



ISLE-Based Learning Media Development Using PhET Simulation to Reduce Misconceptions on Parabola Motion Materials

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Abstract: The objective of this study is to develop ISLE-based learning media using PhET Simulation to minimize students' misconception about parabolic motion concept. This study employs research and development methods (Research and Development/R&D) with the ADDIE development model (Analysis, Design, Develop, Implement, and Evaluate). The results from this study are learning media in the form of ISLE-based Student Worksheets for parabolic motion experiments. To obtain credibility and validity results, the learning media has followed the validation process from material and media experts. Therefore, the learning media is suitable to be implemented for students. The results indicated that the feasibility of developed learning media student worksheet assists students to visualize parabolic motion. Student worksheet prepared using the ISLE model approach is used as a guide in achieving learning objectives to reduce students' misconceptions about parabolic motion concept through PhET Simulations. Moreover, the use of learning media student worksheet provides a visualization display of experimental results which helps students in understanding the concepts and there was a decrease in misconceptions in parabolic motion matter from 42.22 to 12.78%.

Keywords: ISLE; Learning Media; Misconceptions; Parabolic Motion; PhET Simulation

Introduction

The world of education is always developing, to realize it should be done by improving facilities and infrastructure, increasing the professionalism of educators, and improving the quality and creativity of students (Pramana et al., 2021). While one's creativity can be influenced by the ability to understand concepts and critical thinking skills (Siburian et al., 2019). The low ability to understand concepts in adolescents is an unfavorable symptom, because the low ability to understand concepts shows the decline in the quality of mindset towards social life, including education and the future of the nation.

Currently, teaching physics in schools still emphasizes physics concepts that are identical to

mathematical equations and formulas (Irwandi et al., 2020). The number of formulas in physics causes many students to think that physics is a difficult subject to learn (Etkina et al., 2019). This also has an impact on students' misunderstanding of concepts for physics lessons. Until now, this problem is a classic problem that is often encountered by physics teachers in Senior High School (SMA). So far, physics learning in high school is more often carried out in the classroom and uses the lecture method and visual videos. Physics learning more often uses teacher centered learning, students only listen to explanations from the teacher.

Concept misconceptions are one of the causes of low physics learning outcomes in students. Misconceptions have been recognized as a barrier to learning (Kibirige & Mamashela, 2022). Previous studies

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have shown that misconceptions can prevent learners from learning and understanding new concepts (Olde Bekkink et al., 2016).

According to (Pouna et al., 2022), misconception is a concept that is wrong or not in accordance with the concept proposed by experts. Misconceptions include errors due to lack of knowledge, but not all errors are misconceptions. Identifying students' misconception patterns should be done as a form of initial evaluation by a teacher (Chen et al., 2020). Teachers must identify students' misconceptions before the learning process in order to design appropriate and meaningful learning.

Some studies show that misconceptions often occur in the concept of Parabolic Motion. Research conducted by Zulvita et al. (2017), reported that students assume that when the object reaches the highest point, the velocity and acceleration values of the object will be equal to zero. Furthermore, Deviani et al. (2018), reported that a number of students experienced misconceptions by assuming that the mass of the object affects the time it takes for the object to reach the ground. Furthermore, research conducted by Neidorf et al. (2020) shows that students misunderstand the concept that when an object is dropped from a height, it will fall straight down.

Based on the results of interviews conducted by researchers with subject matter teachers who have studied the concept of Parabolic Motion at Al-Uswah IT High School, it shows that there are misconceptions in students. These misconceptions occur in Parabolic Motion by assuming that objects dropped from a height will fall straight down, when the object reaches the highest point, the velocity and acceleration values of the object will be equal to zero, and the mass of the object affects the time it takes for the object to reach the ground. One instructional approach that can lead learners to be able to make conceptual changes in physics is the Investigative Science Learning Environment (ISLE) approach developed by Van Heuvelen (2001) in the application of this approach. ISLE is an integration in the learning process, where education is designed to be directly applied in real-world learning activities, namely to solve problems in everyday life through a learning process as used by scientists.

ISLE-based learning media using PhET simulation directs students to conduct experiments that can hone concept understanding skills which include aspects of observing, measuring interpreting data, concluding and communicating. Along with the experiments carried out, students will understand the concepts related to the experiment.

Based on the background of the problem above, it is necessary to remediate misconceptions on the concept of Parabolic Motion. One of the efforts to overcome

misconceptions is using ISLE-based learning media student worksheet using PhET simulation. Therefore, researchers are interested in conducting research on the Development of ISLE-based Learning Media using PhET Simulation in Overcoming Misconceptions on Parabolic Motion Material.

Method

This study uses the Research and Development (R&D) method, due to the objectives to be achieved in this study. R&D is a research method used to produce a certain product and then test the product (Sugiyono, 2019). This development research aims to develop experimental student worksheet for parabolic motion assisted by PhET simulation. This media development research design is adapted from the ADDIE development model developed by (Dick & Carey, 1996).

The development of ISLE-based learning media for Parabolic Motion experiments was carried out at IT AL USWAH High School which is accredited B, and is located in Blok Sawah, Kota Sigli District, Pidie Regency. Some considerations for the selection of SMA IT AL USWAH, one of which is the willingness of the school to give permission to conduct research and has never been done research on the effectiveness of ISLE-based learning media using PhET simulations to overcome misconceptions on parabolic motion material. This research lasted for 6 months, from January 2023 to June 2023. Data collection in this study was carried out with several techniques, namely: initial interview, questionnaire, test and media trial. The instruments used in this study include; validation instruments, effectiveness instruments, and practicality instruments.

Result and Discussion

Result

Analysis of 2013 Curriculum Based on 21st Century Learning

Curriculum 2013 applies a scientific approach (scientific) in learning and authentic assessment that uses the principle of assessment as part of learning (Gunawan, 2017). In order to master 21st century skills, science learning is seen not only for the transfer of knowledge and skills to students, but also to build high-level thinking abilities (analytical, synthesis, critical, creative, and innovative) through scientific work experiences (Adri et al., 2020; Suryawati & Osman, 2017). To teach learners in the direction of higher-order thinking, the ISLE approach is an alternative that can be used to build a generation capable of facing the challenging 21st century (Buggé, 2020).

Through the ISLE approach, learners learn to be problem solvers, innovators, creators, and collaborators and continue to fill the critical path of engineers, scientists, and innovators that are critical to the future (Emilia, 2020). Not all science topics in the curriculum can be taught using the ISLE approach this is in accordance with its scientific characteristics. In addition, the concepts, principles, and techniques of science are used in an integrated or connected manner in the development of products, processes, and systems used in their daily lives. To identify topics that can be taught using the ISLE approach, it can be done by analyzing the science materials/topics/concepts in the 2013 curriculum.

Analysis of Physics Learning at School

After conducting an interview with the physics subject teacher of SMA IT Al-Uswah about the physics learning conditions that have been taught at school, it can be concluded that the learning that takes place is in accordance with K13 and the material taught so far is done through practicum and demonstration methods (Lunetta et al., 2013). The selection of models and methods chosen in carrying out the learning process in the classroom is adjusted to the conditions and circumstances of the students with the aim that students can understand the material well. Physics learning at the school has not used the ISLE approach using PhET simulation in the learning process. So that the application of ISLE assisted by PhET simulation on parabolic motion material becomes a new learning innovation for teachers and students at the school (Linn et al., 2023). The ISLE approach that requires students to think like scientists in conducting practicum or experiments to find their knowledge.

Design of ISLE-based Learning Media using PhET simulation of Parabolic Motion Material

At this stage the author designs a practicum activity guide for the topic of Parabolic Motion. Learning media worksheet is the development of all aspects of learning (cognitive, affective and psychomotor) in the form of experimental guides. In addition, student worksheet aims to train students in discovering and developing skills. This guide is designed differently from what has been used so far which is generally procedural to investigation. Student worksheet is made as simple as possible which aims to provide opportunities for learners to explore independently with the team. Through this student worksheet, students are also encouraged in character building and more critical thinking.

This ISLE-based student worksheet invites students to take an active part in analyzing formulas about parabolic motion material, by understanding the basic

concepts of physics itself, students are invited to find how to analyze the equation of a physics material concept. For example, such as determining the Maximum Distance, Maximum Height and Travel Time, students are challenged to think more creatively and critically to analyze the equation of parabolic motion, starting from what is parabolic motion, what affects parabolic motion and what happens to objects if the speed, mass, and angle of fire are varied.

With this way of thinking, students are able to understand the concept of parabolic motion well, because basically the ISLE-based student worksheet using PhET simulation prioritizes students who play an active role in learning, building critical, creative, collaborative and communicative ways of thinking. This learning media student worksheet is built based on the initial framework, namely:

Simulation 1 Elevation Angle

Using the PhET simulation application to find the concept of parabolic motion (from the correlation of the elevation angle with the height and maximum distance of the object). Make a hypothesis from the correlation of elevation angle with the height and maximum distance of the object. Comparing the values of maximum distance, maximum height and travel time in the PhET simulation with the theory of parabolic motion equation.

Simulation 2 Initial Velocity

Using the PhET simulation application to find the concept of parabolic motion (from the correlation relationship of initial velocity with height and maximum distance of the object). Hypothesize the correlation between the initial velocity and the height and maximum distance of the object. Comparing the values of maximum distance, maximum height and travel time in the PhET simulation with the theory of parabolic motion equation.

Simulation 3 Mass of Objects

Use the PhET simulation application to find the concept of parabolic motion (from the correlation of mass with height and maximum distance). Make a hypothesis from the correlation between mass and height and maximum distance. Comparing the values of maximum distance, maximum height and travel time in the PhET simulation with the theory of parabolic motion equation.

Vector Simulation

Use the PhET simulation application to analyze the direction of the vector in parabolic motion. Determine the value nilai v_{0x} and v_{0y} . Determine the position of the object with a specified time interval. From this framework, the ISLE-based student worksheet using

PhET simulation was developed to reduce students' misconceptions on parabolic motion material. The parts of ISLE-based learning media student worksheet using PhET simulation can be seen in Appendix 2.

Design of Data Collection Instruments

Pretest and Posttest Questions

The pretest and posttest questions in this study consisted of 10 questions on parabolic motion material in the form of multiple choice and reason answers. This question serves to analyze the effectiveness of student worksheet in reducing students' misconceptions on parabolic motion material. The questions tested were made based on the learning material contained in the student worksheet.

Validation Sheet

The validation sheet is given to the validator in the form of a scoring sheet. The validation sheet aims to determine the assessment of the validator about the student worksheet and test questions that are being developed. The assessment by the validator is filled in on the validation sheet in the form of numbers, suggestions and comments. Furthermore, the validation results from the validator are used as reference material for improvement.

Practicality Sheet

This assessment sheet is given to students after completing parabolic motion experimental activities through the ISLE learning approach using PhET simulations. This assessment aims to see the students' response to the use of student worksheet parabolic motion material.

Development

Learning Media Validation Analysis Results

Data Analysis Results of Media Expert Validation

Learning media validated by three people consisting of Physics Education Lecturer FKIP Syiah Kuala University, Physics Education Lecturer UIN Ar-Raniry and IT Al Uswah High School Teacher. The results of the media expert assessment for ISLE-based learning media using the PhET simulation obtained from the validation of student worksheet by media experts show a very valid category in each aspect of the assessment with an average score of 114 from a maximum score of 130 for all aspects of the assessment. Based on the assessment by media experts for student worksheet, the percentage value of all aspects assessed was 87.7%. The percentage results obtained are then converted into a qualitative scale based on the category, then the student worksheet developed is included in the very valid category and declared suitable for use in learning activities.

Data Analysis Results of Material Expert Validation

Data on the results of material expert validation can be seen in Appendix 2. Learning media validated by three people consisting of Physics Lecturer FMIPA Syiah Kuala University, Physics Education Lecturer FKIP Syiah Kuala University, and Physics Teacher SMA IT Al-Uswah. The results of the material expert assessment for ISLE-Based Learning Media using PhET Simulation show a very valid category in each aspect of the assessment with an average value of 75.3 from a maximum score of 85 for all aspects of the assessment. The percentage value is calculated using Equation 4.1. Based on the assessment by material experts for student worksheet, the percentage value of all aspects assessed was 88.6%. The percentage results obtained are then converted into a qualitative scale based on the categories that can be seen in Table 3.6. Because the indicator value obtained is above the minimum limit of the 80% class interval, which is 88.6%, the student worksheet developed is included in the very valid category and is declared suitable for use in learning activities.

Test Instrument Validation Analysis Results

The data from the validation of the test instrument was validated by the material expert validator. The results of the material expert assessment for the test instrument which shows the results of the validation of the test instrument by the material expert show a very valid category in each aspect of the assessment with an average value of 91.7 from a maximum score of 105 for all aspects of the assessment. The percentage value is calculated using Equation 4.1. Based on the assessment by the material expert for the test instrument, the percentage value of all aspects assessed was 87.33%. The percentage results obtained are then converted into a qualitative scale based on the categories that can be seen in Table 3.6. Because the indicator value obtained is above the minimum limit of the 80% class interval, which is 87.33%, the instrument developed is included in the very valid category and is declared suitable for use in learning activities.

Implementation

Analysis of the Effectiveness of PhET Simulation in Reducing Misconceptions

The student worksheet on parabolic motion using the PhET simulation "Projectile Motion" begins with an explanation of the definition of parabolic motion, objectives, and steps to open the PhET simulation "Projectile Motion". Furthermore, instructions and explanations are given regarding the features that can be changed and observed. Such an introduction is given so that learners can select and operate the simulation appropriately as expected by the teacher.

This part of the practicum consists of four activities, namely: investigate the effect of elevation angle on the farthest distance, maximum height, and fall time of a parabolic object moving without air friction; investigate the effect of initial velocity of an object on the farthest distance, maximum height, and fall time of a parabolic object moving without air friction; investigate the effect of mass of an object on the farthest distance, maximum height, and fall time of a parabolic object moving without air friction; analyze vectors in parabolic motion.

Learning Media Effectiveness Analysis

Results of Pretest Analysis of Learners

The percentage of students based on answers and the CRI Index is grouped into the categories of Understanding Concepts, Not Understanding Concepts, and Misconceptions on parabolic motion material and the percentage of the overall number of participants from 10 questions given based on answers and the CRI Index obtained that there are still many students who experience misconceptions on the concept of Parabolic Motion.

Results of Posttest Analysis of Learners

The percentage of students based on answers and the CRI Index is grouped into the categories of Understanding Concepts, Not Understanding Concepts, and Misconceptions on Parabolic Motion material and the percentage of the total number of participants out of 10 questions given based on answers and the CRI Index obtained after being given treatment, namely the teaching and learning process using ISLE-based learning media using PhET simulations, students are complete in understanding the concept of Parabolic Motion so that it

can be stated that this learning media can reduce students' misconceptions.

Percentage of Decrease in the Number of Misconception Learners

The percentage of misconceptions has decreased in all indicators after remediation activities using ISLE-based learning media using PhET simulations. The decrease in misconceptions shows that there is a difference in the amount of misconception reduction. The largest percentage decrease is in the indicator of analyzing the shape of the parabolic trajectory presented in the form of a picture, namely from 72.22% to 0% and the smallest percentage decrease is in the indicator of analyzing the components of object motion and travel time in parabolic motion, namely 55.56 to 33.33%. Thus it can be seen that after remediation activities using ISLE-based learning media using PhET simulation, there is a decrease in misconceptions in parabolic motion material, which is 12.78%.

Evaluation

The evaluation stage is the final stage in this research. At this stage improvements are made by receiving suggestions from various parties both from validators, teachers and students. Evaluation was carried out at the school studied by reviewing the misconceptions of students and students' responses to ISLE-based learning media using PhET simulations. Data on the results of the response of Class X SMA IT Al-Uswah students to ISLE-based learning media using PhET simulations on parabolic motion material are presented in the following Table 1.

Table 1. Data on Student Response Results

Assessment Aspect	Score	Score Max	Percentage %
Student worksheet Assessment	681	720	94.59
Learning Process	587	630	93.17
Average	634	675	93.88
Category			Very Practical

Overall, the results of students' responses to the use of ISLE-based learning media using PhET simulations fall into the very practical category with a percentage of 93.88%. The utilization of technology and student worksheet in the learning process of parabolic motion has an impact on students so that they become happy to learn physics and understand the concept of parabolic motion well.

Discussion

In this study, researchers used learning media student worksheet as teaching material which is one of the learning strategies. This learning media is a learning

media designed by involving students directly in the scientific process to learn from facts to theory, expecting students to ask why an event occurs, what causes something to happen, then students conduct investigations to find answers, conduct experiments, analyze data logically so that they can find the cause of a symptom or fact can occur.

After analyzing the 2013 curriculum used today, researchers chose parabolic motion material taught to grade X students. The development of ISLE-based learning media using PhET simulation aims to reduce students' misconceptions in managing (obtaining) knowledge gained in teaching and learning activities

and provide the widest possible opportunity for students to make observations, find patterns in the form of general solutions that can be reused or repeated to solve common problems. Learners are also able to make relationships (relation), interpret (explanation), make hypotheses, make predictions and design writing to test hypotheses.

Based on the results of a limited test of ISLE-based learning media using PhET simulation to 18 students of class X SMA IT Al-Uswah, based on the posttest scores of students that after remediation activities using ISLE-based learning media using PhET simulation there is a decrease in (Eveline et al., 2019) misconceptions on parabolic motion material. In the first problem, with the misconception of the trajectory of a bomb dropped from an airplane moving above the earth's surface when viewed from an observer on earth if wind speed, humidity, and air friction are ignored, the bomb will fall straight vertically down in the direction of the plane's motion. This shows that misconceptions occur in accordance with the research found by Fauziah & Darvina (2019). In the pretest, the number of misconceptions reached 72.22% and after remediation, students experienced an increase in concept understanding with a total percentage reaching 100%.

In the second question, with the form of misconception two identical balls are released from the same roof, ball 1 is released downward without initial velocity while ball 2 is released horizontally using a spring then the two balls have different vertical motion, both fall with different vertical distances, at different intervals of time, because the ball released with the push of the spring moves faster because the trajectory is shorter. This shows that there is a misconception in accordance with the findings by (Amalia, 2018). In the pretest, the number of misconceptions reached 55.56% and after remediation it was 33.33%.

In the third question, with a form of misconception, a golf ball is hit by forming a certain angle to the horizontal line. If the wind speed, humidity, and air resistance force are ignored, then the ball has an arbitrary acceleration because the acceleration of the ball at the peak point is zero and the direction upwards after passing the peak point of acceleration is not zero. This shows that misconceptions occur in accordance with the findings (Tamara et al., 2020). In the pretest, the number of misconceptions reached 33.33% and after remediation, students experienced an increase in concept understanding with a total percentage reaching 100%.

In the fourth question, with a form of misconception, a ball is kicked at a certain angle to the horizontal so that it forms a parabolic trajectory. If wind speed, humidity, and air resistance are ignored, then the

speed of the ball in the vertical direction is the same value at position A (top point) and B because position B passes the highest point so it has the same speed as position A. In the pretest, the number of misconceptions reached 38.89% and the remediation was 27.78%.

In the fifth question, there is a misconception that what is not an example of parabolic motion is that basketball players can adjust the strength of the throw and the angle of the throw so that the ball can enter the basket and football players can adjust their strength and the angle of the kick so that the ball is right into the opponent's goal. In the pretest, the number of misconceptions reached 22.22% and after remediation it was 16.67%.

In the sixth question, with identical forms of misconceptions bullets A and B have the same shape, size, and mass. Bullet A is fired with an initial velocity forming an elevation angle of 45° . Bullet B is fired with the same initial velocity as bullet A forming an elevation angle of 30° . If wind speed, humidity, and air resistance are ignored, bullet A will reach the farthest distance and maximum height smaller than bullet B, because the maximum height and maximum distance reached by the ball are inversely proportional to the elevation angle of the ball. In the pretest, the number of misconceptions reached 33.33% and after remediation it became 16.67%.

In the seventh question, with the identical form of misconception balls A and B have the same shape, size, and mass. Ball A is kicked to form an elevation angle of 25° . and Ball B is kicked to form an elevation angle of 65° . If wind speed, humidity, and air resistance are ignored, then ball B will reach the farthest distance and maximum height greater than ball A because the greater the angle, the farther the ball bounces and both balls will reach the same height when both shooting angles total 90° . In the pretest, the number of misconceptions reached 61.11% and after remediation it became 5.56%.

In the eighth question, with the form of misconception, ball A and ball B have a mass of 410 g and 500 g, then ball A and ball B are kicked with a certain initial speed to form an elevation angle of 15° . If wind speed, humidity, and air resistance are ignored, then ball B will reach the farthest distance and maximum height greater than ball A, because the maximum height and maximum distance reached by the ball are affected by mass. In the pretest the number of misconceptions reached 72.22% and after remediation students experienced after remediation to 11.11%.

In the ninth question, with a form of misconception, ball A and ball B are kicked with initial velocities of 5 m/s and 15 m/s to form an elevation angle of 45° . If wind speed, humidity, and air resistance are ignored, then ball B will reach a greater maximum height than ball A, but both will reach the same furthest distance

because only maximum height is affected by speed while maximum distance is not. In the pretest, the number of misconceptions reached 11.11% and after remediation, students experienced an increase in concept understanding with a total percentage reaching 100%.

In the tenth question, what does not include the characteristics of parabolic motion is motion in the Y-axis direction, in the form of Regular Straight Motion (GLB) and motion in the X-axis direction, in the form of Regularly Changing Straight Motion (GLBB) and the equation of parabolic motion, namely $v_x = v_0 \cos \alpha$ and $v_y = v_0 \sin \alpha - \frac{1}{2}gt^2$. This shows that misconceptions occur in accordance with the findings (Busyairi & Zuhdi, 2020). In the pretest, the number of misconceptions reached 22.22% and after remediation it became 11.11%. This shows that misconceptions have the potential to occur anywhere. Jumadi et al. (2018) stated that the misconceptions experienced by students are characterized by students' mistakes in solving problems. The highest misconception occurs in the third concept, namely analyzing the shape of a parabolic trajectory presented in the form of a picture and analyzing the effect of mass to achieve maximum distance and height in parabolic motion, the number of misconceptions is very high at 72.22%.

The highest decrease in misconceptions occurred in the first problem, namely analyzing the shape of a parabolic trajectory presented in the form of a picture where after remediation students experienced an increase in concept understanding with a total percentage reaching 100%. This decrease can be caused because in learning with ISLE-based student worksheet using PhET simulation challenges students to think critically, creatively, collaboratively and communicatively (Taibu et al., 2021). Some of the advantages of developing PhET simulation learning media are that it can reduce students' misconceptions (Ganasen & Shamuganathan, 2017) because PhET simulations can be repeated to minimize doubtful measurements, overcome the problem of lack of time, if time is limited to teach all students in the laboratory until they understand or understand, increase the quality of the experiment, flexible, has an attractive appearance, is able to display phenomena that are difficult to observe directly, has free access and can be downloaded offline, so that the learning process becomes more effective.

The results indicated that the remediation activities of misconceptions using ISLE-based student worksheet using PhET simulation that had been implemented caused conceptual changes in students (Ekawati & Prastyo, 2022). Based on the results of a limited test of ISLE-based learning media using PhET simulation to 18 students of class X SMA IT Al-Uswah, based on the

posttest scores of students that after remediation activities using ISLE-based learning media using PhET simulation there is a decrease in misconceptions on parabolic motion material, which is 12.78% and based on students' responses to the use of ISLE-based learning media using PhET simulation into a very practical category with a percentage of 93.88%. So this research is expected to be used as an alternative remediation activity to reduce misconceptions in parabolic motion material.

Conclusion

ISLE-based learning media using PhET simulation has been successfully prepared and applied to class X SMA IT Al Uswah. Learning media prepared with the ISLE model approach is used as a guide in reducing students' misconceptions about Parabolic Motion material. This learning media challenges students to think critically, creatively, collaboratively and communicatively. Some of the advantages of developing learning media using PhET simulation are that it is easy to use, has an attractive appearance, and can reduce students' misconceptions because it can be done repeatedly to minimize doubtful measurements. The effectiveness of ISLE-based learning media using PhET simulations has met the effective criteria based on the post-test scores of students that after remediation activities using ISLE-based learning media using PhET simulations there is a decrease in misconceptions in parabolic motion material, namely 42.22% to 12.78% and based on students' responses to the use of ISLE-based learning media using PhET simulations into a very practical category with a percentage of 93.88%.

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Author Contribution

This article was prepared by five authors, namely D.R, R, N.Z, Y, and M.S. Each author completed this article by working together at every stage.

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The authors declare no conflict of interest.

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