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The Potential Interactive Digital Teaching Material on Cell Metabolism as a Bridge of Cognitive Processes Toward Student Learning Achievement

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Abstract: Education in the era of digital technology has become a challenge for teachers and lecturers in how this technology can develop comprehensive knowledge and global insight. The purpose of this study is to improve learning achievement through the cognitive process of students in cell metabolism lectures using Interactive Digital Teaching Material (IDTM). The study involved 40 Biology Education students who were taking the third semester at one of the Private Universities in Bandung, West Java. The implementation of lectures and instruments to measure students' cognitive processes is based on the framework of the 1992 Marzano Learning Dimension. The results of the analysis showed that the N-gain value of Acquire and Integrate Knowledge and Extend and Refine Knowledge obtained a percentage of (28%-26%) on low criteria. While Using knowledge with a percentage of N-gain value (32%) on medium criteria. These results illustrate that IDTM facilitates students to train their cognitive processes toward better learning achievement.

Keywords Cognitive Process; Learning Achievement; Learning Cell Metabolism; Web-Based Interactive Digital Teaching Material (IDTM)

Introduction

Development technology and information that increasingly Rapidly already Making an Impact on Education, both positive and negative. The challenge arises as to how to use this technology to support learning to be more meaningful. Some research results show student problems when faced with digital learning, including some Students turning pages without reading and guessing answers randomly without thinking carefully (Baker et al., 2008, Yang et al., 2021). Students often have difficulties when faced with situations where they are asked to read a lot of text (Firetto & Van Meter, 2018). Encouraging social isolation due to increased screen time (Rawashdeh et al., 2021). Technology drives disruption and multitasking, which can hurt learning. Learners do not learn efficiently or effectively due to information overload and the increasing prevalence of invalid information (Steehler et al., 2022). The frequency of digital media use is also a potential risk factor for poor adolescent mental health, although many mediators include social relationship behavior, negative feedback, and socio-emotional development, although further study is needed (Moroney et al., 2023).

In the digital era, printed teaching materials evolved into digital forms better known as e-books. Digital teaching materials can provide a distinctive interactive atmosphere to meet student learning needs optimize the learning process, and have a high level of accessibility (Alhammad &; Ku, 2019). The E-book displays many multimedia features, such as zoom-in,

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visual, and text features that are a major advancement from digital textbooks or e-books and has attracted interest in recent years. e-book Includes video-based learning, interactive content, simple quizzes, text, static images, hyperlinks, and simple quizzes. Function e-books The most promising is the interactivity between books and students (Soga, 2015). The findings showed students seemed to concentrate more in class when using digital textbooks that contained a lot of information in one package (Soga, 2015). Research conducted by Koć-Januchta et al., (2020) indicates that there is no difference between groups of book versions of Artificial Intelligence with e-books, however, increases learning motivation, does not cause cognitive load effects, improves digital literacy skills, supports independent learning, and monitor their cognitive learning processes. Acquisition Extend and Refine Knowledge in students almost ignored by teachers in teaching shows that 86% of teachers never introduce essential thought processes to students, 10% of teachers rarely focus on introducing essential thought processes to students and As many as 4% of teachers found that they occasionally introduce important thought processes to students (Danish &; Arbab, 2020).

Some of the results of article reviews show the successful use of multimedia that contains text, images, audio, video, animation and 3 dimensions can be a solution in teaching and learning (Abdulrahman et al., 2020). The use of gadget-based interactive multimedia on socioscientific concepts is an effective issue to increase Gen-Z science literacy (Widodo et al., 2020). Interactive electronic modules with a contextual approach affect student learning motivation on conductor and insulator materials (Lafifa et al., 2023). Augmented reality-based learning media on the sub-material of fungal sexual reproduction, significantly improves students' analytical thinking than those who do not use augmented reality (Amsyar & Gems, 2023). For teachers to use and utilize digital tools requires A new way of thinking in teaching (Grönlund et al., 2018)

Efforts and solutions made by several researchers to overcome problems in learning cell and molecular biology include reading and integrating into Multiple Biology Texts (Firetto & Van Meter, 2018), and multimedia interactive E-books (Morris & Lambe, 2017). Represent it into visual, diagrammatic, and polygonal models (Kottmeyer et al., 2020) External representation at macroscopic and submicroscopic levels (Torkar et al., 2018). The development of technology in the field of education, especially learning media, is very rapid, some research on the use of learning media such as articulate storylines and Interactive case-based methods can improve student problem-solving (Daryanes et al., 2023).

Based on the results of previous research conducted, it shows that learning still uses text manuals/printed teaching modules and has not used teaching materials Interactive Digital Teaching Material accessible to all students. Strengthened by previous supporting data related to the profile of the cognitive system of students Various efforts are still needed to improve thinking skills in learning cell biology Especially the concept of cell metabolism where in previous studies this material was one of the materials that was considered difficult and complex to study (Tresnawati et al., 2022).

Based on the above problems, the importance of biology textbooks is a source of science information that is easily accessible to students to overcome content learning problems. The development of Interactive Digital Teaching Material based on learning dimensions adapted from the Marzano framework is expected to bring positive feedback on student learning achievement. Based on the background above, the question in this study is how is the potential of Interactive Digital Teaching Material in improving the cognitive process of biology students? Based on this, this study aims to improve student achievement in cell metabolism lectures using Web-Based Interactive Digital Teaching Material (IDTM).

Method

This study aims to improve learning achievement through the cognitive process of students in cell metabolism lectures using Interactive Digital Teaching Material (IDTM). Participants in this study were 40 students in semester 3 with 34 women and 6 men in the Cell Biology course. This research was carried out in the Biology Education Study Program, one of the Private Universities in Bandung. In this activity, students study in groups (small group discussion) and are then given access to login to web-based IDTM. The following is a digest of the characteristics of learning with interactive digital teaching material media using learning dimension steps adapted from the Marzano framework as in Table 2.

This instrument was developed from the learning dimension of the Marzano framework with multiple choice instrument types of 25 questions and essays of 4 questions. Here is the instrument grid of cognitive processes measured in this study as in the following Table 3.

Table 2. Learning characteristics of the Interactive Digital Teaching Material (IDTM) assisted learning dimension

Learning dimensions	Table of content	Feature characteristics of IDTM	Student interaction with IDTM
Attitude and perception	Introduction	Creating a fun learning atmosphere through Interactive Digital Teaching Material (IDTM)	Watching videos related to diseases and abnormalities in metabolic processes and then discussing with the group
Acquire and Integrate Knowledge	Session 1. Mitochondria 1. Introduction 2. Mitochondrial structure Mitochondrial Functions Session 2. Aerobic Breathing 1. Introduction 2. Stages of aerobic breathing/aerobic respiration 1) Glycolysis 2) Oxidative decarboxylation 3) Krebs cycle 4) Electron transfer Session 3. Anaerobic Respiration/ Fermentation 1. Lactic acid fermentation 2. Alcoholic fermentation Session 4. Catalase Enzyme Practicum 1. Virtual Lab Practicum 2. Practicum Live-worksheet	Presenting learning videos, observing 3-dimensional animations, drag and drop mitochondrial structures, simulating concept maps, interacting with virtual laboratories about catalase enzymes, and live worksheets.	Learn in groups, read materials, discuss, observe, answer stimulus questions, interact with 3D animations, practice matching mitochondrial structures to their parts, fill out concept maps, try virtual labs, fill out Live worksheets
Extend and Refine Knowledge	Deepening Session 2. Aerobic Breathing 1. Introduction 2. Stages of aerobic breathing/aerobic respiration 1) Glycolysis 2) Oxidative decarboxylation 3) Krebs cycle 4) Electron transfer Session 3. Anaerobic Respiration/ Fermentation 3. Lactic acid fermentation 4. Alcoholic fermentation	Presents pictures of glycolysis, oxidative decarboxylation, Krebs cycle, and electron transfer accompanied by reaction results. Analyze cases of lactic acid buildup and cases of cyanide poison.	Group and collaborate to discuss the material learned about theory, drawing, glycolysis drag and drop, oxidative decarboxylation, Krebs cycle, and electron transfer as well as analyzing cases of lactic acid buildup and cases of cyanide poison
Using Knowledge Meaningfully	Session 5. Concept and connection 1. Godwit 2. Cyanide poison 3. Strenuous exercise Mountaineers	Presenting concept and connection mountaineer, Godwit Bird experiment practice enzyme catalase	Group and collaborate to discuss by analyzing the concept & and connection of material related to metabolism when reaching maximum altitude shortness of breath occurs, Striped Godwit Able to fly 11 days 1 hour without stopping, Predict and investigate the results of catalase enzyme practice experiments
Habits of mind		Feedback on lessons learned	Student response

Table 3. Cognitive Process Dimension Grid, Marzano Framework

Cognitive prose	Developed indicators	Types of instruments and number of questions
Acquire and Integrate Knowledge	(1) Identify; (2) Determine specific characteristics (3) Sequencing processes (4) Generalize concepts	Multiple choice: 12 questions
Extend and Refine Knowledge	(1) Comparing (2) Classifying (3 Deductive reasoning (4) Analyzing errors (5) Analyzing perspectives	Multiple choice 9 questions and essay 1 question
Using Knowledge Meaningfully	(1) Decide on alternative solutions (2) Resolve problems (3) Predict the results of experiments and (4) Investigate the process	Multiple choice 4 questions and essay 3 questions

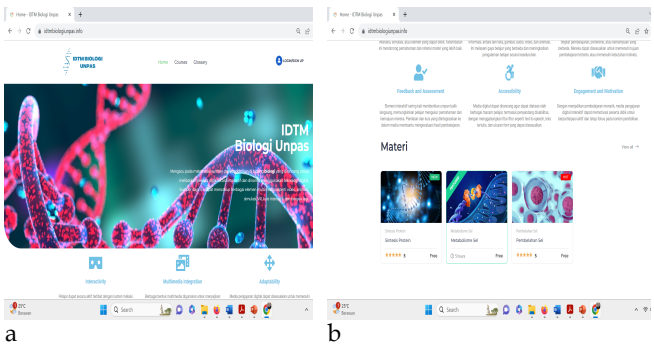
The research procedure was carried out by giving a pre-test to all 3rd semester students then continued with IDTM media trials and then post-tests. Data analysis techniques are carried out by examining test results, providing scores, organizing and organizing data into categories, and describing results so that conclusions are obtained. Categorization is measured based on the N-gain value in each ability to be developed following the N-Gain criteria as in Table 4 below:

Table 4. Normalized Gain Interpretation

Gain Value	Interpretation
G > 0.70	Tall
0.30 < G ≤ 0.70	Keep
G ≤ 0.30	Low
G = 0.00	No increase
-1.00 ≤G ≤ 0.00	There was a downturn

(Sundayana, 2016)

The development of IDTM media is web-based which is developed based on the needs and characteristics of the material as well as the stages and abilities to be achieved by students. Here is the Display of Interactive Digital Teaching Material (IDTM) as shown in picture 1 below



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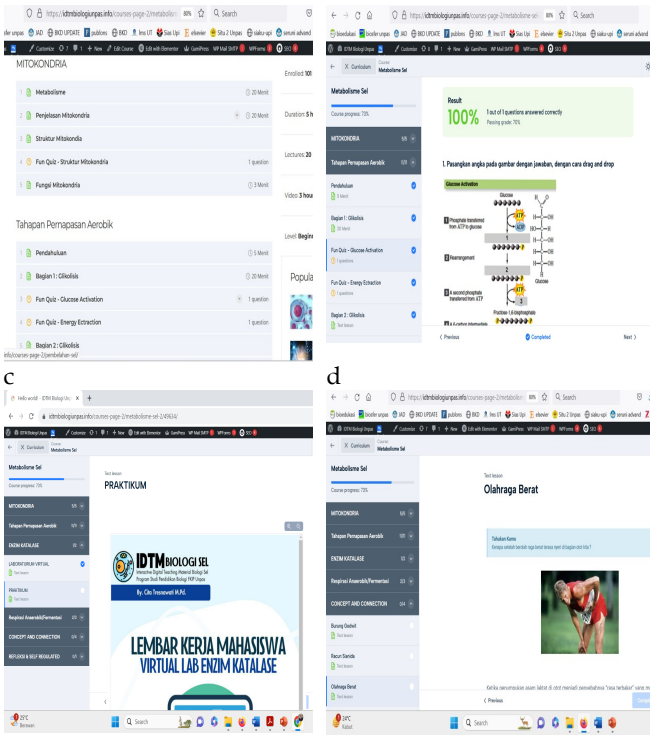

c d e f

Figure 1. Display of Interactive Digital Teaching Material (IDTM) on the concept of metabolism. Figure a. front view, b. learning start menu, c. table of content feature d. Drag and drop feature, e. student live-worksheet feature, f. concept & connection feature

Results and Discussion

Research has been conducted to obtain information about the Potential of Web-Based Interactive Digital Teaching Material Cell Metabolism on Cognitive Processes Towards Student Learning Achievement. The research data are presented in Figure 2.

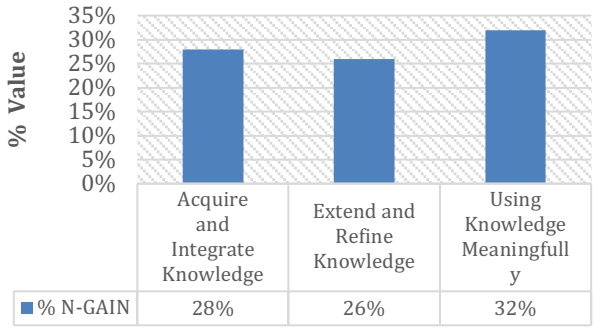

Figure 2. Percentage value of N-gain cognitive processes

Based on Figure 2, the N-gain percentage value of students' cognitive processes in acquiring and integrating knowledge was 28% in the low category, Extend and Refine Knowledge was 26% in the low category, and Using Knowledge Meaningfully was 32% in the medium category. The test analysis was supported by direct observations in the field when students interacted with IDTM to complete the discussion. The following are the results of the analysis of the characteristics of Interactive Digital Teaching Material in guiding the cognitive processes of biology students in detail described below:

Based on the results of the analysis when students conduct learning through Interactive Digital Teaching Material (IDTM) which presents features such as theoretical explanations, observing learning videos, answering stimulus questions, observing 3-dimensional animations, drag and drop by practicing matching structures with their parts, simulating concept maps, interacting with virtual laboratories and live worksheets. This feature has not shown optimal potential in developing the ability to Acquire and Integrate Knowledge based on the calculation of the percentage of N-gain obtained a value of (28%) on low criteria. These results indicate that IDTM has not been optimal in directing students' cognitive processes in acquiring and integrating knowledge on several indicators: (1) identifying, (2) determining specific characteristics, (3) sequencing processes, and (4) generalizing to the concept of metabolism.

Based on this, a more in-depth study of IDTM features is needed so that it can guide students' cognitive processes during learning. Some student responses related to features that are considered quite difficult in IDTM are in the Concept Map section, virtual laboratory, and live worksheet regarding the activity of the catalase enzyme. This section is considered quite difficult because students are learning for the first time, besides that practicum experience greatly determines student success in conducting material analysis. The findings in this learning students did not read the practicum instructions and seemed to rush immediately to complete the task. Here is a section that students find quite difficult on the concept map feature. Here are the 3 IDTM features in the Concept map section

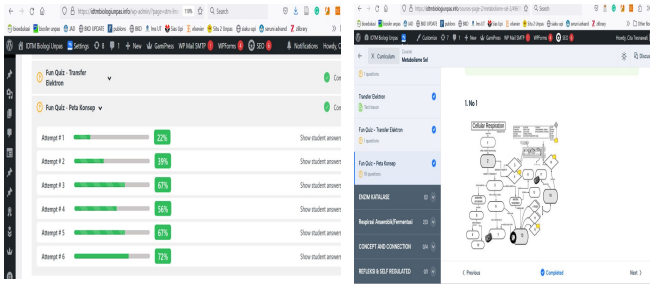

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Figure 3. Student interaction with IDTM on the concept map features a. interactivity, b. concept map feature in IDTM

Based on this, several IDTM features encourage students to try and repeat learning until the expected results are achieved. By practicing, students are expected to more easily remember parts and sequences in learning, especially cell metabolism material.

While the parts that are considered easy and fun are the sections of observing videos, 3-dimensional animations, and drag-and-drop mitochondrial structures, in this section students can integrate new information with information that previously became meaningful knowledge and stored in long-term memory. This was identified when students interacted with IDTM and were able to analyze videos correctly, and the results of direct observations when students interacted with the 3-dimensional structure of mitochondria looked enthusiastic, and fun. The results were strengthened by the fun quiz feature through interactive drag and drop, almost all students obtained 100% marks and did not find many repetitions. Here is one example of student results in completing the drag & drop fun quiz as shown in Figure 4.

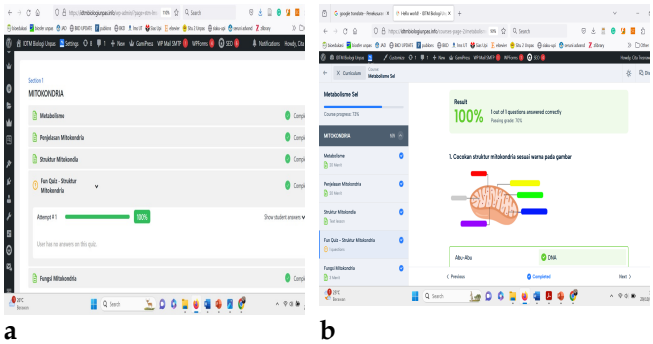

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Figure 4. Fun quiz feature, a. student performance results recorded through the system and b. interactive drag and drop feature

Figure 4. Showing parts that are considered easy to learn, the results of the analysis show that students already know the structure and parts of mitochondria obtained earlier. Other research assigned to the ability to

Acquire and Integrate Knowledge Marzano dimensions In fact, it is very closely related to the way content is delivered in the most desirable way to ensure maximum content transfer (Danish &; Arbab, 2020). Learning involves an interactive process involving five dimensions of thinking, including acquiring and integrating knowledge (Brown, 1995). Able to improve creative thinking skills (Rowais, 2019). Marzano's learning framework is effective in improving higher-order thinking skills, namely critical and creative thinking (Syriac, 2023, Irvine, 2020). Acquire and Integrate Knowledge divided into 2 categories, namely: declarative knowledge and procedural knowledge. Declarative knowledge focuses on helping learners know or understand some type of information and Procedural knowledge requires learners to perform a process, demonstrate a skill, or act (Marzano et al., 1997).

Other activities identified when students interact with IDTM present theoretical features and images about glycolysis, oxidative decarboxylation, Krebs cycle, and electron transfer accompanied by reaction results, then several cases of lactic acid and cases of cyanide poison. This feature has not shown optimal effectiveness in developing the ability to Extend and Refine Knowledge based on the results of N-gain calculations obtained a percentage value of (28%) on low criteria. The cognitive process of extending and refining knowledge is measured through indicators of comparing, classifying, deductive reasoning, analyzing errors, and analyzing perspectives, direct observations show that students are not accustomed to interacting with the media, lack accuracy, and look unfocused. Here's Figure 5. one example of IDTM features that presents the ability to compare students

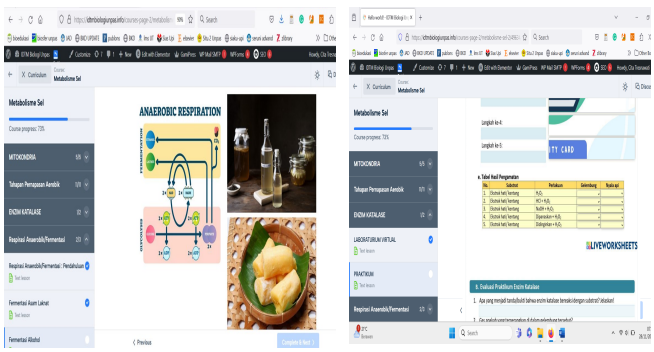

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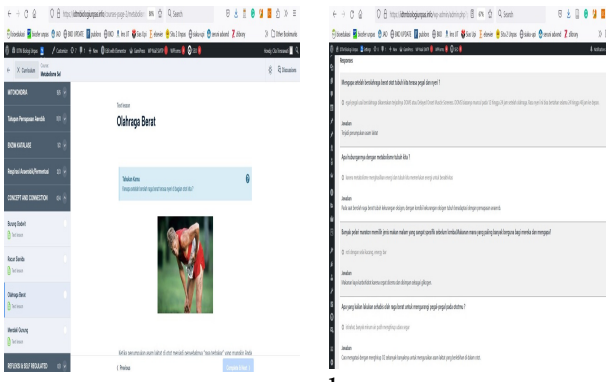
Figure 5. Examples of IDTM Features are a. comparing aerobic and anaerobic breathing, b. Perspective Analysis of the Results of Virtual Practicum Activities

Figure 5. Demonstrate IDTM features that lead students to the ability to compare and Perspective analysis, but this ability still needs to be trained and learned to make this ability a habit of thinking. From a pedagogical perspective, Extending and refining knowledge helps students understand the process at critical and difficult steps in the reasoning process in learning (Marzano, 1992). Extending and refining knowledge develops a reasoning process to help students identify and articulate similarities and differences, group, and infer (Li, 2020).

Analysis of cognitive processes then using student knowledge is obtained through indicators of deciding alternative solutions, solving problems, predicting experimental results, and investigating processes. This ability is learned by students when interacting with IDTM, especially in the concept and connection section related to metabolic processes. During learning, students are led to group, collaborate, discuss, and analyze the concepts & and connections related to climbers when reaching maximum altitude shortness of breath, Striped Godwit Bird Able to fly 11 days 1 hour without stopping, Predict and investigate the results of catalase enzyme practice experiments. In this section, IDTM can affect information processing which leads to the improvement of students' cognitive processes in the medium category with a percentage N-gain value of 32%. The results of the analysis showed that students were able to relate previous knowledge with the knowledge they had just obtained. Concepts and connections in this section can multiply students' ability to analyze processes, associate with ideas, associate with other disciplines, and relate to everyday life. The concept and connection section at IDTM is very important to increase students' global insight. Figure 6. is a feature and interactivity of students in learning using the IDTM Concept and connection section



a b

Figure 6. Examples of IDTM features, a. concept and connection features, b. answer results

Using knowledge teaches students how to take control of new knowledge and skills and effectively apply them to a variety of tasks and roles in school and outside of school (Apthorp, 2000). Using knowledge Provides practical skills and capacities for individuals to address different types of problems and tasks. Therefore, in the global dimension of competence Using knowledge is conceptualized and characterized as

global practical skills (Li, 2020). The results of other studies suggest that interactive e-books need to be added sound, description, animation, and three-dimensional animation (Ormancı &; Çepni, 2020). Some experts reveal Media capabilities, such as interactive e-books, can shape messages into reality such as content, media display, interaction, and design technology (Bozkurt &; Mujgan, 2015).

The following is a picture of the activities of prospective biology teacher students in learning the concept of cell metabolism through IDTM as shown in Figure 7.

Figure 7. Lecture Activities Using Interactive Digital Teaching Materials (IDTM)

Conclusion

The results and discussion show that the characteristics of Interactive Digital Teaching Material (IDTM) can bridge student interactions in learning concepts to make them more fun, independent, and structured. Several activities can encourage students to try, repeat, analyze, and argue with new ideas. Positive feedback on cognitive processes such as the processes of acquiring and Integrate Knowledge, Extending and Refining Knowledge, and Using Meaningful Knowledge has increased, although several dimensions of thinking still need to be drilled into to develop. even betterIn this research, there are several limitations and weaknesses, including the following: 1. The time required exceeds 2 lesson hours, so several sessions are completed through assignments, 2. Some of the features displayed still require revision and improvement. Based on the weaknesses in this research, the suggestions from this research require designing media that is adapted to the time allocation that has been determined so that learning targets can be achieved.

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Author Contribution

Cita Tresnawati: Data collection, data analysis, manuscript writing, and editing
Adi Rahmat, Taufik Rahman, and Kusnadi: Guiding and directing during research and writing the manuscript

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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