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The Mathematics of Skateboarding: A Relevant Application of the 5Es of Constructivism

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Abstract

Getting high school students to enjoy mathematics and to connect concepts to their daily lives is a challenge for many educators. The Mathematics of Skateboarding demonstrated innovative and creative ways to engage students in content and skills mapped to state requirements for high school students in Algebra and Geometry.

Keywords: constructivism, algebra, geometry, mathematics, science

1. Introduction

Getting high school students to enjoy mathematics and to connect concepts in Algebra and Geometry to their daily lives is a challenge for educators. As part of a weeklong mathematics summer enrichment program held in the summer of 2010 at a southern university in the United States (US), eighty-five high school students participated in a unique set of activities designed to integrate mathematics concepts and skateboarding. Project leaders used a constructivist framework to design student-centered experiences implemented in the outdoor setting of a local skatepark and in campus classrooms. The activities designed for students in "The Mathematics of Skateboarding" demonstrated innovative and creative ways to engage students in content and skills mapped to state requirements for high school students in Algebra and Geometry.

1.1 Background of the Study

Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP) is a federally funded program designed to better prepare students for college. One GEAR UP program in a southern US state serves high school students and involves a partnership consisting of a local university, a state technical college, and area public independent school districts. The partnership works with students and teachers through academic preparation programs, professional development activities for educators, and college access information for families.

The Summertime Travels Opening Mathematical Possibilities (S.T.O.M.P.) program is part of a mathematics initiative program through GEAR UP that was designed to create positive associations and experiences in the field of mathematics for at-risk students or those who might be academically marginilized. The necessity of fostering better attitudes and creating better experiences in the field of mathematics for these students was clearly evident in the disparity of mathematical attitudes and skills currently present within the urban, public education arena. In addition, the program was designed to engage the students in critical thinking strategies, to strengthen their basic mathematical skills, and to build the students' confidence and understanding in mathematics.

As a focus for beginning the 2010 Project S.T.O.M.P., the students were immersed in activities directly related to *Dr. Skateboard's Action Science*, a curriculum supplement integrating both skateboarding and bicycle motocross (BMX). In order to make this effort applicable to the needs of Project S.T.O.M.P., program designers combined the ideas and approaches of *Dr. Skateboard's Action Science* with mathematics concepts in Algebra and Geometry. Achievement in learning in mathematics has been linked to strategies that increase student motivation to learning and put students in situations where they have to construct their own mathematical understanding (National Research Council 2001; Kamii and Lewis 1990). Project designers focused all student materials on key mathematical concepts for the identified grade levels to align with district and state standards in the curriculum developed in the local GEAR UP program.

1.2 Purpose of the Study

Early on, program designers recognized that in order to make this approach successful, much attention needed to be paid not only to the content of the activities but also to the methods of instruction. As a result, the team used a constructivist framework to make the learning student-centered and active. As a learning strategy, constructivism builds upon students' existing knowledge, beliefs, and skills (Brooks and Brooks 1993). Within a constructivist approach, as students encounter new information, they work to synthesize new understandings based on their current experiences and their prior learning (Eisenkraft 2003). "It includes skills and activities that increase curiosity for research, satisfy student's expectations, and make the student focus on an active research for information and understanding" (Ergin, Kanli, and Unsal 2008, p. 57). The "5E" constructivist approach uses five phases of learning: engagement, exploration, explanation, elaboration and evaluation (Bybee 2006). Students and adults construct a deeper, more comprehensive understanding through activities that match their cognitive capabilities. "The important point is that each (learner) has their own construction, their own understanding, rather than some common reality" (Duffy and Jonassen 1992, p. 6). Key to this approach is building on previous learning and applying new learning in a meaningful context. Learners are required to actively address their own understandings in the context of new experiences and learning situations.

Setting this constructivist strategy in the context of a youth-centered activity (skateboarding) proved to be of great interest to the students. What follows is a synopsis of how the 5Es of constructivism, action science and the Mathematics of Skateboarding was integrated into an impactful student-centered learning experience.

2. Method

2.1 Engagement in the Mathematics of Skateboarding

Establishing a relevant and relatable connection to content is critical to gaining student interest and increasing motivation in classroom topics, especially in the areas of mathematics and science. For high school students, a critical point comes at the beginning of a lesson or program, as they quickly decide if they will actively participate or withdraw from instruction.

Engagement activities should help the students to make connections between past and present learning experiences, to move the students to become thoughtfully involved in the concept, process, or skill to be learned. In other words, the student should relate to the problem being posed and be invested in pursuing a solution. Previous studies using skateboarding, specifically the constructions of ramps, as a hook to engage students in real world applications of mathematics "lend support to the argument that all students can benefit from and deserve the opportunity to engage with interesting and challenging problems" (Stephens, Botge and Rueda 2009, p. 525).

Upon students' arrival at the skatepark, Dr. Skateboard, a science education professor at a southwestern university, and a small team of skateboarders did a demonstration to engage local students in explorations of mathematics and science in context. In viewing the athletes showcasing complex athletic moves using skateboards, the group of students was exposed to concepts they would explore such as center of gravity, acceleration, motion, velocity and many in greater mathematical depth as the day progressed. As one teacher commented, "Facilitating this type of education is a powerful way to engage our students and to build ways for incorporate sharing and collaboration."

Establishing the relevance of this approach and how mathematics was an integral part of skateboarding was key to getting students engaged and taking ownership of their own learning in a real world context. Used as an instructional strategy, active and relevant engagement activities have been shown to increase student motivation for content and be an active strategy for accessing prior knowledge of the subject (Eisenkraft 2003). The skatepark became the classroom, and as the students watched and participated in the demonstration, they felt connected to their learning and were willing to actively engage in the lesson. As one student commented, "Dr. Skateboard was my favorite and I liked him because I could relate to him."

2.2 Exploration of Mathematics Concepts

A quality exploration activity is central to building on the initial aspects of getting students engaged. In the case of the students engaged in the Mathematics of Skateboarding, specific group activities had been designed to incorporate developing teamwork and data gathering. In a constructivist framework, the exploration phase should provide students with a common base of experiences and build on the aspects of the engagement activity directly. As students actively explore their environment for learning, in this case, the skatepark, they identify and develop concepts, processes, and skills based on an open-ended approach. “The correlation between the subjects taught in Science and especially Physics lessons and daily life is very important” (Ergin, Kanli and Unsal 2008, p. 57). Since mathematics is often called “the language of science” and has a relevant and practical connection to both Algebra and Geometry, the context for this integration of physics concepts and mathematical processes seemed quite appropriate. The purpose of this interdisciplinary approach within the exploration phase was to allow the students to explore meaningful science and mathematics topics set in the context of something they enjoy doing.

The task of the teams was to gather data from three different stations in the skatepark where the riders would perform maneuvers. The first station was the half-pipe, a semicircular ramp structure, where riders moved back and forth and where students had to calculate angular motion. The second station was an inclined plane that was approximately one meter tall and three meters long. The riders would drop in on the inclined plane ramp and the student would record the time it took the rider to reach the edge of the ramp. From this data, the students could calculate the acceleration of each rider. The third station was a grind bar, a metal pole affixed to the ground on which a rider would travel up and over. The student teams had to calculate the velocity of the rider as each athlete got to the grind bar, and to determine at what minimal velocity a rider could encounter the grind bar and still make it to the end.

As students explored mathematics and science concepts in a real context, they developed a broader understanding of those principles. When students were able to share their experiences through small group discussions, they were able to strengthen their understandings of the mathematical concepts. This sharing within cooperative groups is a fundamental strategy in the constructivist approach as it allows the teacher to facilitate the learning process, and also helps students to develop a common base of experiences on which to make connections to content. As one teacher commented, “I can best use the knowledge and skills from this experience to help my students be responsible for their won learning”, which forms the basis of the constructivist method. This approach has also been shown to increase congruence in teaching, an instructional strategy that aligns the coherent relevance of a curriculum with the specific content knowledge and skills of a lesson to create optimal learning (Bybee 2003).

3. Results

3.1 Explanations of Mathematics Concepts in Field-based Settings

Getting students engaged and exploring concepts must invariably help students to master content, and this approach should extend beyond purely prescriptive approaches. When students have authentic tasks that allow them to directly manipulate data, they uncover content that is relevant to the ideas they have been exploring. In the skatepark project, after gathering the data in teams, students had to make algebraic and geometric calculations, discuss their results, and justify their solutions within each group. This strategy required student teams to actively interact with the content of the lesson, to collate the content from the worksheets, and to discuss their collective experience to provide logical solutions requiring analysis and synthesis of information. According to the National Council of Teachers of Mathematics (NCTM), at the high school level, reasoning and sense making are critical factors to help students organize their knowledge in ways that enhance the development of mathematical understandings (Martin 2009).

Student teams were asked to work on mathematics questions within the activity while in the skatepark, and also to continue their work during lunch. At the end of this time period, the student teams had to turn in their calculations and solutions to the Project S.T.O.M.P. staff members, who used this information as a formative assessment to provide feedback to the students during the week. This information was used to facilitate, modify, and differentiate mathematical activities later in the week to meet individual student needs. It also gave them insight as educators into what concepts were well understood by the student and which might need more time and enrichment opportunities.

3.2 Elaborating on Mathematics Concepts in Hands-on Classroom Activities

Following the morning of demonstration and field-based activities, Dr. Skateboard, and the Project S.T.O.M.P. staff members, led a series of afternoon workshops for the participating students. The students chose from a menu of four activities, which centered on the topics of Forces, Motion, Newton’s Laws of Motion and Simple Machines. The purpose was to provide students with a menu of activities based on their interests, as well as hands-on explorations that focused on specific concepts in Algebra and Geometry that were aligned with the state's academic standards.

This elaboration phase was designed to extend students' conceptual understanding into applications of skills and behaviors, and to deepen and broaden their content knowledge. During these activities in the classroom, the students were again assembled into teams in new groups based on their own workshop selections. The students then had to solve problems in the focus areas that centered on Algebra and Geometry. For example, in the activity on Simple Machines, the students had to construct a catapult and calculate distances and the angle of release for each trial. In doing so, the students also had to address specific state standards in mathematics, such as the foundations of functions for Algebra II and the use of geometric thinking and reasoning for Geometry. As one graduate student commented, "Action Science can impact science, technology, engineering and mathematics (STEM) education by engaging students in the learning process in all these areas." This indicates that the interdisciplinary nature of these mathematics activities extended into the elaboration phase, a connection that that fosters deeper and broader understandings of the connections and relevance of mathematics in real life.

Another activity centered on the concepts of thrust and drag in which students had to construct a hovercraft out of familiar classroom materials (cardboard, tape, straws) and to utilize a balloon in order to provide a cushion of air for movement along a table. In this instance, the students had to calculate the distances traveled, the velocities generated and the losses due to friction. Additionally, students had to understand the mathematical concepts in Algebra and Geometry related to solving extension problems and to describe processes using graphs, tables and models.

3.3 Evaluation towards an Understanding of Mathematics Concepts

Finally, at the end of the project day, the students were provided with a chance to evaluate their own learning and write reflections about the day. This phase is vital to gauging students' understandings, but it should also be pointed out that evaluation by both the students and the Project S.T.O.M.P. staff members was a constant part of each phase of the activities. The use of creative learning situations, such as the skatepark, provided a context for students to ask their own questions about their learning experiences as they developed their mathematical knowledge as it related to algebra and geometry. As a culminating event, the evaluation gave the students an opportunity to gauge their own progress and for the facilitators to see exactly what students understood as a result of the experiences in the Mathematics of Skateboarding.

In summary, the evaluation phase required learners to assess their own understanding and abilities as well as allowed the teacher to evaluate students' understanding of key concepts and skill development. In the case of the Mathematics of Skateboarding, conducting the activities in a constructivist framework gave students a chance to assess their own understandings in Algebra and Geometry. Additionally, students filled out surveys and turned in the recording sheets for the activities to be evaluated. After the day of workshops, the Project S.T.O.M.P. staff members, Dr. Skateboard and the team riders assembled to debrief the learning of the day and to review the comments and feedback from students in order to better understand students' gains and needs for improvement in the focus areas.

4. Discussion

How do educators get students to enjoy mathematics? The Mathematics of Skateboarding program answered this question by filling the day with exciting activities that allowed students to discover connections between mathematics and skateboarding. Key elements were presented in order to keep the students engaged and wanting to learn. Students were "hooked" to the opening activity because the skateboarding exhibition in the skateboard park captured their interest and they were able to relate to the content. As one Project S.T.O.M.P. staff member commented, "This approach can impact mathematics teaching and learning because it inspires students and gives them the opportunity to make connections to real life."

Students were able to explore the activities in a skateboard park by collecting and analyzing data from relevant student-centered learning experiences. In turn, students then discussed their findings with their colleagues, Dr. Skateboard, the riders, and the Project S.T.O.M.P. staff members. As one participant stated, "I think this is the way that subjects should be taught. It makes the subjects more exciting and enjoyable to learn."

By engaging, exploring, and explaining the content in relevant terms and experiences, the students could then elaborate on their skills and understandings by doing other activities directly connected to their various interests. Finally, students evaluated their own conceptual understanding by reflecting on the day's activities. "Essential to expertise is mastery of concepts that allow for deep understanding. Such understanding helps the learner reformulate facts into useable knowledge" (Bybee 2003, p. 350). As one student participant wrote, "So far this has been the most engaging way of learning I see throughout school. Using something like skateboarding that relates to student's lifes (sic), it opens many doors to introduce different content areas."

The students' actions showed their enjoyment of learning mathematics through skateboarding as a result of making personal and relevant connections to their own experiences and interests. The Project S.T.O.M.P.staff members also commented on the high level of motivation of the students during each phase of the activities, indicative in this sample comment, "I think the students learned a lot of self-confidence in their skills through being able to work in a small teacher to student ratio situation and also in being able to work with their peers to solve problems. I also think that the students learned a lot about problem solving and using multiple skills to solve mathematical problems."

Often classroom teachers face the pressures of high stakes testing and of covering massive amounts of material in limited periods of time. In mathematics, students are often not engaged and do not seem to enjoy learning skills, nor do they see connections between the real world and the topics being studied. By implementing the constructivist approach of the 5E lesson model in an innovative and creative way, students were immersed in mathematical content and participated at a higher cognitive level, while having fun!

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