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Investigating Two Methods of Teaching Mathematics Based on Work Mathematics and Understanding Mathematics Included in the General Mathematics

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ABSTRACT

Objective: The didactics of mathematics, as well as the process of learning this subject, are considered fundamental components within the curriculum of educational institutions worldwide, spanning from primary schools to universities. Nations that prioritize and support mathematics education allocate substantial resources towards this endeavor. The primary objective of this article is to conduct an in-depth analysis of two distinct methodologies for imparting mathematical knowledge, specifically tailored for the general mathematics course.

Methods: To fulfill this objective, we commenced by elucidating the fundamental concepts underpinning the process of learning, delving into its historical context, followed by an exploration of diverse definitions associated with learning phenomena.

Results: Within our discourse, we delved into the realm of conditional learning, shedding light on the aspect of knowledge retention and the potential obstacles that may hinder the permanence of acquired knowledge. Furthermore, we elucidated the concept of learning through the analogy of two distinct pulses, each consisting of two intricate stages. The initial pulse revolves around the challenges and limitations encountered in the learning process, while the subsequent pulse focuses on the enhancement and development of one's cognitive capacity. These stages were meticulously employed in the pedagogical approach to teaching mathematics, accompanied by illustrative examples to elucidate each facet of the learning process.

Conclusions: Subsequently, a critical analysis of different pedagogical strategies in mathematics education was undertaken. Two distinctive approaches for teaching general mathematics (course 1) to engineering students were proposed:1. Instruction through active mathematical problem-solving. 2. Instruction emphasizing conceptual understanding in mathematics.

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Introduction

The discussion of learning theory has a rich and diverse heritage. Almost a hundred years ago, the topic of learning was under the domination of philosophical theories including the philosophical point of view of Aristotle and Plato. With the first experimental investigations carried out by Ebbinghaus, Pavlov and Thorndike, research methods in natural sciences were also used in learning issues, and based on the mass of scientific evidences that was the result of the work of psychological laboratories in different parts of the world. More comprehensive theories and more precise principles were presented in the topic of learning (Bishop, 2007).

The countries of the world are trying to re-engineer their educational systems to adapt with the rapid acceleration of social and economic changes. In this regard, one of the areas of school curriculum that is gaining special and increasing attention is the area of mathematics education. This interest is not surprising because all countries of the world see mathematics as the key for accessing the benefits of technological changes, with all its effects on obtaining the benefits of economic development and modernization(Bishop, 2007).

There have been several national and international efforts to re-examine mathematics curricula and mathematics teaching strategies at the elementary and secondary levels. Development and planning of educational reform should be research based. Due to the lack of local experts and researchers, excessive reliance on imported ideas and knowledge has been a common solution in emerging countries. Usually, the results are likely to be disappointing because the ideas and knowledge from different contexts are not suitable for the needs of an emerging country. In order to ensure the best chances of success, the formulation and planning of educational reform should be based on local research studies (Bishop, 2007).

Mathematics education is concerned with the development and implementation of appropriate mathematics curricula, and all matters relating to the teaching and learning of mathematics. In keeping with the lifelong concept of learning, math education includes learners of all ages and at all levels.

Mathematics education is not only related to the educational program, classrooms, teachers and students of schools and university; Nevertheless, the issues related to mathematics in schools and universities have always been of interest.

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Despite the clear boundaries between mathematics and didactics of it, many mathematical education programs are nothing more than teaching mathematics content. This is evident in teacher training courses and courses for lecturers in universities.

Learning

Learning is one of the most important subjects of education. Learning is the function by which new or existing knowledge, behaviors, abilities, or choices are acquired, understood, or enhanced, and modified, perhaps leading to a potential change in data composition, depth of knowledge, approach, or behavior relative to the type and range of experiences(Anderson, 2013). In fact, learning means acquiring knowledge and making changes in behavior and emotions by using that knowledge (Bishop, 2007).

Learning in humans can be part of the process of education, personal development, and exercises that may be purposeful or done by motivation. In fact, if learning does not lead to behavioral changes, it has not happened.

Behaviorists believed that the basic foundation of any type of learning is simple relationships of the conditioning type(Loukas& Robinson, 2004). Learning happens through using what has been learned and searching for possible uses of it. How learning occurs is a part of the discussion of educational psychology, neuropsychology, learning theory and educational sciences. Learning may occur as a result of habituation or classical conditioning, or as the result of a complex task such as playing(Papanastasiou, 2000).

Learning can be done both consciously and unconsciously. Learning is a relatively stable change in a person's feeling, thinking and behavior, based on an experience. [Ernest ropiequet hilgard and Marquis and a group of colleagues] behaviorists such as John Watson and Skinner, who considered human nature to be flexible, believed that in Growth of a person, learning plays the main role.

Hergenhann and olson have said that now days learning is one of the most important fields in psychology, and at the same time, one of the most difficult concepts to define. Psychologists such as Hans believed that what appears to be functioned by an innate biological program can be influenced by environmental events(Uzel& Uyangor, 2006). According to many researchers, memory processes are a part of the learning process and learning will not occur without memory and memory problems. Also, learning can be behavioral changes and have behavioral manifestations. Topics related to new experiences are related to previous knowledge and

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experiences. On the other hand, Claude Bernard states that knowledge hinders. One of the ways to prevent prior knowledge from being an obstacle to our learning is to practice not to prejudge and analyze while learning as much as possible(Lotfi et al, 2007). For instance, if we are learning and reading a new subject, when the material we read is finished we will think about it and come up with the concluding examples. If we see that the topics and books that we read are in the direction of confirming our previous knowledge and beliefs, we should check if we are really learning or are we in a vicious cycle?

Learning has a very broad concept that is manifested in the forms of transformation, breaking habits, creating interest, new attitudes, understanding value and prejudice. The way of combining and applying information in reasoning, thinking, theorizing, problem solving, feeling and the transformations that occur in the whole personality, all originate from learning(Mafakheri et al, 2013).

Edward Tolman distinguished between performance and learning. He proposed the concept of latent learning and stated that learning may not immediately show itself in a person's performance(Uzel& Uyangor, 2006). Some describe learning as relatively stable changes in ability, attitude, or capacity of responses(Mafakheri et al, 2013).

According to this point of view, learning occurs before behavioral changes. There are different types of learning, one of which is learning through insight. This type of learning takes place when the learner understands how the components or elements are related in a phenomenon and masters the whole set. This type of learning is the most effective and sustainable one(Haghi et al, 2020). In this sort of learning, by accurately understanding the phenomena and knowing the relationships between the components or elements of a phenomenon the learner finds the opportunity to mentally discover and create. This type of learning is very important in teaching mathematics. The discrepancy between algorithmic skills and deep perceptual knowledge of the learning process highlights the void of methods for creating internal, programmed relationships between concepts and algorithms. The connection and correlation of mathematical concepts with each other and their application in solving problems provides the basis for a mental organization and the appropriate schemas in the minds of learners. The difference between doing mathematics and mastering its concepts makes the students have the ability to understand the concepts and their application in different situations(Van den, 2000).

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Psychology has become a behavioral science. Everything we study as a psychological matter, must be presented through behavior. But this does not mean that the behavior we observe is learning. The learning process cannot be studied directly, but the nature of learning can only be inferred from behavioral changes. Every learning does not lead to a specific performance because people learn many things that they do not necessarily apply. Therefore, distinguishing between learning and other things that lead to a behavioral change, such as fatigue, illness, maturity, and drugs is vital. Learning lasts until it is forgotten over time or replaced by a new one. The duration of changes resulting from learning or temporary states cannot be precisely determined. But as we said, learning is relatively stable.

Robert Ginn believes that "learning is a change in a human position and ability that occurs over time and cannot be considered as changes that are resulted by the maturity process."

As Richard Mayer claims about learning "learning is a relatively permanent change in knowledge or a behavior dependent on experience." This definition has three components:

1) The duration of the change is long-term.

2) The change originates from the content and structure of knowledge in the learner's memory or behavior.

3) The cause of change is experience rather than environmental factors, fatigue or drug use.

Tony Bingham and Marcia Conner believe that "learning is the process of transferring information. In fact, learning is the internalization and integration of information with what we have already experienced. This process changes our knowledge. This experience is based on inputting, processing and reflection of data. This is what changes us."

in "Learning How to Learn: Applied Theory for Adults," Smith states, "It has been suggested that the term *learning* defies precise definition of it because it has been applied to multiple applications. Learning refers to:

1) acquiring and mastering something

2) expanding and clarifying the meaning of one's experiences

3) a deliberate and organized process of examining ideas about a problem.

In other words, it is used to describe a product, a process or a function.

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Peter, Brann, Rodger, and McDaniel state that learning is "acquiring knowledge and skills as well as having easy access to them in your memory, so that you can have a clear understanding of future problems and challenges."

In How to Learn Things: Seven Research-Based Principles for Smart Teaching, Susan Ambrose et al, state that, “A process that leads to changes that follows experience and increases the potential for improved performance and future learning."

We define learning in simple terms as follows:

"Learning is a relatively stable change that occurs, based on an experience."

Different types of conditional learning

Conditioning is a more accurate term used to describe the actual methods of changing behavior. There are two types of instrumental and classical conditioning.

Classical conditioning

This type of learning was first proposed by Pavlov. Based on it, a stimulus such as nutrition is given to an organism, which causes a natural and automatic reaction such as the secretion of saliva. The stimulus that causes this natural reaction is called an unconditioned stimulus, which in this case is nutrition. A natural and automatic reaction is called an unconditioned response. In this example, it is salivation.

A neutral stimulus such as sound or light is given to the organism just before the presentation of the unconditioned stimulus. This neutral stimulus is called conditioned stimulus.

After combining the unconditioned stimulus with the neutral stimulus for several times, in which the neutral stimulus always comes before the unconditioned one, the neutral stimulus can be presented alone and it will lead to the secretion of saliva in the organism. In this case, we say that a conditioned response has been created.

Operant conditioning

Not all our behaviors have the same results. Some have positive and some have negative ones. Positive results make the person repeat the behavior, in fact, the desired result is considered as a reinforcement for the behavior.

Escape and avoidance conditioning are the special types of instrumental conditioning. For example, in escape conditioning, consider a mouse that struggles to escape the electric shock, it

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accidentally presses a lever, and the electric current is cut off. The mouse will associate pressing the lever with the interruption of the shock.

In avoidance conditioning, suppose the shock is intermittently given to the animal and a cue appears five seconds before each shock. The mouse quickly learns to associate the light with the shock and presses the lever every time the light comes on to avoid it.

Learning and survival

Throughout history, our human bodies have acquired the ability to automatically respond to some needs such as breathing, body temperature regulation, etc. Auto-adaptive processes are called critical life balancing mechanisms because their role is to maintain the physiological balance. Most living organisms reflexively avoid painful stimuli. If we were to rely solely on vital balancing mechanisms to satisfy all needs, we would not survive very long. Learning allows living things to solve those basic needs that are not satisfied through vital balance mechanisms and reflexes through interaction and adaption with the environment.

Through classical conditioning, we learn which things in the environment are beneficial for survival and which are harmful; And through instrumental conditioning or operant conditioning, we learn how to get desirable things and avoid undesirable ones.

According to many researchers, memory processes are all a part of the learning process, and learning will not occur without memory and its problems. Also, according to the definition of learning, learning can come with behavioral changes and have behavioral manifestations while memory processes are completely subjective.

Examining the principles of learning helps us to understand the causes of our behavior. Awareness of the learning process not only helps us to understand normal and adaptive behavior, but also allows us to come with a better understanding about the conditions that lead to maladaptive and abnormal behavior, thus creating more effective psychotherapy methods.

Child rearing methods can also benefit from learning principles. It is obvious that people are different from each other and these individual differences can be explained in terms of different learning experiences. Language is one of the most important characteristics of a human being, and without a doubt, the special abilities of speech are mainly obtained from learning. In addition, there is a close relationship between learning principles and teaching methods.

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Learning disorder

The term learning disability arose from the need to recognize and serve students who consistently fail in their academic work and at the same time are not included in the age framework of exceptional children. They have a normal appearance, their physical growth and height and weight indicate that they are normal. Their intelligence is more or less normal, they speak well, play like other children and communicate with others like their peers. At home, they also have the necessary help and do well the tasks that their parents entrust to them. But they don't have the necessary ability to flow information, express it and especially writing them. So, according to the general characteristics of these students, they can be placed in a new group called students with learning disabilities, and it can be said that these students have a disorder in one or more mental processes that are related to understanding, using oral or written language. This disorder can manifest as a complete inability to listen, speak, read, write, spell, or do math calculations.

This term covers the conditions such as cognitive disabilities, brain injuries, minor brain dysfunction, and dyslexia. This definition does not include those students who have learning problems due to visual, hearing or movement disabilities, as well as mental retardation or environmental, cultural or economic deprivations.

Learning disabilities are not synonymous with terms such as compensatory reading or learning delay. This definition specifically refers to children and adolescents who have severe learning disabilities. Students with this problem need special education, according to Ames, they have to deal with special, unusual exercises with an unusual quality. This is separate from the regular educational methods that most children use. The duty of the experts in this field is to be responsible for compensating the learning disability, especially for the child, in the form of individual training or training in small groups.

Learning stages

We categorize learning into two pulses of disability and ability, each pulse consisting of two stages. Therefore, learning has four stages.

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First pulse		Second pulse	
First stage: Unconscious disability	Second stage: Conscious disability	Third stage :conscious ability	**Fourth stage: unconscious ability**

Unconscious disability

At this stage, the person does not have the ability to perform the skill, and of course he does not know that he does not have this ability, in fact, he does not know that he doesn't know. This is the worst stage for the learner because he thinks he is doing well and doesn't realize that he doesn't know many facts about the discussing subject. In fact, he doesn't know what he doesn't know and it makes him not to learn. For instance consider, a child who thinks he can walk or feed himself with his own spoon because he sees that others are doing it without any discomfort.

In math education, this stage can appear as follows. Suppose a student is asked to discuss the convergence or divergence of the following integral.

$$\int_{-2}^{2} \frac{2xdx}{x^2-4} dx$$

At this stage of learning, the student imagines that he has encountered an integral of the odd function in the symmetric interval, so he concludes that the answer to the integral is zero and writes that the integral is convergent, while this answer is completely wrong. In fact, the student has an unconscious inability in the subject of improper integrals, that is, "he does not know that he does not know", he must first check the behavior of the function in terms of continuity in the interval of integration.

Conscious disability

At this stage, the person does not have the ability to perform a skill, but he realizes that he does not have this ability, in fact, he "knows that he does not know". The person at this stage becomes aware that he needs to improve his skills and takes action to do so. In this stage, the desire for Learning emerges in the individual, like someone who realizes that he needs to be trained in order to drive.

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This step in math education for the same example of integral convergence or divergence can appear as follows:

In this case, the student notices the points x=-2 and x=2 in the integration interval, which are the roots of the denominator, and the asymptotic discontinuity points of the function are in the integration interval, so he acts as follows:

$$\int_{-2}^{2}\frac{2xdx}{x^2-4}=\int_{-2}^{0}\frac{2xdx}{x^2-4}+\int_{0}^{2}\frac{2xdx}{x^2-4}$$

$$=\lim_{a\to-2^+}\int_{a}^{0}\frac{2xdx}{x^2-4}+\lim_{b\to2^-}\int_{0}^{b}\frac{2xdx}{x^2-4}$$

$$=\lim_{a\to-2^+}ln|x^2-4|]_a^0+\lim_{b\to2^-}ln|x^2-4|]_0^b$$

$$=-\lim_{a\to-2^+}ln|a^2-4|+\lim_{b\to2^-}ln|b^2-4|$$

And he is stopped from continuing the solution, because he faces the ambiguous state ∞-∞ and he cannot resolve the ambiguity, because the variables are not the same, he cannot use his knowledge about calculating the limit. As we can see, he could not get the answer to the problem, that means, "he knows that he does not know". In fact, he comes to the realization that his knowledge of improper integrals is not enough, so he needs more training.

Conscious ability

At this stage, the person acquires the ability to perform the skill with awareness, in fact, he knows that he knows. This stage is the most difficult stage, because the person consciously tries to learn the skill and turn it into a habit, and at this particular stage in many cases, the learner gives up on continuing and learning a skill because it is difficult. For instance consider a driver who is at this stage, he has made the connection with driving and he is conscious of all his movements so he requires a lot of concentration and effort.

In this case, one's mind will be focused on the same task and while doing it, they will not be able to think about anything else.

In math education, for the same example of the improper integral, the student refers to the theorems of convergence and divergence of it and learns that if in the sum of two integrals, one of them be divergent, the resulting integral will be divergent. Therefore, he writes the integral as follows:

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$$\int_{-2}^{2} \frac{2xdx}{x^2-4} = \lim_{a\to -2^+} \int_{a}^{0} \frac{2xdx}{x^2-4} + \lim_{b\to 2^-} \int_{0}^{b} \frac{2xdx}{x^2-4}$$

$$= \lim_{a\to -2^+} ln|x^2-4|]_a^0 + \lim_{b\to 2^-} ln|x^2-4|]_0^b$$

In this case, he checks only one of the limits. Because the result of the limit of the first integral becomes infinite, it is concluded that the integral is divergent. In fact, in this case "he knows that he knows".

Unconscious ability

At this stage, the person acquires the ability to do the work and has practiced so much that he does the activity unconsciously and out of habit. Therefore, at this stage, the person performs the skill unconsciously. Like someone who has learned to drive well, he drives unconsciously and enjoys driving.

In mathematics education, for example, for the same integral, the student has been exposed to a large number of improper integrals and has come to the insight that both types of p-integrals of the first and second type are divergent in the case of p=1. He considers the given integral to have the same function as $f(x) = 1/x$. So, without thinking about the problem, he unconsciously recognizes that the integral is divergent.

Teaching math by using two methods of Work mathematics and Understanding Mathematics

Definition of Work mathematics

Any action that is done based on skill in learning math without considering concepts is called practical math.

Teaching by using practical math method includes practicing and repeating the solution of math problems so that by observing a problem, the learner, refers to the solution of problems similar to this one and uses the model of solving them, So that for solving the current problem, he applies the same method that he had previously used. In this type of training, we mostly focus on problem solving skills rather than analyzing the structure, type of the problem and the conditions for the existence of a possible solution to the problem.

The most important factor in learning through this type of training is practice and repetition of different solutions. In fact, whenever we solve a large number of similar problems without considering a specific point in it, we have done a Work mathematics operation. Mathematical

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teaching helps with strengthening the learning process, so by presenting different math problems in the class, we will come to solve the desired problem. In this type of teaching, the variety of issues makes the student face various issues. So, the method we apply to solve a problem, using the solution of previous sample problems, is an example of learning by Work mathematics method. For example, consider the improper integral which was previously mentioned. If the student writes the method of solving the problem as stated in the second case and concludes as in the third case that the integral is divergent, it means that he has done a Work mathematics task. In fact, the student has seen problems similar to this type of improper integral before, and by remaking this problem similar to the previous ones, he was able to get the answer to this question.

Definition of Understanding Mathematics

Any operation based on mathematical concepts for learning is called Understanding Mathematics. This teaching method is based on insight learning. In this type of teaching, we try to lead the learner to understand mathematics so that he can master the entire content of the subject. As stated, this type of learning is the most effective and sustainable type of learning.

For example, we consider the convergence or divergence of improper integral. A cognitive mathematical perspective to teach this concept goes through the following steps:

First step: What is an improper integral?

Second step: What is convergence and divergence?

The third step: classification of all three kinds of improper integrals.

The fourth step: classifying the specific types of improper integrals such as p-integral, exponential or geometrical integral and...

Fifth step: Theorems related to the convergence or divergence of improper integrals

The sixth step: solving sample problems

Sample example. Find the result of each of the following integrals.

1) $\int_{-1}^{1}[2x]dx$ 2) $\int_{0}^{1}x^3e^{x^2}dx$ 3) $\int_{-1}^{1}\sqrt{1-x^2}dx$ 4) $\int_{-1}^{1}(2+x)\sqrt{1-x^2}dx$

In part (1), a student who has an unconscious disability writes the answer as follows:

$$\int_{-1}^{1}[2x]dx=\int_{-1}^{0}-1dx+\int_{0}^{1}0dx=-x|_{-1}^{0}=1$$

In fact, this question is for the cognitive mathematical mode. If the student has not understood the concept of bracket correctly, we expect such an answer. In fact, the student should have calculated

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the bracket comparing it between two consecutive numbers and from there realized that he should have rewritten the integral as follows:

$$\int_{-1}^{-1/2} -2dx + \int_{-1/2}^{0} -1dx + \int_{0}^{1/2} 0dx + \int_{1/2}^{1} 1dx$$

In part (2), students who have a conscious disability offer two types of solutions.

A group of students wrote the following solution using the change of variable method and realized that they could not solve the problem with this method.

$$u = x^3, du = 3x^2dx$$

The second category uses the by parts method and provides the following solution and refrains from continuing the solution.

$$u = x^3, du = 3x^2dx,$$

$$dv = e^{x^2}, v = ?$$

In fact, the student must first change the variable $x^2 = t$ and convert the integral as $\int_0^1 te^t dt$ and then obtain the answer by using the by parts method.

In part (3), a student who has a conscious ability, first pays attention to the evenness of the function under the integral sign and rewrites the integral as $2\int_0^1 \sqrt{1-x^2}dx$. According to the relativity between trigonometric functions, he writes $x = \sin\theta$ or $x = cos\theta$. In fact, this type of question you need to apply both types of Work mathematics and Understanding Mathematics, because on the one hand, the student must be familiar with the concepts of trigonometric functions and be able to determine the values of trigonometric functions for the values of integral limits (Understanding Mathematics) and from The other side he must have previously solved such problems in order to solve this correctly (practical math).

In part (4), a student who has unconscious ability writes the answer π unconsciously, because unconsciously he considers the concept of integral as area when the function under the integral sign in the interval of integration is positive, on the other hand, he considers that the integral answer of the odd function in the symmetric interval is zero considers, so he writes the answer as it is in his mind as follows:

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$$\int_{-1}^{1}(2+x)\sqrt{1-x^2}dx = 2\int_{-1}^{1}\sqrt{1-x^2}dx + \int_{-1}^{1}x\sqrt{1-x^2}dx$$

$$= 2(The\ area\ of\ a\ circle\ with\ a\ radius\ of\ one)+0=\pi$$

■

Conclusion

Choosing the type of teaching math courses in the classroom, especially for technical engineering students, has always been challenging. the method that teacher chooses for teaching is very important. In many cases, the usual teaching methods of mathematics are faced with the problem of students not learning it. Mathematics education not only orders the minds of learners but it determines the way of connection between mathematical concepts and their application in solving different problems. In this article, we specified two methods of teaching mathematics (Work mathematics and Understanding Mathematics) for teaching general mathematics to technical engineering students. The use of both methods in teaching mathematics can have a positive effect on improving students' conceptual understanding. In fact, the correct and precise use of both methods according to the related topic, has a very important effect on the students' learning.

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Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by ethics committee of Islamic Azad University.

Author contributions

All authors contributed to the study conception and design, material preparation, data collection and analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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