COGNITIVE COMPUTER TOOLS IN UNDERGRADUATE CALCULUS: A QUALITATIVE RESEARCH STUDY

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Introduction

The use of high powered software programs in college level mathematics is becoming increasingly common. Online courses, computer-based tutoring, and adaptive testing are popular applications of computers in post-secondary mathematics. But what happens when the use of software becomes an integral part of the teaching and learning process in an on-campus course? Instructors, curriculum developers, and developers of instructional technology need to understand ways in which students may use cognitive computer tools in the mathematics classroom to support high-level thinking. A cognitive computer tool is defined as a software application that assists the user in performing cognitive tasks through reorganization or representation of ideas and information (Landauer, 1988; Schoenfeld, 1988). It is instructional tasks that require high levels of cognitive demand which result in significant learning gains because of the thinking and reasoning that is encouraged (Stein, Smith, Henningson, & Silver, 2000).

Purpose

There is minimal amount of research addressing the impact of such computer tools on developing mathematical understanding (Zbiek, 2003). Research must be that specifically addresses the use of such computer tools in the college mathematics classroom. The purpose of a study by Borchelt (2004) was to explore the use of a cognitive computer tool by undergraduate calculus students as they worked cooperatively on mathematical tasks. Specific attention was given to levels of cognitive demand in which the students were engaged as they completed tasks with the assistance of MathCAD, software that combines a computer algebra system, graphing utility and mathematical word processor into a single worksheet environment. The following question guided the study: In what ways does the use of a cognitive computer tool affect the level of cognitive demand on students in undergraduate calculus within the context of small group mathematical tasks?

Mathematical Tasks Framework

Stein, Smith, Henningsen, & Silver (2000) discuss a Mathematical Tasks Framework by which the different phases of a mathematical task can be analyzed. The conceptual framework classifies tasks based on the level of cognitive demand that is required of students throughout the task from the writing of the task through its implementation. The authors discuss four levels of cognitive demand. The first two levels in the Mathematical tasks Framework include: Memorization and Procedures Without Connections. These are considered low levels of cognitive demand. The level of Memorization describes tasks that involve reproducing information such as facts or formulas. There is no connection to concepts or meanings that underlie the reproduced information. At the level of Procedures without Connections, a task is very procedural and the approach to solving the problem is immediately evident. The focus at this level is on producing correct answers and the work does not require any explanation. The second two levels of cognitive demand are described as: Procedures With Connections and Doing Mathematics. These categories require high levels of mental reasoning. At the level of Procedures with Connections, a task must focus student attention on the use of procedures in developing deep understanding of mathematical concepts, involve multiple representations, and require some degree of cognitive effort. At the level of Doing Mathematics a task has the following characteristics: complex thinking, exploration of relationships, applications of previous knowledge, and some level of anxiety. This study focuses on student cognitive demand during four in-class labs that were written in and facilitated with the use of MathCAD. Reviewers familiar with the Mathematical Tasks Framework assisted the researcher in determining the cognitive level at which the task was written. The researcher wanted to determine if these levels of cognitive demand were maintained or if there was a decline to lower levels of cognitive demand during implementation.

Methodology

Participants were students enrolled in a first semester calculus course at a state university in the southeastern United States. The twenty-eight participants were assigned to heterogeneous working groups consisting of four students each using purposeful sampling. One of these groups was selected to serve as a specific case to be closely analyzed for the study. A very important aspect of the class is that every student had access to their own notebook computer. This is a university-wide requirement as part of the institution's commitment to ubiquitous computing across the curriculum. The students were expected to bring their computers to and from class each day. In addition, students were required to purchase and install MathCAD on their computers for use as an integral part of the teaching and learning process. The instructor of the course also acted as researcher for this study. While teacher research combines theory with practice, it still involves systematic inquiry through an emic perspective (Bauman & Duffy, 2001). Data was collected from several sources including student questionnaires, individual interviews, completed student assignments, audio recordings of student discussions, and video recordings of nonverbal communications. The collection of the data was centered on four in-class labs which provided the participants with applications of concepts already discussed in class and exploratory investigations into concepts not specifically presented in class.

Analysis

Initial coding procedures resulted in the emerging of four categories that describe ways in which students used MathCAD: organization, calculation, representation, and communication. Evidence emerged within the questionnaires and interviews indicating the participants perceived that the use of MathCAD allowed them to explore mathematics, spend more time on interpreting results, and focus on understanding. Analysis of the group interactions indicated that use of the cognitive computer tool reduced reliance on low-level thinking skills and allowed for creativity in problem solving permitting students to move toward high levels of thinking. Four additional categories emerged from the data that indicated high levels of cognitive demand were maintained during the mathematical tasks: recollection, cooperation, construction, and frustration.

In subsequent coding procedures, conditions surrounding each of the categories were examined to provide cumulative knowledge of connections between and among categories. The eight coding categories were separated into related groups. The categories of Recollection, Construction, and Frustration all related to student learning. In addition, the Mathematical Tasks Framework suggests that each is characteristic of activities supporting the highest levels of cognitive demand. The categories of Organization, Calculation, Representation, and Communication all refer to how students implement MathCAD in the learning process. The ways in which the cognitive computer tool was used both supported and structured their thinking. This allowed the students to focus on the exploration of the calculus concepts and promoted the construction of mathematical meaning. Lastly, there is the category of Cooperation. This category proved to be very significant. The cooperative atmosphere provided a support structure for implementing the use of technology. When one member of the group was unsure how to implement the technology, somebody else was there to assist them. Working in groups also enabled the students to engage in valuable mathematical discourse. When necessary, the students would work together to recall previously learned concepts in order to apply them within a new context. The interactions also allowed the group to construct shared mathematical meaning. The relationships between the categories are represented by the concept map shown in Figure 1.

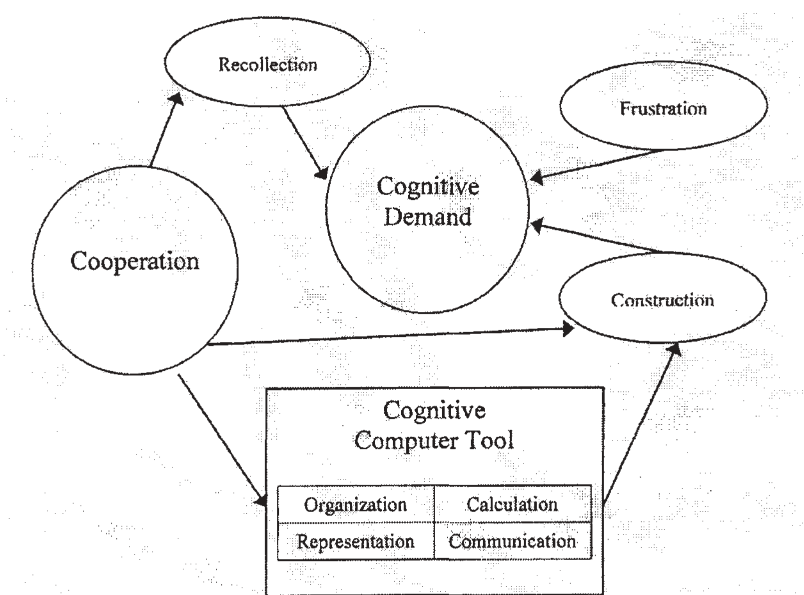

FIGURE 1 – CONCEPT MAP

Conclusion

The researcher hoped that the results of this study would indicate if the use of a cognitive tool had any effects on the level of student cognitive demand in which students engaged during mathematical tasks. What was discovered is that their focus was still on solving problems and attempting to understand concepts. Most of the time, the technology became an afterthought. The cooperative groups seemed to provide students with a support structure that enabled them to implement the technology effectively. Analysis of the data indicated that the level of cognitive demand at which each of the labs was written was maintained during implementation with one exception. In the third lab of the semester, there was a decline from the level of Procedures with Connections to a level of Procedures without Connections. This was not an affect of using MathCAD, but instead was caused by the group's inability to apply previous knowledge to a new situation. The students struggled with topics from high school geometry and these difficulties were not anticipated. They were left with little time to monitor their work and focused too much on the procedures for obtaining an answer. This resulted in logical mistakes and incorrect responses.

As the use of computers in the classroom increases, there is a need to move away from traditional teaching methods such as lecture and recitation. Analysis of the data suggested that the use of MathCAD generally reduced reliance on low-level skills, allowed for creativity in problem solving, and permitted students to move towards high levels of thinking. The three coding categories of recollection, construction, and frustration are all referenced in the Mathematical Tasks Framework as indicators of high levels of cognitive demand. These results may provide a basis to continue the consideration of various issues that challenge collegiate mathematics educators regarding the use of software tools similar to MathCAD. Undergraduate mathematics educators committed to integrating computer software into the teaching and learning of calculus concepts must consider how to effectively provide experiences that promote high levels of mental reasoning. Discussions should continue regarding appropriate uses of cognitive computer tools in classroom settings in ways which can benefit learning.

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