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Relational Understanding of the Derivative Concept through Mathematical Modeling

Introduction

The concept of derivative may not be fully understood relationally due to compartmentalization of these big ideas in students' conceptual systems. The data indicated that the participants' understanding of derivative was rather instrumental. Their explanations couldn't reveal the role of the big ideas regarding what they mean and how they are related to each other. As part of learners' mathematical competency, the relevance of conceptual comprehension, as well as procedural fluency, has been stressed. Without opportunities to make connections between concepts and their underlying relations, students could have compartmentalized learning. This causes deficiency in the conceptual understanding of important concepts in mathematics. Students could fill this deficiency with procedural understanding and computation - computation would be regarded as the essential and the limit.

Theoretical Approach

In this study, students' understanding of big ideas was investigated in light of Skemp's (1976) theory on conceptualization of mathematical understanding. A student who understands the concept of derivative can explain why the instantaneous rate of change at a point is the same as the slope of the tangent at that point. An instrumental understanding implies knowledge without making sense of what these concepts mean and how they are interrelated.

Methodology

In this study, it is examined the phenomenon regarding three graduate students' understanding of derivative in terms of their awareness of the big ideas and relationships among them in the context of mathematical modeling. This study utilizes case study design, which is a strategy of inquiry in which the researcher explores in depth a program, event, activity, process, or one or more individuals.

The participants of this study were three second-year graduate students in a public university in Ankara, Turkey. They were selected purposefully from among eight mathematics education graduate students based on their high performance in derivative as measured with tasks requiring the use of derivative concepts and rules. The participants expressed that they had studied the concept of derivative during both secondary school and college and received high grades from tests related to the topic.

Participants read and discussed a warm-up reading comprised of information from various health-related websites. They then worked as a group on a mathematical modeling task entitled "An Emergency Patient with High Blood Pressure". Participants were provided with laptop computers with MS Excel spreadsheet software installed. Participants were asked to work as a group on a model exploration activity. Researchers listened to their way of thinking without making any judgments regarding the correctness of their thoughts and comments, and provided them with a different point of view when they were stuck in their thinking process.

Findings

Rate of Change in Relation to the Derivative

Participants were unable to make sense of derivative in a real-life context, other than the well-known velocity-time context that students encounter in most textbooks. More precisely, they sometimes interpreted derivative as speed and sometimes as acceleration, as they perceived that the rate of change is the same thing as the speed of change. Participants were not only unsure regarding when to use the terms speed and acceleration, but also what these concepts are and how they differ in nature.

Limit in Relation to the Derivative

Participants' understanding of limit in the context of derivative was limited to knowing the rule in the algebraic definition of derivative. On the other hand, they couldn't explain the role of the limit in terms of the approximation of the slope of the secant lines to the tangent lines. They could only draw a graph based on their previous-knowledge where representations related to the slope and tangent line were not placed on the graph.

Slope of Tangent in Relation to the Derivative

In the implementation of a model eliciting activity, participants were asked to define derivative as "the slope of a tangent line which is drawn to the curve at a certain point". However, it was observed that they could not make sense of the relation between the slope of the tangent and the derivative at a point, since they interpreted this definition as an equation for a function.

Rate of Change in Relation to the Limit

Participants' conceptualization of rate of change was "speed of change"; they could not integrate the limit concept into the rate of change. They could not realize that with the help of limit, the average rate of change approximates the instantaneous rate. The participants were trying to explain the algebraic definition of derivative provided by researchers.

Rate of Change in Relation to the Slope of Tangents

The participants defined derivative as the slope of the tangent line at a certain point when interpreting the change in the blood pressure on the graph. Their explanations did not include the concept of instantaneous rate of change since they thought that the change could not be examined instantaneously.

Limit in Relation to the Slope of Tangents

None of the participants were able to draw the secant line on the graph from point A to point B. This is why they could not make sense of why the slope of these lines approximate to that of the tangent line in the geometric definition of derivative.

Discussion

In this study, none of the participants had difficulty connecting the mathematical concept (i.e., derivative) embedded in the model eliciting and model exploration activities. Participants' understanding of derivative was not relational; they did not understand the relationship between rate of change and derivative. In the twelfth grade, for example, "the derivative is the general name for the instantaneous speed" in an application problem. There is no particular emphasis on the usage of physical and/or geometrical models, other than those in the velocity-time context.

Conclusion

According to this study, the notion of derivative should be presented and developed in connection to three major ideas (i.e., the rate of change, the slope of the tangent, and the limit). The study's findings show that if even one of these large concepts is disregarded, the notion may not be properly grasped relationally. More study is needed on the importance of correctly selected issue scenarios and suitable application procedures that allow teachers to explore their students' knowledge.