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Learning to Develop Mathematics Lessons with GeoGebra

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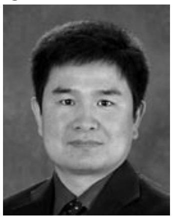

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Abstract

This paper describes how prospective secondary mathematics teachers' Technological Pedagogical Content Knowledge (TPCK) and perspectives about teaching and learning mathematics were enriched as they worked individually and in small groups to develop and present lessons with GeoGebra. We also note how Geogebra can be used as a vehicle for building links between a research-focussed university and secondary school teachers.

Introduction

The International Society for Technology in Education (ISTE) [3] calls for change in teacher education programs. The ISTE's National Educational Technology Standards for Teachers (NETS·T) [5] emphasize the increased role that technology plays in improving the teaching and learning and suggests standards and performance indicators for teachers in five areas to promote appropriate uses of technologies in education. Despite current reform efforts, our education system fails to address the specific needs of today's students, who are "digital natives", growing up with new technologies [6]. One problem facing education today may be that the educators, who, as "digital immigrants", speak an outdated language to their digitally minded students [6].

Many prospective teachers have insufficient knowledge about teaching and learning mathematics with technology, and research has shown that they often rely on their learning experiences as a student to make instructional decisions (e.g., [1]). Therefore, prospective teachers must be prepared for the changing classroom environments with new interactive technologies so that they become critical thinkers and consumers of the new pedagogical resources and develop thought-revealing learning activities (e.g., [4]) as they teach mathematics to their future students. We think that methods courses for prospective teachers are critical in helping them develop Technological Pedagogical Content Knowledge (TPCK). We as educators may not be and do not have to be skilled in creating computer games for mathematics, but we must incorporate powerful dynamic technologies in our teacher education courses to create rich environments in which prospective teachers explore ways of teaching mathematics with appropriate technologies.

The use of technology within the mathematics classroom has become widely acknowledged in the research literature. Recently, innovative and dynamic mathematics software environments – for example, GeoGebra [2] – have made possible interactions between students and computers, which have the potential to improve mathematics curriculum and classroom dynamics. As a result, preparation of prospective mathematics teachers for incorporating technology in mathematics has changed over the past few decades and will require further study and improvement.

Difficulty with incorporating technology–based teaching and learning in methods courses is further complicated by content and pedagogical issues associated with technology. For instance, when students are exposed to multiple representations, they often rely on technology to translate among representations as they learn mathematics, which may compromise the development of their mathematical understanding. Moreover, there is an increasing importance of dynamic linking of multiple representations in facilitating students' visualization because students can explore, solve, and communicate mathematical concepts in various ways, such as using dynamic multiple representations and mathematical modelling. Simply showing pictures or figures is not sufficient to encourage students to visualize or use various representations.

This leads to the question of how we as teacher educators provide rich learning experiences to help prospective teachers develop TPCK and enable them to design appropriate activities and describe pedagogical strategies for the effective teaching and learning of mathematics with technology. We believe that collaborative and group lesson planning and implementation should be embedded into teacher education programs to help prospective teachers develop TPCK as a foundation in the teaching and learning of mathematics and appropriate pedagogical strategies for mathematics content. In this study, prospective teachers developed lessons using GeoGebra [2] to teach various areas of secondary mathematics. The prospective secondary mathematics teachers were asked to consider teacher actions and possible questions to be asked, and student actions, misconceptions, questions, and possible responses as their future students explored mathematical concepts or problems.

GeoGebra

GeoGebra [2] is an open source mathematics software program that accepts geometric, algebraic, and calculus commands and links multiple representations (Fig 1). GeoGebra users can create dynamic worksheets that can be used with any Internet browser supporting Java on any operating system. The software was developed to enable multiple representations and visualization of mathematical concepts. Thus, GeoGebra lends itself to create activities

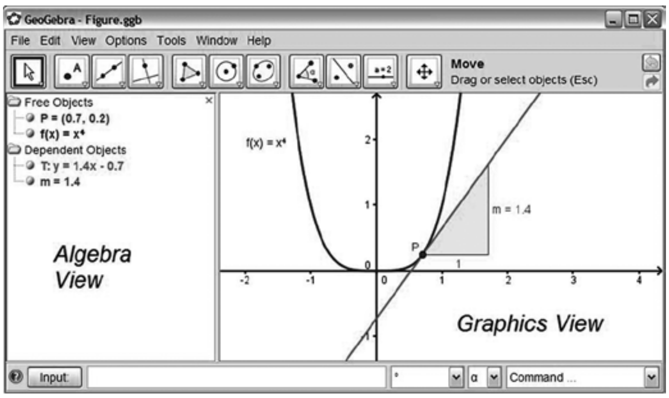

Fig 1 – GeoGebra

incorporating multiple representations of mathematical concepts that are linked dynamically. Without having to spend a significant amount of classroom time on drawing figures, objects, or functions, students can explore mathematical concepts and dynamically connect algebraic, graphic, and numeric representations of these concepts.

Methods

During the summer and fall 2008 semesters at a major research university in the south eastern United States, 44 prospective secondary mathematics teachers enrolled in two methods courses participated in this study. At the beginning of each semester, we provided instructions about GeoGebra [2]; that is, the prospective teachers first explored the GeoGebra website including GeoGebraWiki where worksheets, lessons, and other teaching materials are shared by educators from all over the world. After becoming familiar with the menus and toolbars of the software, they learned how to create basic mathematical objects and figures such as points, drawing line segments, graphs, or polygons. Then, the prospective teachers were asked to illustrate a mathematical concept or problem with GeoGebra in any area of secondary mathematics content. As they designed GeoGebra worksheets and developed lessons, they were encouraged to work collaboratively with their classmates. Throughout the semester, they were asked to describe how they would teach their lesson, (e.g., include teacher actions and possible questions to be asked, and student actions and possible responses), consider how their future students would explore the problem or concept illustrated with GeoGebra, and explain what and how they would expect their future students would learn through their activities. Each prospective teacher made a thirty minute presentation of his or her technology supported lesson, and their presentations were critiqued by the class. At the end of each semester, the prospective teachers wrote open–ended reflections on their experience of developing lesson plans with GeoGebra.

Results

In our class discussions, we discussed the importance of creating dynamic worksheets by emphasizing that just showing pictures, figures, or diagrams is not sufficient to facilitate students' learning or their use of various representations and visualization. As a result, once the prospective teachers became familiar with the software to be able to draw mathematical objects and figures, they collaborated with their classmates to convert GeoGebra [2] worksheets with static drawings into dynamic constructions.

As an illustrative example, screen shots of worksheets are presented. For instance, to draw a graph of a linear or quadratic function and its inverse simultaneously (Fig 2), not only did they have to determine what tools to use, but they also they explored their own understanding of inverse functions graphically and algebraically (e.g., symmetry with respect to the line y = x, restricting domains of quadratic functions). Designing a real life activity about ranges of cellular phones and forwarding phone signals to switching stations to explore graphs and equations of circles in standard and non–standard forms was a rich and challenging learning task for prospective teachers (Fig 3). To situate learning of slopes of linear functions in real life context (e.g., distance–time graph of a car travelling at a constant speed, slowing down, or speeding up), they had to synthesize their content knowledge (e.g., slope, intercepts, and equation of a line), technology knowledge, and their understandings of real life applications of the concept (e.g., interpreting distance–time graphs). Creating dynamic worksheets illustrating an isosceles trapezoid (Fig 4) and a triangular prism (Fig 5) enabled them visualize how changing dimensions (i.e., base, leg, or height) affected the interior angles of the isosceles trapezoid and the volume of the triangular prism. As they created dynamic GeoGebra worksheets for their lessons, we observed that they synthesized their content knowledge, pedagogical knowledge, and technology knowledge. In their reflections, almost all prospective teachers expressed positive views about teaching and learning mathematics with GeoGebra.

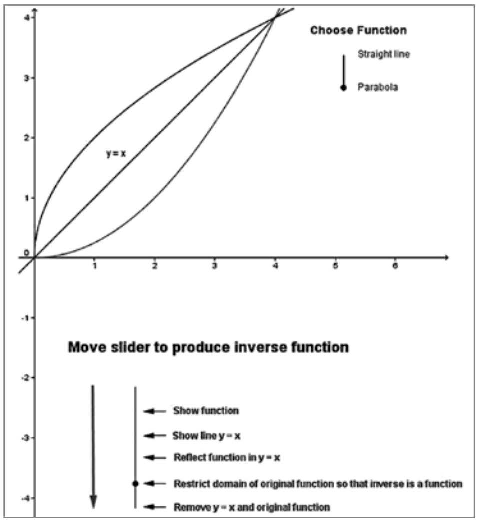

Fig 2 – Inverse functions

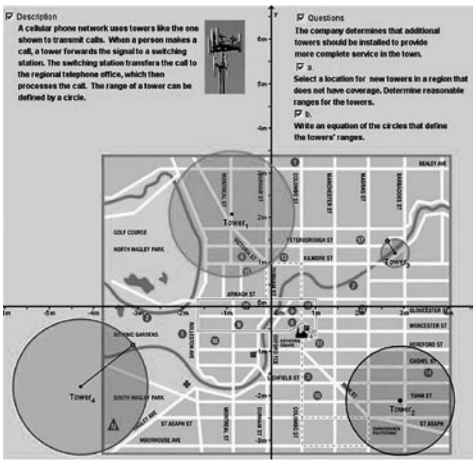

Fig 3 – Graphs of circles

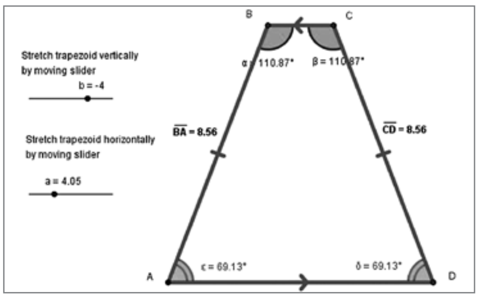

Fig 4 – Isosceles trapezoid

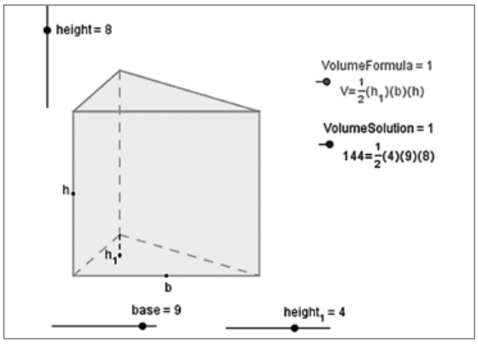

Fig 5 – Triangular prism

Conclusions

Our work with prospective teachers has shown that developing and presenting lessons with GeoGebra [2] positively influenced prospective teachers' views about teaching and learning of mathematics with technology and led to effective development of lessons in various content areas of secondary mathematics. In describing how their future students would learn in their lessons, they used the language, conventions, and representations of mathematics, and dynamic worksheets to attend to student learning needs in a technology-rich classroom. We inferred that they developed preliminary TPCK as a result of their participation in the activities of the study. We must note that drawing mathematical objects and figures is not enough, and that creating dynamic activities is essential to the development of their TPCK. This seems to be consistent with the general notion of mathematical understanding as one's growing competence to navigate through various representations of mathematics concepts illustrated dynamically. We can deepen prospective teachers' knowledge of teaching and learning mathematics with technology by creating a rich and collaborative learning environment and challenging them with new problems, new pedagogies, and new solutions associated with the use of technology.

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