Chapter 4
Geometry for Computer Graphics in K-12 Education

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ABSTRACT

Computing education and computational thinking have gained increasing attention in education both as means to support the learning of other subjects, such as mathematics, science, and humanities, and as outcomes by themselves. This chapter proposes a focus on teacher knowledge of geometry for computer graphics used for virtual image manipulation and coding in the context of an online graduate course for teachers. Teachers were required to design tasks for their classrooms that incorporated the content of the course and to participate in an online discussion forum. These tasks, along with the discussion entries, are analyzed, and suggestions are provided for how to incorporate relevant geometrical content used in computer graphics. Teacher challenges to learn and incorporate this content in the classroom are addressed, along with recommendations for teacher education. The findings of this study are discussed in terms of teachers' knowledge for teaching geometry for computer graphics.

INTRODUCTION

Programs of studies in mathematics at K to 12 levels around the world are slowly introducing new topics such as cryptography and network (or graph) theory to their curriculum. However, teachers are not likely to be familiar with these new topics. Addressing this issue, the University of Calgary has developed a graduate certificate for teachers to explore mathematics beyond what is traditionally included in such programs of studies, but which can still be taught at school level. One of these courses, *Geometry in Art, Nature and Computer Graphics*, specifically addresses mathematical content for virtual image manipulation. This content is relevant for teachers to incorporate computer education in their classrooms.

The content of this course has not yet been commonly addressed as part of computer education. For instance, Hubbard (2018), in a review of the literature, noted that scholars included specific topics as part of teachers' required knowledge for computing education, namely: arrays, control structures, data structure, decomposition, direct and indirect referencing, formal language grammar and syntax, functions,

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generalization, input and output, logical thinking, parameters, problem-solving skills, procedures, reusability, thinking in modules, user interface and variables, algorithms, bubble sort, metaphor, programming, recursion, and unified modelling language. While some of these topics, such as arrays, are very specific, others, such as problem-solving skills, are more general, with specific skills varying depending on the subject. In contrast, the content of the course described in this chapter comprises specific geometrical topics such as proportion, trigonometry, vectors, fractals, transformations, tessellations, and symmetry in the contexts of their use for image manipulation and animation.

This course also takes a different approach to what has been the predominant focus in the literature on computer education and computational thinking; namely a focus on teaching either these independently, or in support to other subjects. For instance, Weintrop and colleagues (2016) draw from the literature, from interviews with mathematicians and scientists, and from instructional materials to propose a framework for integrating computational thinking for mathematics and science. The framework consists of four categories: data practices, modeling practices, computational problem-solving practices, and system-thinking practices. While some elements that might be related to computer graphics are mentioned, such as computer simulations and graphical interfaces, the specific mathematical knowledge is not addressed. The main approach of the framework is to incorporate computational thinking in mathematics and science instruction, which contrast with the approach of this chapter that focuses on mathematical knowledge that can support computer education.

The purpose of this chapter is to investigate how geometry for computer sciences can be introduced in K to 12 education through an analysis of teachers' task designs for their classrooms and the online conversations that were part of the graduate course. Teachers' challenges to learn and incorporate the content of the course in their classroom offer insights relevant for both the implementation of geometry for computer graphics at school levels and teacher education in this area. The chapter also discusses the specialized knowledge required for teaching geometry for computer sciences.

BACKGROUND

Geometry for computer graphics can be loosely defined as the relationships between geometry and programing, in particular with respect to the manipulation of virtual images. This also includes programing for robotics, with involves spatial elements. Knowledge for teaching geometry for computer graphics deserves particular attention, as offered in the next subsection.

Knowledge for Teaching Geometry for Computer Graphics

This study, conducted in the context of mathematics teacher education, is intrinsically related to extensive scholarly work on mathematics knowledge for teachers that dates back more than four decades. Such work continues to be a prominent focus in the literature. Early results of this work repeatedly showed little or no correlation between teachers who possess extensive teachers' college credits in mathematics and the performance of their students on standardized tests (Begle, 1972, 1979; Monk, 1994), prompting the realization that the knowledge required for teaching mathematics should be specialized and go beyond mere mathematical knowledge.

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