smooth the course of learning activities consisting of learning objectives, problems, discussion sheets, practicum sheets, independent assignments, analysis and evaluation, and practice questions (Janah et al., 2018). The advantages of Problem-Based Learning include: students will get used to facing problems and be challenged to solve problems not only related to learning in class but also facing problems that exist in everyday life, Foster social solidarity by getting used to discussing with friends, and Getting students used to doing experiments.

Physics is a subject that studies nature and natural symptoms (Winarti et al., 2021). In studying physics there are two inseparable aspects, namely physics as a product (knowledge of physics that consist of facts, concepts, principles, laws, and theories) and physics as a process (scientific activity) (Masril et al., 2018). Physics lessons, especially in measurement material, are very dominant in student boredom because they are based on numbers or calculations, the Problem-Based Learning model can solve problems and make students' curiosity increase. With the problem-based learning model, students easily remember the measurement procedures by the specified rules so this will greatly trigger an increase in student learning outcomes (Sipahutar et al., 2022). Measurement is an activity of determining numbers for an object systematically. Measurement plays an important role, both in the development of science and technology and in the presentation of information. Mastery of measurement is the ability to compare the value of the quantity we are measuring with other similar quantities that are used as a reference. In the measurement process, there are several things included in the measurement process, such as measurement uncertainty, measurement results, important numbers, and important number rules in measurement. Meanwhile, quantities and units are everything that has a value and can be expressed by numbers, and a comparison in the measurement of a quantity (Nasution, 2019).

The difficulty of students in measurement material is reading the scale, because the main and vernier scale lines are close together without being able to enlarge the scale display there is real equipment. Measurement activities using both tools require careful observation to get the right readings without parallax errors (Rohimat et al., 2022). Most of the students think that physics is a difficult subject to learn (Rahim et al., 2020). Students are very difficult in receiving physics lessons. The difficulties faced by students can be influenced by two factors, the first factor is from external factors that come from outside students and the second factor is internal factors that come from within students (Nasution, 2019). If this is allowed to continue, the quality of education will deteriorate. Based on the description above, the purpose of this study is to determine the effect of the problem-based learning model on the physics learning outcomes of SMA Negeri 3 Padang students.

Method

The method used in this research is the quasi-experiment method. According to Sugiyono (2016), this method has a control class, but cannot function fully to control external variables that affect the implementation of the experiment. The design used in this research is a Randomized Posttest Only control group design. This design consists of two groups, namely the experimental group and the control group with a posttest. Posttest is a test given after learning activities are carried out, the aim is to determine the extent to which students master the material that has been taught. The experimental class was treated with Problem-Based Learning and the control class was treated with a scientific approach. In simple terms, this research design is presented in the Table 1.

Table 1. Research Design (Sugiyono, 2016)

Class	Treatment	Posttest
Experiment	X_1	O
Control	-	O

The population studied in this study were all students of class X Phase E of SMA Negeri 3 Padang who were enrolled in the odd semester of the 2023/2024 academic year. In this study, sampling was carried out using a purposive sampling. The sample selection was carried out with the consideration of the subject teacher who categorized two classes that were homogeneous and had the same average ability in terms of the diagnostic test results. The two classes are Class X Phase E.5 as the experimental class and Class X Phase E.6 as the control class with total students of 36.

The research procedure consists of 3 stages including the planning stage, the implementation stage, and the completion stage. The procedure in this research can be seen in Figure 1.

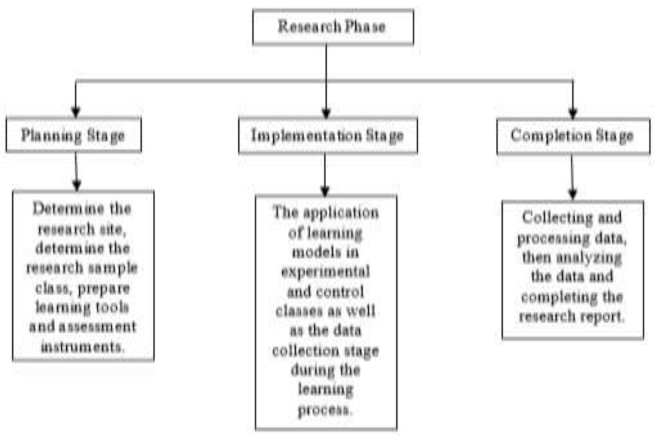

Figure 1. Research stages

The data in this study is the physics learning outcomes of students on measurement material. Data collection techniques using the final test questions in the form of multiple choice as many as 14 items. The items used in this test have been tested for validity, reliability, difficulty level, and differentiation. Data analysis techniques using normality test with lilies test and homogeneity test with F_t. Data requirements are normally distributed $L_c < L_t$ and data requirements have homogeneous variance $F_c < F_t$. After the data is normally distributed and homogeneous, hypothesis testing is carried out with the t-test to determine whether H_0 is accepted or rejected. H_0 testing conditions are accepted if $t_c < t_t$ and H_0 is rejected if it has another price at a significant level of 0.05. After processing the data, it is then analyzed and conclusions are drawn in the study.

Result and Discussion

Description of Learning Using Problem-based Learning Model (PBL)

This research was conducted by researchers from July 13, 2023 to August 15, 2023 at SMA Negeri 3 Padang. This study used two classes as samples, namely class X Phase E 5 as the experimental class which was treated using the Problem-based Learning model while class X Phase E 6 as the control class was treated using the learning model used by teachers at school. The implementation of this research was carried out for approximately six weeks, where one week consisted of one meeting in each class with a time allocation of 3 × 45 minutes.

In the first meeting to the fifth meeting, learning begins with preparing the class then followed by student prayer. Furthermore, researchers pay attention to the psychological and physical readiness of students before participating in the learning process by paying attention to cleanliness around the environment, order and student attendance. Then the researcher informed students that today's learning would be held in the form of groups which would later be divided by the researcher. The researcher conveyed the material to be learned, namely about measurement. The researcher conveyed the learning objectives to be achieved then continued by providing apperception. Then the researcher motivates students by linking in everyday life. The second meeting of the class atmosphere was quite good but there was a little commotion, but the researcher was still able to overcome the atmosphere of commotion in the class. The third to fifth meetings the researcher was able to organize and control the class atmosphere in forming his group.

Furthermore, the researcher distributed worksheet to each group and asked students in each group to read and understand the problems in the worksheet then the researcher asked students to discuss with their respective groups in order to obtain answers to the problems that had been given. In this second meeting, it was seen that students experienced confusion in conducting group discussions, they were more likely to ask the teacher than discuss with their group friends. This is because they are not used to learning using worksheet. Then the researcher guided students to understand how to fill in the worksheet. When the discussion took place, it was seen that members between groups gave arguments to each other on the problems given, but there were groups that discussed only a few people, not all group members discussed. For this reason, the researcher went around to observe the work of each group and provide guidance to groups who asked questions and had difficulties. After each group solved the problem on the worksheet, the researcher asked representatives of one or two groups to write answers and present the results of their group discussions in front of the class, while the other groups listened and paid attention to provide responses to the presenting groups. Furthermore, the researcher helped students to evaluate the results of the discussion. When the group finished presenting the results of their discussion, there were still students who were afraid and hesitant in responding to the results of the discussion from the presenting group.

The researcher and students together concluded the learning at each meeting, initially the researcher appointed one of the students to conclude then the researcher gave the opportunity to other students to add to the previous student's conclusion. Furthermore, at the end the researcher concluded and provided overall justification about the material at each meeting. In the second to fifth meetings, students already understood the procedures for filling in the worksheet and many students had begun to be active in responding to the discussion results of the presenting group. To see the extent of students' abilities, the researcher gave 2 practice questions to do. At the end of the lesson, the researcher delivered the next material and closed the lesson with a greeting. At the sixth meeting, a posttest was held with the material tested on measurement. The posttest was held in the first to third lesson hours. The posttest question consists of 15 objective questions with an allocation of 3 × 45 minutes.

Description of Data on Physics Learning Outcomes in the Knowledge Aspect

After analyzing the data, researchers obtained data in the form of physics learning outcomes of students in class X Phase E SMA Negeri 3 Padang. Data obtained from the aspect of knowledge (cognitive). Data on student learning outcomes in the knowledge aspect were obtained after the learning process through written tests in the form of objective questions. This test was given to both samples at the end of the research activities. Based on the results of statistical calculations, the average value ($\bar{X}$), standard deviation (S), and variance (S2) of the experimental and control classes were obtained as in Table 2.

Table 2. Mean Value, Highest Value, Lowest Value, Standard Deviation, and Variance of Sample Classes

Class	N	Value Max	Value Min	$\bar{X}$	S^2	S
Experiment	36	100	60	82	151.10	12.30
Control	36	93	53	71	161.71	12.71

Table 2 shows the average value of students' physics learning outcomes in the knowledge aspect of the experimental class is higher than the control class. The standard deviation value of the experimental class is smaller when compared to the standard deviation value of the control class, meaning that the physics learning outcomes of the experimental class students are more evenly distributed than the control class.

Data analysis was carried out to see whether the average difference between the two sample classes was significant or not. Before concluding the research results, data analysis was carried out through statistical hypothesis testing. Hypothesis testing is done to find out whether the hypothesis is accepted or rejected. The steps taken in hypothesis testing are through normality test and homogeneity test of both sample classes first, then hypothesis testing is carried out.

The normality test is used to determine whether the samples used in the study are normally distributed or not. So, the normality test was carried out using the Liliefors test. From the results of the normality test carried out, the prices L_c and L_t were obtained at the real level (α) 0.05 for N = 36 as in Table 3.

Table 3. Results of the Normality Test

Class	α	N	L_c	L_t	Description
Experiment	0.05	36	0.10	0.14	Normal
Control		36	0.11	0.14	Normal

Table 3 shows that both sample classes have a value of $L_c < L_t$ at a real level of 0.05, meaning that the final test data of the two sample classes are normally distributed.

After the normality test is carried out and the results show that the data is normal, then a homogeneity test is carried out to see whether the data of the two sample classes have homogeneous variances or not. The results of the homogeneity test calculation can be seen in Table 4.

Table 4. Results of Homogeneity Test

Class	α	S^2	F_c	F_t	Description
Experiment	0.05	151.10	1.07	1.30	Homogeneous
Control		161.71			

Table 4 shows that the results of the variance homogeneity test carried out on the final test data of the two sample classes were obtained $F_c = 1.0702$ and F_t with a real level of 0.05 at dk numerator 36 and dk denominator 36 is 1.3034. The results show $F_c < F_t$, this means that the data of the two sample classes have a homogeneous variance.

After conducting normality and homogeneity tests on the final test data of the two sample classes, it was found that the data in the two sample classes were normally distributed and had homogeneous variances. Then hypothesis testing was carried out to determine whether the hypothesis was accepted or rejected using the two mean equality tests. To test the research hypothesis, the t-test was used. The calculation results can be seen in Table 5.

Table 5. Results of the Hypothesis Test

Class	1-α	N	$\bar{X}$	S^2	t_c	t_t
Experiment	0.95	36	82	151.10	3.58	1.66
Control		36	71	161.71		

Table 5 shows that t_c = 3.589 while t_t = 1.667 with testing criteria H_0 is accepted if $t_c < t_t$ and H_0 is rejected if it has another price at a significant level of 0.05 with degrees of freedom dk = (n1 + n2) - 2. Because the price of t is not in the H_0 acceptance area, it is concluded that H_1 is accepted at a real level of 0.05.

Based on the statistical analysis conducted from the data of the two sample classes, there is a difference between the applications of the problem-based learning model with a scientific approach in the knowledge aspect. The complete t-test results can be seen in Appendix 12. In the knowledge aspect, it shows that this is in the H_0 rejection area, which means that the difference in treatment in the two sample classes has an effect. So, there is a difference between the use of a problem-based learning model and the use of a scientific approach (5M) on physics learning outcomes of students in class X Phase E SMA Negeri 3 Padang in the knowledge aspect.

Discussion

During the first meeting to fill in the Learner Worksheet, students looked confused because they had never been given a Learner Worksheet with a problem-based learning model before. So that it causes many students to ask questions, which makes researchers feel overwhelmed in dealing with the situation. However, this can be overcome by providing further instructions or explanations on how to fill in the Learner worksheet, then the researcher gives time for them to discuss with their respective group friends. If there are still questions, the researcher will investigate each group and help direct so that slowly students can understand it well. The Learner worksheet helps students to find a new concept to solve a problem. Where in the Learner worksheet there are stages that help students to solve a problem so that it can improve student learning outcomes. The way that teachers can enhance students' of the concept is by choosing the right learning models (Sundari et al., 2024). The problem-based learning model can encourage the quality of student learning in understanding learning materials (Erayani et al., 2022).

When students conducted group discussions and then continued with presentations in front of the class, at first it seemed that students were shy and not used to it because usually the teacher directly informed or explained the learning material in front of the class, so this caused students to be less active in conducting group discussions. The researcher in this case tried to make all students actively involved in group discussions by providing opportunities for each student in turn to express their respective opinions from the results of the previous group discussion. Then the researcher will give a reward by adding 1 point for students who are involved in the discussion, so with these students become motivated to be more involved in the implementation of the discussion. Over time there was an increase at each meeting. In the next meeting, students are getting used to the application of the problem-based learning (PBL) model where this model requires students to be actively involved in the learning process. The opinion of Istiqomah et al. (2021) is that the PBL model requires students to be active in solving problems in learning materials and educators only as facilitators in teaching and learning activities. Students have begun to be able to discuss in their respective groups and begin to respond and give conclusions on learning at each meeting. So that learning becomes more meaningful.

The results stated that the analysis of the post-test results showed a difference. Based on the results of the analysis, it shows that the average score of students in the experimental class is higher than the control class. Where the experimental class itself uses the problem-based learning model so that students' interest in learning increases and has an impact on student learning outcomes and fosters critical ideas to solve problems during learning. If you review the student scores on the diagnostic test scores at the beginning of learning, there is an increase in the average in both sample classes when compared to the initial data of the sample, indicating the growth of learning motivation for students. This is to the research of Paradina et al. (2019), which states in their research that there is an effect of learning using the problem-based learning model on student physics learning outcomes. Learning outcomes on cognitive aspects using problem-based learning tools developed can be used for student learning outcomes (Gunada et al., 2017).

This is because being given treatment with the problem-based learning (PBL) learning model makes students understand the subject matter and students play an active role in the learning process besides that it can foster student curiosity about physics lessons with the subject matter of measurement. This is to the research of Agusmin et al. (2018) which states that learning with the problem-based learning model can improve learning outcomes, learning motivation, and student learning activities. According to Hasanah et al. (2021), when applying the problem-based learning model, students are faced with problems that commonly occur in life that must be solved by discussing groups consisting of five to six members. Then to conclude from the results of the discussion, each group summarizes the results of the discussion and is presented in front of the class.

Students are interested in the activities carried out during the learning process, with the problems given by the teacher making students challenged to solve these problems. Students with their groups try their best in solving the problems given by the teacher because they want to succeed in solving these problems. According to Hasanah et al. (2021), in this learning students are given real problems to be solved with cooperation between groups so that learning is student-centered. This kind of learning process requires students to play an active role in learning activities that are not only teacher-centered so that it can improve student learning outcomes on the subject matter presented. Problem-based learning model is a learning model that uses real-world problems as a context for students to learn about critical thinking and problem-solving skills (W. Sari et al., 2023).

From the explanation above, the problem-based learning model has a better effect in developing student learning outcomes on measurement material than the scientific approach (Observing, Questioning, Gathering Information, Associating, and Communicating). Learning in the experimental class with the problem-based learning model is more fun because in the learning there is group work and investigation. While in the control class with a scientific approach, students play less role in learning, learning is more dominated by the teacher. The difference in student learning outcomes in Physics arises because of the different treatment between the control class and the experimental class. In PBL, teachers and students need to play different roles in learning using a scientific approach (Yasminah & Sahono, 2021).

One of the obstacles faced by researchers in this research is that when carrying out experiments it is difficult to control the time and all student activities because students feel interested in the experimental tools that will be used. To overcome this, at the time of the experimental activities tried to supervise students closely, so that the time to carry out experiments can be used effectively and efficiently.

The second obstacle, there are still some students who do not read and understand the objectives of the activities and learning objectives in the worksheet based on the problem-based learning model, so they do not understand the subject matter and learning activities contained in the worksheet. To overcome this, the teacher tried to guide students and remind them to read the worksheet properly and correctly.

Conclusion

Based on the research and discussion that has been done, it can be concluded that there are differences in the physics learning outcomes of students in class X Phase E in the physics subject of measurement material using the Problem-based Learning model and the scientific approach. This is indicated by the value of t_{count}=3.58, while t_{table}= 1.66. Thus, it is known that that $t_{count}>t_{table}$ is 3.58>1.66 which means H_1 is accepted and H_0 is rejected. With this, it shows that there is a significant difference in the use of the Problem-based learning model and the scientific approach to the physics learning outcomes of students in class X Phase E of SMA Negeri 3 Padang in the 2023/2024 academic year.

Author Contributions

All authors have contributed to the completion of this manuscript. P.D.S; validated the research instruments and reviewed manuscript, W.S; conducted the research, H.H; validated the teaching material used in the research, and S.Y.S; validated the instrument test.

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Conflicts of Interest

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