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Completion for a Geometric-Function Problem: Process and Resources in Efficiency Consideration

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Abstract
The cognitive level between teachers and students is clearly different in problem-solving. In the mathematics context, especially the function problem was only in geometric expression form, for knowledge construction and student's learning should use their cognitive level capacity. Not only the solving process is based on that, but also learning should be efficient for all students, and analyzing those processes is the purpose of identification inefficient issues in this study. This investigative study was held on three respondents purposively selected from a science program of senior high school in West Jakarta, Indonesia. This study found that in the solving process, all students chose to construct an algebraic representation of the function by organizing concepts relevant to fragmented conceptualization. The process has held to apply each concept procedurally. There has been a resource and that is one concept of the domain of function, so the completion is an inefficient process because all three students were ignoring it to use. All three process for solving to the student's academic culture, most common for emphasizing in learning related to the problem and their cognitive capacity.

Keywords: algebraic representation, calculus, conceptualization, domain function.

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INTRODUCTION

Currently, an integral part of most mathematics classrooms is problem-solving (Bicer et al., 2013; Maulyda et al., 2020). In mathematics learning, problem-solving encompasses context and skill (Dossey, 2017). It's contexts like a learning approach and a skill like a strategy to solve. On the one side, mathematics learning had only not for a student with cognitive levels above average (Angelina et al., 2021; Azami et al., 2021). On the other side, there is a requirement for most of the students to be able to solve a problem, and it must not be forgotten, that is a resource that was on the solver. Each student has a cognitive capacity on a different level (Sudirman et al., 2020; Widodo, Cahyani, & Istiqomah, 2020), so there are students who have difficult to solve a problem (Faradillah, 2018; Jelatu & Kurnila, 2019; Philpot et al., 2017). Specifically, the most error frequently from students was in conceptualizing a completion (Alghadari, Yuni, & Wulandari, 2019; Veloo & Krishnasamy, 2015). Hence, there is a needed way of conceptualization in solving a problem through an efficient conceptual process for students who have difficulties (Alghadari et al., 2019; Yuni et al., 2021).

Cognitive activity in problem-solving from student with high level can be exemplified for a student who is at a low level. It means the need is about an efficient problem-solving model regarding relevant concepts in aspects related to resources in human (Lin & Lin, 2014; Radmehr & Drake, 2018; Maulyda et al., 2020). In mathematics, especially in the relationship between geometry and function, it is known that there are still few studies focused on the design of problem-solving based on resources in the student. One of the resources for solving a problem is the information processing system (Lin & Lin, 2014), that interprets individual cognitive system characteristics about the base of conceptual knowledge which was assumed when a person performs to solve a problem (Alghadari & Noor, 2021; Berger et al., 2010). Theoretically, the optimizing function of resources in problem-solving is an efficient process (Alghadari et al., 2019).

In this study, students solve an open-ended mathematics problem. A mathematical problem in open-ended context is a non-routine task which has a solution and completion approach more than one, so its problem will be able to invite different thinking process (Alghadari et al., 2019), and using higher-level cognitive skill and reasoning (Berger et al., 2010; Gareis & Grant, 2015). The non-routine problem meant is a geometric-function problem and stated as an open-ended type because, theoretically speaking, at least there are two views based on completion possibility. The geometric-function problem is to sketch the first derivative function graph of a curve that drawn on the rectangular coordinate but all the pair-points and the algebraic representation of function its curve has no defined (Alghadari et al., 2019; Yuni et al., 2021).

There are only three studies focus on studying the geometric-function problem. Yuni et al. (2021) studied the category of problem and student achievement levels. Alghadari et al. (2019) studied two models of the conceptualization process. Hutajulu et al. (2022) studied conceptual systems in cognitive operations. According to these studies, the process of solving geometric function problems has been studied. However, details of efficient cognitive activity are a student product to be analyzed according to this research framework. Its framework is: (a) investigate solving process a geometric-function problem for finding a point of efficiency issues, (b) identify the efficiency issues on completion so knowing a source of mathematics concept which affected toward student finding solution. The point of efficiency issues in problem-solving causes students to spin around in their inflexibility to apply a conceptual system (Ozdogan et al., 2019). This issue is an important knowledge for mathematics educators to be followed up on during the learning process, so that students have an opportunity to think complexity and improve cognitive capacity in information processing. Based on the framework, this current study was addressed to identify efficiency issues in solving process a geometric-function problem.

METHODS

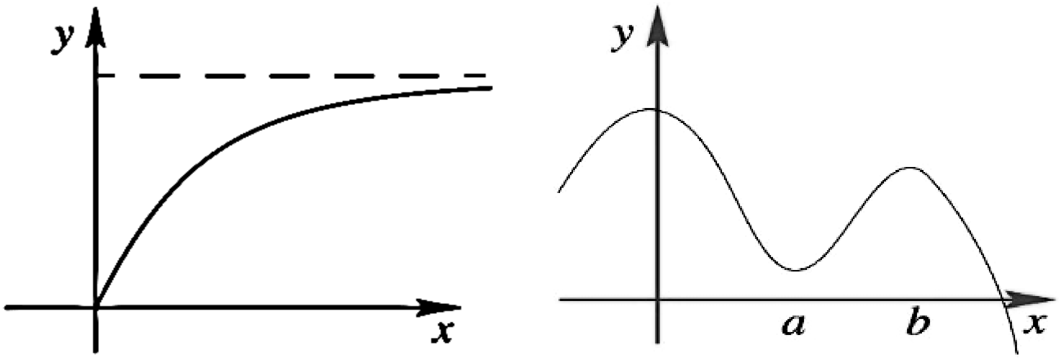
This is an investigative study for identifying efficiency issues on resource student information processing system when they solve a geometric-function problem. On the student completion, some material that investigated is like a strategy for processing a completion, cognitive dimension process, knowledge dimension, and mathematics concepts applied in conceptualizing. From the result so that is known: a) efficient conceptualization student completion, and b) an efficiency issues on the process.

Student's Participants

This study was held on respondents purposively selected from a science program of senior high school in West Jakarta, Indonesia. Initially, the respondent in this study is the seven number of students. All the students were they who have been recommended to their mathematics teacher based on a high-level student mathematical ability in the school. Because there has been an efficiency problem-solving context as purposive investigative analysis, so the completion was required to be an effective process. An investigative analysis standard of the effective solving process was based on completion that has been student found. By its analysis, just there have been the only three students who meet the standard process effectiveness. All three students have been initialed by AN, NI, and PR.

Data Collection

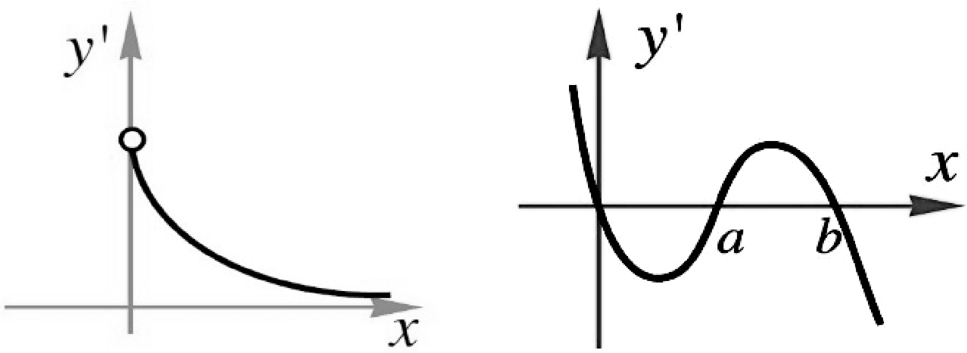
Data has been collected through a test. The test was a geometric-function problem that had been adapted by Tobin (2007). There were two tests that a completion made by students. Two number of the test was everything to sketch the derivative graph of the function that was only served graphically on the rectangular coordinate. The function graph at the following is for number the test (a) and (b).



(a) (b)

Figure 1. Graph of the function for test

Figure 1 is a graph for a geometric-function problem in the number (a). The graph was started from the origin of the coordinate axis and curved with a positive gradient direct to zero. The domain function of the graph was a real positive number. There was a horizontal asymptote on the y -positive ill-defined real number, and this asymptote was an upper bound of the function range. A geometric-function problem in this study not only load an asymptote but also a stationary point. The problem that has a stationary point as given information is like a graph on the problem for the next test in Figure 1(b). Figure 1(b) is a graphic form with the domain and range was in real positive and negative number. There was the point at a and b in real positive number domain where b is more than a. Given that the local maximum point was at x was equally b, a local minimum point at x was equally a, a global minimum point at the x was on more than b, and the global maximum point at x was equally 0. According to Tobin (2007), at the following is the right answer for each corresponding number.



(a) (b)

Figure 2. Graph of the derivative function for the answer

All the number of geometric-function problems would have been solved by a student. Students have solved the paper. The ways of conceptualizing a completion would be explained in the paper as the interpretation of their process. That has been data collection for analyzing.

Data Analysis

Based on the ways of collecting data, there has been two types of data, that is: a) student completion based on paper and pencil, and b) interpretation of the solving process for every number of tests. Analyzed data was how students optimize resources through planning, organizing, directing, and monitoring process, so the completion has been obtained theirs efficiently. Efficiency is about an issue in processing after completion has been found, and theoretically that it is a student's ability to use resources correctly and appropriately (Hanafi, 2015; Radmehr & Drake, 2017). A problem-solving strategy based on student's cognitive level, then how students processed its mathematics concept efficiently (Alghadari et al., 2019). Problem-solving strategy is one thing that unified between knowledge and cognitive process dimension. For a solving process on the analyzed data that has been coded refers to (e.g. Bicer et al., 2013; Gareis & Grant, 2015; Hess, 2006) and based on cognitive process dimension by revised Bloom's taxonomy.

Coding for efficiency issues in each process has been about the optimization mathematics concept applied on completion strategy according to the theory. If the strategy was not efficient, so the sources would not be empowered optimally (Hanafi, 2015), or there has been a failure in processing that affected an effectivity.

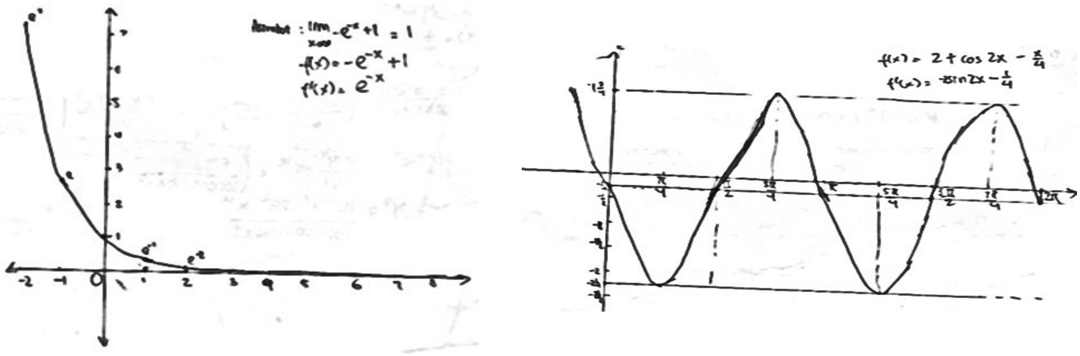
RESULTS & DISCUSSION

Based on data analysis, there is a conversion process by students. That is a strategy that students do, but with different content knowledge. An investigation toward the cognitive process on the content knowledge has been identified, so the finding is about: a) completion for every respondent, b) resources for completion, c) efficiency issues in the process, and d) student cognitive level.

The result of this study found that each student constructed an algebraic representation of the function graph by different mathematics concepts. That is distinguished by their knowledge dimension too. The following is each illustration by students about the conceptualization process for completion.

Completion by AN

For a problem (a), the shape of the derivative function graph, or we call as the first derivative function graph sometimes, has been sketched by AN like in Figure 3.



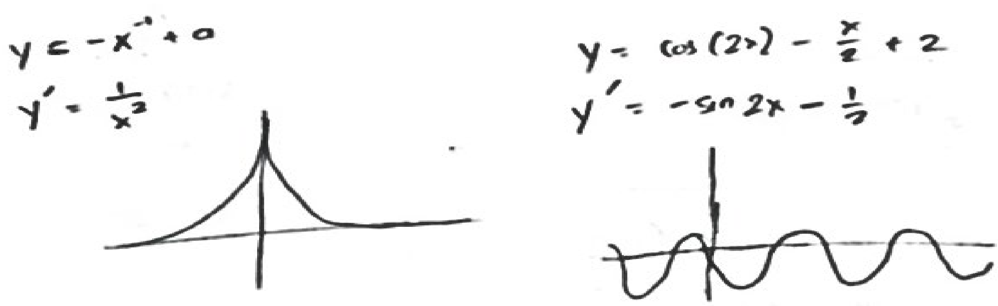
(a) (b)

Figure 3. Graph for solution of the probem by AN

Figure 3(a) is completion by AN, which is a sketch of the derivative function graph for Figure 1(a), the same goes for numbers (b). In the end, AN has generalized an algebraic function representation that its form has been similar to the problem (a), that is $y = -e^{-x} + a$ where a element real number. AN constructed the graph of Figure 3(b) by using few given elements, like at the specific domain that the graph was decreasing, the function was also increasing-decreasing. Based on the analysis, so AN conceptualize that the graph was involving trigonometry and polinom concept.

Completion by NI

There is no different with the completion strategy before that NI has also solved a geometric-function problem by constructing an algebraic function. The derivative graph is the problem (a) and (b) in Figure 4.



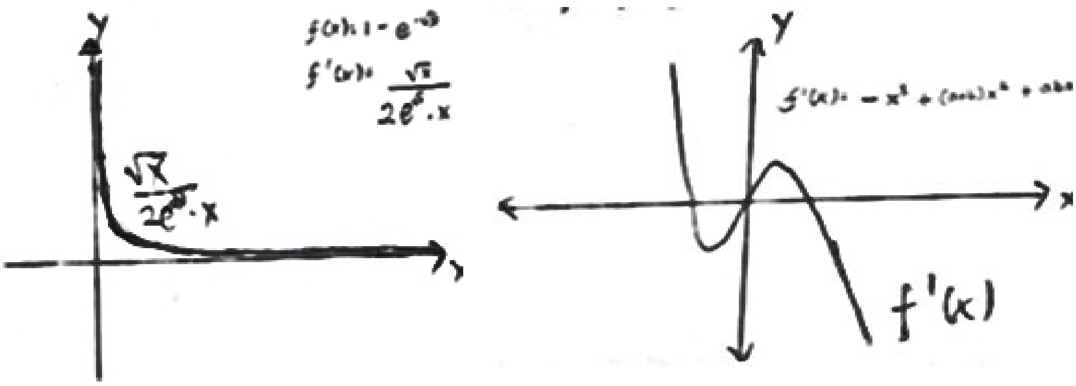
(a) (b)

Figure 4. Graph for solution of the probem by NI

Based on Figure 4(a), NI stated that a graphic in problem (a) has been categorized as a form of function $y = -1/x$. As a result, on constructed algebraic representation by NI, that is $y = -x^{-1} + a$ where a element real number, there is a real number, although it was not defined his. Figure 4(b) is the derivative function graph for the problem (b). NI did not use a maximum and minimum local in Figure 1(b) as a source for being utilized.

Completion by PR

The solving process by PR has been also with the construction algebraic function representation strategy. The following is the first derivative function graph of the problem (a) and (b) by PR in Figure 5.



(a) (b)

Figure 5. Graph for solution of the probem by PR

Figure 5(a) is a derivative function graph with the algebraic representation was $y = \sqrt{x} / 2xe^{\sqrt{x}}$. PR initialized his exploration at the exponent function by a definite number in a degree of a variable. Reflection and translation were also applied by PR so in the end, he has defined a representation in similarly with Figure 1(a) is $y = 1 - e^{-\sqrt{x}}$. For problem (b), there are different conceptualization process for completion by PR from two other people before. PR utilized given a maximum and minimum points. At the end the form that sketched by PR like Figure 5(b). In Figure 5(b), sketched a model of function by PR and written that algebraic representation for the graph is $-x^3 + (a+b)x^2 + abx$. PR used three stationary points to construct algebraic form, so the graph has been a model for a fourth-degree polynomial.

Resources for Completion

According to investigation result, there was some process by all three respondents has been acted when they conceptualize for completion a problem. That process was initialized by the planning phase. In the planning phase, all three students solved a problem by a strategy to construct an algebraic function representation. These strategies were essential in this problem-solving episode because in the next process that students have not found a significant problem. On the other hand, students look at the main point of the problem is because of the deficiency of an algebraic representation. Student's view toward a problem is about the status of knowledge and how the way each individual constructs problem space (Alghadari & Noor, 2021; Ward, 2012).

The emerging problem-solving strategy as the product of though toward a problem regarding the effectivity of applied mathematics concepts, cognitive level, and capability. Dossey (2017) and Philpot et al. (2017) stated that applied strategy by students for solving a problem is a significant way toward their conceptual knowledge. This case was the same with statement Tokgoz and Gualpa (2015) that students who faced with a function graph for sketching a derivative function graph, so they will be intended to find an algebraic representation of the graph. On the other side, Vale and Barbosa (2018) stated that students tend to use algebra for processing visual information because they did not yet have a mathematics knowledge for analyzing a problem, or in spite of they have, but it is not yet to understand. Therefore, students tend to depend on algebraic thinking style (Alghadari et al., 2019; Choi & Hong, 2014; Hutajulu et al., 2022; Yuni et al., 2021).

There were some processes on the organizing phase for the purpose is to optimize given information on the problem as resources. Generally, its process is: a) estimating algebraic representation of function for a graphic form in the problem with exponential, trigonometry, or fourth degrees polynomial, b) fitting between algebraic representation and the graphic form toward the graph in a problem with applying transformation, c) defining algebraic representation for primitive function in a problem as the result of fitting process, d) applying differential power rule theorem to algebraic representation of primitive function, and e) sketching a graph in the rectangular coordinate. Its process by students did is concerting activity of representation from a graph to the algebraic function and then to the graph again. Students who used multiple representations, transformation among the representation are a facility for developing problem-solving (Csapó & Funke, 2017; Fashihah & Qohar, 2020). Based on its process, Alghadari et al. (2019) have stated that the completion has been constructed by organizing several concepts relevant to fragmented conceptualization.

The happened cognitive process is an optimal function of the required capacity to operate a resource of knowledge. Two domains in revised Bloom's taxonomy cannot be viewed separately in identifying an interaction between cognitive process and knowledge (Ward, 2012). There is a relation between problem-solving strategy and action in the solving process. A strategy is a selected representation based on decisions toward an experienced phenomenon (Dossey, 2017; Ward, 2012). That is indirectly reflected that factor of student experienced in learning process affected their decision to determine a problem-solving strategy (Alghadari et al., 2019; Csapó & Funke, 2017; Kop et al., 2015; Nagle et al., 2013). On conversion activity a graph representation function to algebraic, there was an ability in algebraic thinking processing context. Kop et al. (2015) stated those cases regarding student activity in action as a process that had needed an ability to read an algebraic expression and make an approximation from an emerging pattern in representation. As a resource of knowledge, several applied mathematics concepts are exponential, geometry transformation, and differential for algebraic and trigonometry function.

In the directing phase, there were several concepts were applied to optimize a given in the problem. Alghadari and Herman (2018) stated that the directing phase in problem-solving is because there were constraints on the one-solving approach ways. Whereas in Hanafi (2015), the directing phase is about how students use resources optimally. Therefore, based on its concern that the resource was also different among the two phases. Borji et al. (2018) stated that organizing phase processes to be dealing with a situation. The resource on the organizing phase is a mathematics concept for the framework that the purpose of a given problem. As a resource in directing phase is given information in the problem. The resource of knowledge has applied in the correct place. Those concepts include a process in the organizing phase. Its fact was not different from a statement by Hong and Thomas (2014) and Tokgoz and Gualpa (2015) that needed a concept for solving a derivative function problem is the knowledge about the limit, asymptote, property, and interval.

The next phase is controlling. Based on the finding in this study, all three students have not shown that there is a mathematics concept was applied for verifying the completion. But actually, there is a difference between students' completion and the correct answer according to Tobin (2007). All completion by students has been different from a standard of the solution. Equality of disorientation has reflected a concept that was not to be a consideration in the directing phase (Alghadari et al., 2019). This is to be a point efficiency issue of problem-solving in this study. On the other hand, student completion cannot be efficient when there is a mathematics concept on the given information that was not applied corresponding to the theory. An investigation toward student's completion has been acted for the context is finding a disorientation identity.

Issues in the Inefficient Process

There have been several recorded cases regarding efficiency issues when students solving a geometric-function problem has been revealed as a finding in this study. From the recorded cases that there is no factor from the cognitive process on taxonomy as a cause of students was a failure to find a completion. Based on identification result in each respondent's solving process, there is a similar content of the resource in every case where it is one of the efficiency issues. Identification results toward the issue of cases directed to one point, and it has shown that there is a given mathematics concept on the problem which was a function not yet to be optimized for completion. In other words, there was an ignored concept when a student's constructing the process in directing phase. Here, efficiency has been to be the one important issue as well in problem-solving and learning context. In this study, an efficiency issue has been related to a resource on the knowledge dimension, that is at the domain concept of function. Basically, domain function is the origin for every function (Kop et al., 2015), in spite of all three students ignored this given information to be applying in the solving process.

According to the efficiency issue, Vale and Barbosa (2018) stated that an ignored concept happens in solving where it must be involved because students had had knowledge, but they did not understand it. Here, students tend to use their skill procedurally in problem-solving, so there has been an indication that students do not understand correctly for differential chapter conceptually and a consequence is a procedural process as an essential (Alghadari et al., 2019; Hutajulu et al., 2022; Yuni et al., 2021). Besides, without a conceptual knowledge so the procedural knowledge can be limited (Radmehr & Drake, 2017, 2018). Like this case, a lot of research which has explained students constrain in handling a function just for a graphic form. Most students can solve an easy and routine of a differential problem, but they did not have to understand the representation of the derivative graph conceptually (Borji et al., 2018; Hutajulu et al., 2022; Panaoura et al., 2016).

One side, students has been late probably to realize the relation between derivative and primitive function as the result lack of respected to the relation in graphic representation (Borji et al., 2018; Yuni et al., 2021), or because the factor of student's ability to read a served information just for in a graphic form, so they need to think about the complexity characteristic (Choi & Hong, 2014). On the other side, Yee and Bostic (2014) and Nagle et al. (2013) stated that academic culture played a big role in how a student solves a problem. Learning context to be relevant with the usually operated in process cognitive domain (Noor & Alghadari, 2021). Based on Choi and Hong (2014) and Wagner and Sharp (2017) study that students tend to learn differential chapter by emphasizing the algebraic algorithm skill or memorize a mechanical process.

Student Cognitive Level

The strategy, solving process, and the representation in problem-solving is an indication of a student's understanding of their acquired knowledge (Yee & Bostic, 2014). The fact, the conceptualization of completion with several relevant mathematics concepts has been acted by students in separately, so effectiveness at the one process affected to next another process. Students conceptualize a completion by the way of operationalizing concepts through procedural technique, and it was an indicator of the level of solver's ability in cognitive processing (Alghadari et al., 2019; Noor & Alghadari, 2021; Yuni et al., 2021). In this case, students connected to different knowledge from related mathematics concepts, combined between method, concept, and mathematics fact for revealing the result of the process and achieving the next result.

According to Çalışkan, Kahya, and Durmus (2018), problem-solving activity by those ways was at reasoning level with synthesizing of cognitive process domain. Whereas, according to Bicer et al. (2013), because of the solving process by complexity and abstractly ways of thinking toward graphic form so that is identically like a strategic thinking level. It is a minimal level for student completion in this case. Based on problem-solving strategy and some process on organizing phase, so the classification of student cognitive level is including in the creating aspect on revised Bloom's taxonomy (Gareis & Grant, 2015), and strategic thinking/reasoning level with the cognitive process domain in synthesizing (Hess, 2006). Based on its several references, so students who solve a geometric-function problem in this study is they were in minimal at strategic thinking level with the cognitive process domain is in creating.

CONCLUSION

Based on the data analyzed, students solve a geometric-function problem by constructing an algebraic representation strategy of the graphic function. All the identified cases have reflected students' disorientation toward a domain of the graphics function. Thus, a domain concept as the point of efficiency issues in solving a geometric function problem for this study. There is no way except learning mathematics conceptually because there was an indication that students did not correctly understand a differential chapter. This study just investigated an applied differential concept and not to how students understanding differential. For that, so there is a probable student conceptual understanding side to further study related to specific issues.

CONFLICT OF INTEREST

This paper also describes our original work and is not under consideration by any other journal. All authors approved the manuscript and this submission. The five authors do not have any conflict of interest in this manuscript.

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