Enhancing Scientific Inquiry: Case of Limiting Analysis

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Abstract. STEM experiences can be organized in a variety of ways and support diverse learning goals. While the effects of the methods of mathematics on discoveries in physics are unquestionable, using mathematical reasoning to enhance understanding of physics is still being researched. This study is posited to contribute to that research. Twenty freshman college physics students applied the idea of limits to analyze acceleration of two objects connected by a massless string. Their responses supported the study thesis that integrating more sophisticated mathematical apparatus opens a gate for advancing students' scientific inquiry skills.

1 STEM as a Platform for Exploring Multidisciplinary Inquiry

The acronym STEM has multiple definitions in educational research and practice. Moore [1] defined STEM as an effort to link some or all the four disciplines of science, technology, engineering and mathematics into one unit. McComas [2] termed it as an interdisciplinary approach to learning that links academic concepts with real-world situations.

Students' successes in science and engineering depend on their skills of modeling where the ability to merge mathematics reasoning with scientific inquiry is an essential skill. Mathematics provides a computational system and helps conveniently encode a rule from natural phenomena [3] and further hypothesize its behavior. Hence, emphasizing modeling in physics that draws on algebraic concepts can benefit potential STEM students and ensure their college readiness. A broad range of learning objectives supported by STEM makes it prudent to create such learning experiences. This study is an example of such undertaking. It focuses on enhancing students' scientific reasoning skills by using and interpreting limits. As a context, the motion of two masses, connected by a string, was used.

2 Study Logistic, Treatment Design and Pretest-Posttest Discussion

This study was conducted with a group of twenty freshman college physics students. The students took a pretest at the beginning of the course. During the instructional unit, refer to [4] for the details, they reviewed properties of rational functions and the techniques of evaluating limits. After studying the chapter of dynamics, they took a postest that contained two problems. Analysis of one of the problems constitutes this study.

Problem. Consider a system of two masses, as illustrated in Fig. 1. The mass of the cart, $m_{1,}$ is 2 kg. The mass of the object m_2 is initially 2 kg, but more masses are continually being added, eventually increasing the mass to a very large and infinite value. Assume that the surface of the table and the pulley are frictionless.
a) Predict the magnitude of the system acceleration when the mass m_1 remains constant and equal to 2 kg and when the value of the mass m_2 increases to an infinite value.
b) Using Newton's law, formulate an expression for the acceleration of the system, convert it to an algebraic function and, by using the idea of limits, confirm or refute the predictions.

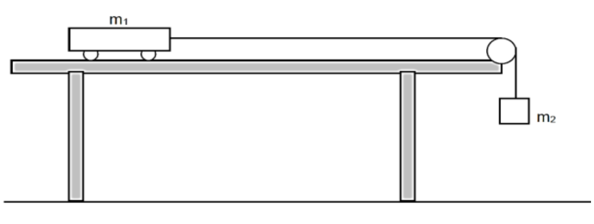

Fig. 1 Two masses connected by a massless string

2.1 Pretest-Posttest Analysis

Most students concluded that the acceleration would increase, but only (N=4, 20%) reached the conclusion that the acceleration will be about 9.8 m/s^2. Some verbatim students' responses were as follows: *The acceleration will increase to infinity; the acceleration will be very large because there is more mass hanging, thereby making the acceleration larger; acceleration will increase because higher mass will increase the force of gravity; it will approach infinity because of the heavier weight pulling the system; acceleration is infinite; the acceleration would significantly increase; the acceleration will increase quickly.* All students did have a prior calculus background, but no student attempted to apply it.
On the posttest (N=9, 45%) reached a correct conclusion. Some verbatim students' responses follow; *The acceleration will be 9.8 m/s^2 because the two infinity values will cancel each other out; acceleration goes to infinity because increasing m_2 gives a high force of gravity and the system has the same inertia; if m_2 increases to infinity, then the acceleration would primarily just be g because the infinity in the denominator would cancel out with the m_2 in the denominator* (the student wrote $a(m_2) = \frac{m_2 g}{2 + m_2}$). While attempting to formulate algebraic function, many students faced difficulties to classify variables as independent or constant.. These students who did not rename the variables, usually stated that the limit has a value of one, instead of *g*. Most of the students who labeled the changing mass as *x* computed the limit correctly. When asked to support their answers, the majority of the students (N=16, 80%) attempted to analyze the algebraic structure and use it to support their answers; the rest of the students (N=4, 20%) used scientific reasoning.

2.2 Discussion

The posttests revealed that students' scientific reasoning was enhanced when they used attributes of algebraic functions to inquire about the system's behavior. It seemed that they possessed more means to support their answers. Students also found the applications of limits in physics intriguing and thought-provoking, yet the transition from formulas to algebraic functions needed more instructional attention not only in physics but also in mathematics classes. Perhaps the era of widely propagated STEM education will prompt more actions to help students apply more sophisticated mathematical apparatus to learn about physical phenomena.

References

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