Converting Algebra Lessons that Emphasize Movement into Online Lessons Using a Simulation

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In order to develop an interactive mathematics content module within a content course, funding was received from NSF to create an innovative curriculum for preservice K-8 teachers. Due to the Corona-Virus Disease 2019 (COVID-19) pandemic, significant changes in delivery of curriculum were needed. Lessons scheduled to be taught in classrooms through interactive group activities had to be quickly converted to socially distanced, independent online lessons. In this presentation, we outline our learning trajectories in creating virtual lessons in mathematics that emphasize movement and motion.

Keywords: online algebraic learning, preservice K-8 teachers, movement in mathematics

Algebraic concepts can be challenging for all learners. Preservice teachers (PSTs) are often challenged by the algebraic idea of slope. For instance, Stump (1999) found that PSTs consistently failed to develop the concept of slope in real-world situations even though they will be teaching the conceptual and procedural aspects of this knowledge to future students. Byerley and Thompson (2017), in research to measure secondary teachers' meanings for slope and rate of change, found that most teachers conveyed primarily formulaic meanings for slope and rate of change on a written assessment. Only a few teachers conveyed a rate of change by comparing the relative sizes of changes in two quantities. These studies imply that an over-emphasis on a formula to find slope could contribute to the students' difficulties in making connections among slope and rate of change.

Technological tools can play a critical role in supporting inquiry and, while it has great potential in enhancing mathematics instruction, PSTs generally lack the knowledge and experience to use technology successfully to support student learning (Clarke & Zagarell, 2012; Kirschner & Selinger, 2003; Shively & Yerrick, 2014). Many educators consider integrated curriculum that includes technology use (such as the lessons we designed and taught) to be preferable to learning subjects in isolation (e.g., Becker & Park, 2011; Stohlmann, Moore & Roehrig, 2012). Our project guided PSTs to experience and practice technology use in the context of learning mathematics emphasizing algebra.

Conceptual Framework

In order to improve our K-8 PSTs' experiences in a mathematics content course, an instructional redesign created interactive motion lessons to support the development and deepen PSTs' understanding of the concept of slope. The redesign emphasized an interactive component of learning that encouraged the use of technology, including motion sensors, data loggers, ramps, and carts. Due to the Coronavirus Disease 2019 (COVID-19) pandemic, significant changes to the delivery of curriculum were made. Here, we outline some of the strategies we used to incorporate socially distanced online learning to encourage conceptual understanding of mathematical movement in algebra.

Literature Review

Greenberg and Walsh (2008) describe some of the inadequacies regarding the mathematical preparation of elementary PSTs on a national scale. Specifically, they describe the need for algebraic instruction that focuses on constants, variables, equations, graphs, and functions. We focused on these areas, and we transformed instruction to encompass modeling within the context of algebra. Moreover, our lessons specifically focused on improving PSTs' quantitative literacy by using meaningful real-world examples that emphasized measuring movement (Grawe, 2011; Hitt, 2002; Hughes-Hallett, 2003).

Michelsen (1998) reviewed various theoretical arguments, provided by numerous authors, that all emphasized that mathematical conceptualization is a process that starts with an action on objects. The findings imply that students can use physical experimentation as a starting point to get acquainted with contexts that give rise to the mathematical concept. For example, Koirala and Bowman (2003) report on a course for preservice middle-school teachers. They allude to the use of some motion activities to teach graphing and algebra. At a more advanced level, several reports describe the use of physics activities in connection with college-level mathematics instruction. Carlson (2002) described mental actions and behaviors associated with learning mathematical ideas related to physical motions. She cites abundant evidence, both from the literature and from her curricular studies, which demonstrate improvements in students' mathematical reasoning and understanding when engaged in performing physical movements of their body and real objects. At the middle-school level, Town and Espinosa (2015) provided a brief but clear discussion of how certain motion activities may be used to teach graphing and slope. Their students were able to apply an understanding of linear graphs and *y*-intercepts to predict the motions of toy cars successfully.

Framework/Structure

To address our challenge of creating motion activities to support algebraic learning, we developed a 5-week unit that included an emphasis on actual, physical movement. Our strategy was to engage groups of students in carrying out and observing certain movements, and then analyzing the mathematical representations of these movements. However, safety conditions for teaching during the COVID-19 pandemic required significant changes. We converted all previously in-class synchronous group work into asynchronous online activities that could be conducted individually or with a partner. Some modifications focused on a deeper understanding of common mathematical terms.

Demonstrated Activities

Significant changes were made to the original face-to-face instructional approach. For example, in one lesson students worked in groups of approximately 15 to time a person walking for approximately 12 meters. Data were to be collected and graphed in order to create a line of best fit. To accommodate the need to reduce social interactions, videos were created that could be viewed asynchronously instead. The videos featured a man walking with designated meter marks. The PSTs used a timer to gather data. Various lessons were developed that showed how changes in speed impacted the graph. In another video, the man starts walking slowly then picks up his pace to a jog. The change in speed impacted the graph. PSTs are able to explore how these graphs changed by gathering data using the videos.

In another lesson, students were originally going to work in groups to gather data on movement using data loggers and motion sensors. The collected data were then going to be critically analyzed within the context of algebra. However, significant changes had to be made to create virtual activities that PST could watch from anywhere to complete the tasks. To support the development of position/time and velocity/time graphs, an online app called "The Moving Man" was used instead. (https://phet.colorado.edu/sims/cheerpj/moving-man/latest/moving-man.html?simulation=moving-man) When using the app, a man can be moved along a horizontal path, and position/time and velocity/time graphs are generated based on the movement. Figure 1 provides an example. Here, the man started at approximately -5 meters, walked at a somewhat steady pace toward, then beyond the house. He turned around and walked toward the tree, and briefly stopped at the "0" mark before finishing his walk toward the wall near the tree. The corresponding velocity graph offers insight into his speed and direction of movement. (Positive values of velocity correspond to motion toward the right; negative values, motion toward the left.)

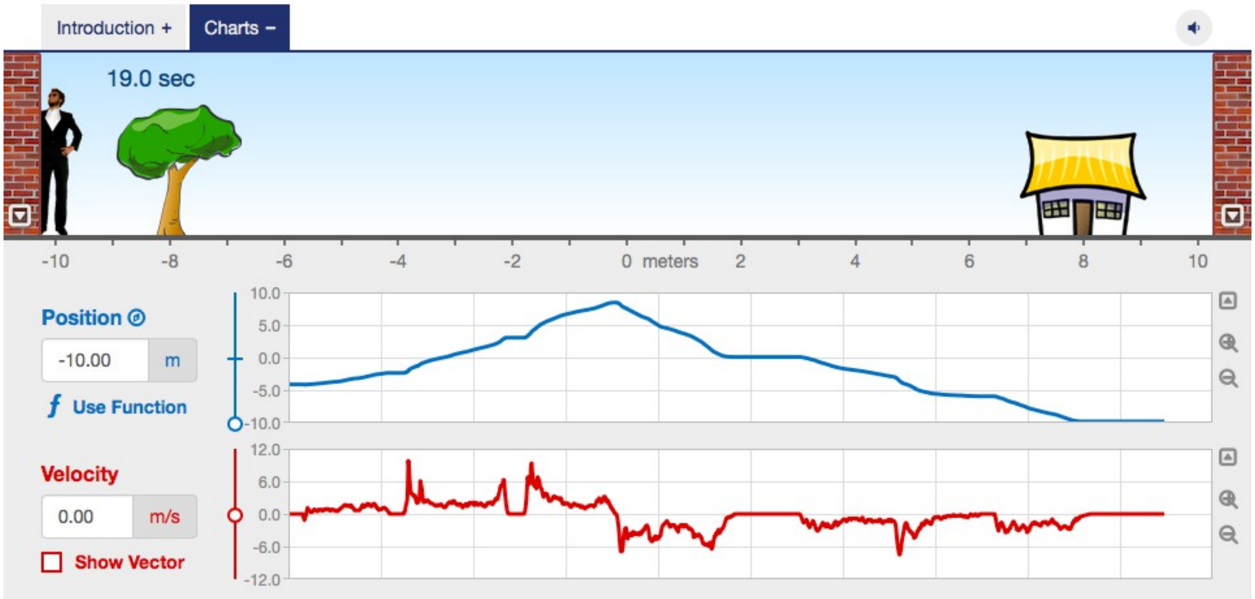

Figure 1. The Moving Man app can be used to show how movement is represented on position/time and velocity/time graphs.

In the face-to-face version of the curriculum, students worked in pairs to create graphs with given features. For example, students were asked to create a position/time graph in the shape of a W using a motion sensor and data logger. In the online version, students worked in pairs to create the same kinds of graphs using the Moving Man app while in different physical spaces. Zoom and other communications technologies were used by the students as needed. They were asked to take screenshots of their results, and then interpret and explain both the position/time graph and the velocity/time graph. Finally, they were asked to explain how one type of graph's displayed image corresponds to the other type of graph. In other words, they were asked how they know when the moving man stopped, or moved (or sped up or slowed down) on the position/time graph and what that movement look like on the velocity/time graph.

Major Aspects

As stated earlier, technology enhancements can play a critical role in supporting discovery. Unfortunately, PSTs often lack the knowledge and experience to leverage technology successfully to support student learning (Clarke & Zagarell, 2012; Kirschner & Selinger, 2003; Shively & Yerrick, 2014). PSTs experienced and practiced technology use in the context of learning mathematics, through the medium of carefully guided, online movement activities. Many educators consider integrated curriculum that includes technology use (such as the lessons we will design and teach) to be preferable to learning subjects in isolation (e.g., Becker & Park, 2011; Stohlmann, Moore & Roehrig, 2012). To meet this need, continued development of online curriculum to meet the ongoing challenges of teaching remotely is a key aspect of this curriculum.

Motivation

In our transformed curriculum, instead of merely manipulating abstract context-free equations such as $y = (-3/4)x + 3$ and $y = -3$, students plotted graphs, wrote the corresponding linear equations, find slopes and y-intercepts, and interpreted their meaning using technology. Initially, the goal was to emphasize the mathematical concepts through physical motion; our goal was to get students moving while learning algebra. The immediate feedback displayed on the motion detection technology provides experiences that are not often seen in mathematics classroom. While using the current app instead of actual physical movement is not ideal, the original goals of the redesign are still being addressed. There is a focus on understanding mathematics by modeling real world concepts through the integration of movement. The motivation for these activities was to continue to address our objective of improving algebraic learning through the use of motion despite the social distancing directives. Technology was used through asynchronous learning in order to meet the goals of the project as well as the goals of the redesign.

Conclusion

Our curriculum was designed by integrating movement and technology to provide PSTs meaningful contexts to learn key algebraic concepts of slope and rate of change. By engaging in this curriculum, PSTs experienced opportunities to develop the concept of slope in context and understand formulaic meanings for slope. There are visual images that connect the physical movement to changes on a position/time graph. Also, in consideration of social distancing caused by COVID-19, the technology integration was enhanced by adapting videos and an interactive online app. We hope our framework provides other educators some insights regarding the development of interactive online curriculum when adjusting curriculum to meet the challenges of teaching remotely Collaboratively sharing challenges and solutions is crucial.

Significance of Work

This project is unique in that it focuses on middle-school STEM teacher education through the seamless integration of well-tested instructional activities on movement *into* a mathematics content course, as the primary means of communicating that content. This is not a science course, nor a combined "mathematics/science" course, but instead, a course that focuses specifically on mathematics. Elementary and middle school teachers often intentionally evade coursework in science, thus depriving them of a natural context in which mathematical ideas may easily be applied. The curriculum we designed and implemented provides PSTs with exposure to the natural world through a mathematics content course, to address that need for exposure to real-world contexts of mathematics use. We expect to have an impact on the future students of these PSTs by providing experiences that model positive, meaningful activities, featuring hands-on motion experiments that employ technological tools. We expect that carrying out and analyzing these experiments will motivate PSTs to better understand and teach mathematics-focused activities appropriate for grades K-8. Pending our analysis of outcomes, we are hopeful that our novel curriculum elements may contribute to a national model for improving the teaching of middle-school mathematics.

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References

Becker, K., & Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education: Innovations and Research*, *12*(5/6), 23-37.

Byerley, C. & Thompson, P. W. (2017). Secondary teachers' meanings for measure, slope, and rate of change. *Journal of Mathematical Behavior, 48*, 168-193.

Carlson, M. P. (2002). Physical enactment: a powerful representational tool for understanding the nature of covarying relationships. In F. Hitt (ed.), *Representations and Mathematics Visualization*, (63-77). Working Group Representations and Mathematics Visualization, North American Chapter of IGPME, Cinvestav-IPN, Mexico.

Clarke, G. & Zagarell, J. (2012). Teachers and technology: A technological divide. *Childhood Education, 88*(2), 136-139.

Grawe, N. D. (2011). Beyond math skills: Measuring quantitative reasoning in context. *New Directions for Institutional Research*, *2011*(149), 41-52.

Greenberg, J., & Walsh, K. (2008). No Common Denominator: The Preparation of Elementary Teachers in Mathematics by America's Education Schools. National Council on Teacher Quality. Available: http://files.eric.ed.gov/fulltext/ED506643.pdf

Hitt, F. (2002). *Representations and Mathematics Visualization*. Working Group Representations and Mathematics Visualization, North American Chapter of IGPME, Cinvestav-IPN, Mexico.

Hughes-Hallett, D. (2003). The role of mathematics courses in the development of quantitative literacy. In B. L. Madison and L. A. Steen (Eds.) *Quantitative Literacy: Why Numeracy Matters for Schools and Colleges*, p. 91-98. Princeton, N.J.: National Council on Education and the Disciplines. http://www.maa.org/ql/pgs91_98.pdf

Kirschner, P., & Selinger, M. (2003). The state of affairs of teacher education with respect to information and communications technology. *Technology, Pedagogy and Education, 12*(1), 5–18.

Koirala, H. P., & Bowman, J. K. (2003). Preparing middle level preservice teachers to integrate mathematics and science: Problems and possibilities. *School Science and Mathematics*, *103*(3), 145-154.

Michelsen, C. (1998). Expanding context and domain: A cross-curricular activity in mathematics and physics. *ZDM*, *30*(4), 100-106.

Shively, C. T., & Yerrick, R. (2014). A case for examining pre-service teacher preparation for inquiry teaching science with technology. *Research in Learning Technology*, *22*(1), 1-13.

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *2*(1), 28-34.

Stump, S. L. (1999). Secondary mathematics teachers' knowledge of slope. *Mathematics Education Research Journal, 11*(2), 124-144.

Town, J. & Espinosa, A. (2015). Racing toward algebra and slope. *Mathematics Teaching in the Middle School, 21*(3), 169-175.