The Effect of Implementing a Content-Methods Calculus I Course Into a University Science and Mathematics Secondary Teacher Preparation Program

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Abstract

This quantitative study examined the feasibility of implementing a content-methods Calculus I course into a university secondary mathematics certification program. The content-methods Calculus I course contained the complete university introductory calculus curriculum along with discussion and modeling of mathematical methods and knowledge needed for secondary teaching. An independent measures *t* test was used to compare the $n = 47$ treatment students' final course grades with that of a control group in both Calculus I and Calculus II. This study found that students who had taken the Calculus I content-methods course performed at least as well in Calculus II as students who took the traditional university Calculus I course and then a traditional Calculus II course. The results of this research could lead to changes in the courses that mathematics department's offer for secondary mathematics preservice students with the goal of creating a more effective teacher workforce.

Introduction

This research study was designed to test whether or not it is feasible to create content-methods courses out of pure content courses in the degree plan of mathematics majors who are also seeking certification in secondary mathematics teaching. The author defines a content-methods course to be one that is traditionally a pure content course within a university mathematics degree plan that is modified to include both the full content subject matter and curriculum along with discussion and modeling of classroom teaching methodology and philosophy specific to mathematics. The reasons for conducting this research are twofold. First, the conclusions of two recent important national studies call for the strengthening of mathematics and science instruction and preparation of teachers in the United States. According to a report issued to Congress called Rising Above the Gathering Storm by the NAS (2005) the United States has lost its competitive edge in a global market largely due to the lack of academic preparation of well trained personnel in the areas of mathematics, science, and engineering. A suggestion of this report was that more and better trained mathematics and science teachers are needed who can inspire youth to pursue science and mathematics careers, and perhaps more fundamentally pre-service mathematics and science teachers need to be better trained in both their content areas and in effective methods for teaching mathematics and science. These same concerns and recommendations were echoed in the latest TIMSS (2003) report. As a response to these reports, the goal of this research was to explore the innovative idea of discussing and emphasizing the mathematical connections, analysis of topics, and mathematics knowledge needed by preservice teachers within content courses in the degree plan in order to better prepare preservice students for future mathematics instruction. It must be mentioned that a content-methods course is not the typical survey or topics course that is usually present in content certification program. The research question associated with this researcher's study was, "Is there a significant difference in academic achievement, as measured by final grades, of pre-service students who took Calculus II after taking an experimental Calculus I content-methods class compared to a control group of students who took a typical university Calculus I and Calculus II class?" The hypothesis statistically explored was:

> H_0: There is no significant difference in the grades achieved in Calculus II between students in the content-methods treatment group and the control group
>
> H_1: There is a significant difference in the grades achieved in Calculus II between students in the content-methods treatment group and the control group.

Essentially, the research question investigated whether or not subject students could effectively learn the full curriculum of Calculus I even though time and discussion within the course was devoted to developing the concept of mathematics knowledge needed for teaching in secondary settings. A comparison of the Calculus I and Calculus II grades of the subject students and the control group was conducted in order to gain insight into subject student learning.

Theoretical Framework

In response to the crisis situation that has been identified as a threat to the global status of the United States and the consequent recommendations for dealing with this problem, one question to be asked is, "What types of modifications can be enacted in a secondary mathematics and science teacher preparation programs to effectively prepare pre-service students to teach, challenge, create, and inspire future mathematicians, scientists, and engineers?" Research by Begle (1979) and Monk (1994) found that the number of mathematics content courses taken by teachers did not significantly affect student learning. These studies have suggested that it is a certain aspect of content knowledge, called *pedagogical content knowledge*, that is most important to teacher success as measured by student achievement (Shulman, 1986), and that teachers need to be better trained in this area. The importance of the training and acquisition of pedagogical content knowledge (PCK) in preservice and in-service mathematics teachers is the key to effective teaching (Shulman). According to Schulman, PCK consists of the subject knowledge that specifically allows for the ability of the teacher to communicate concepts, connections, and representations of subject matter through teaching processes that enable students to effectively construct a knowledge base of relevant content objectives. Important to PCK in secondary mathematics instruction, as proposed by the National Council of Teachers of Mathematics (NCTM, 2000), is knowledge of the use of manipulatives and relevant technology such as graphing calculators and computers. Effective teachers are aware of various methods and activities that make the content they convey the most meaningful to their students. According to the President's Committee of Advisors on Science and Technology (1997), for mathematics instruction, this awareness usually takes the form of a constructivist approach with the use of cooperative and discovery learning techniques that take advantage of available technology and manipulatives to make conceptual connections in students' learning.

The Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America (CUPM, 2004) had direct recommendations for pre-service mathematics teacher education programs. As a challenge to elementary and middle school mathematics preservice programs, CUPM suggested that future elementary and middle school mathematics teachers should develop:

1. A strong knowledge base at the highest level of certification in such topics as number operations, algebra, functions, geometry, and data analysis,
2. A broad range of critical mathematical thinking, reasoning, and connection skills,
3. An understanding of the application and uses of mathematics in multiple areas, and
4. Confidence and motivation to pursue mathematics as a professional and life-long endeavor.

CUPM also had recommendations for pre-service programs that prepare secondary mathematics teachers. In addition to acquiring the skills recommended for elementary and middle school teachers, secondary pre-service mathematics teachers should:

1. Make connections between the secondary curriculum that they will teach and advanced mathematics,
2. Fulfill the requirements of the typical undergraduate mathematics major,
3. Learn the history of mathematics and its development until present times, and experience mathematical modeling and the use of technology. (p. 53)

With the findings of the research cited in mind, the framework of the Calculus1 content-methods course was devised. The course delivery and methodology was based on a cumulative consideration of the relevant literature pertaining to content, pedagogy, and mathematics knowledge needed by secondary teachers in the mathematics classroom. While the typical college calculus course is large with 100 or more students and is completely lecture based, each of the three sections that the author taught contained approximately 25 - 30 students. Most of the students in each section were seeking secondary mathematics certification, but some were seeking secondary science certification. Only those seeking mathematics certification were followed. Lecturing was done about 50% of the time. The lecture presentation made consistent use of Socratic questioning. According to Bertrand Russell (1945), Socrates was not the inventor of this dialectic method consisting of gaining and disseminating knowledge through use of questioning, but Socrates practiced and perfected the method. Fifty percent of the class time was spent using discovery learning methods conducted through use of group problem solving activities involving relevant problems with consequent student exploration and presentation of results (Bowen, et. al., 2000). Great emphasis was placed on analyzing and discussing the development of the underlying mathematical ideas and topics covered in the course. These important ideas were also connected to the topics that secondary mathematics teachers deliver in their classrooms (CUPM, 2004).

Method

This study was a quasi-experimental quantitative study using a modified control-group interrupted time series design (Creswell, 2003). The study tracked the achievement (course grades) of 47 mathematics majors in a secondary mathematics and science university teacher preparation program who had taken an experimental content-methods Calculus I class and then the normal subsequent Calculus II course. The Calculus I and Calculus II grades of the study group were statistically compared to a same sized randomly selected control group of university mathematics majors who had taken the typical university Calculus I course and Calculus II courses. An independent measures *t* test was used to test whether there was any significant difference in performance in the Calculus I and Calculus II courses between the two groups.

Population and Sampling

The treatment group of interest to the study consisted of preservice mathematics students from three small Calculus I experimental content-methods classes who agreed to participate in the study and who also continued on to take Calculus II. The experimental Calculus I class consisted of science and mathematics majors intending to be certified for secondary mathematics instruction. Only the mathematics majors in the classes were considered for this study. The size of the treatment group was $n = 47$. The size and constituency of the treatment group was determined simply by the fact that the class enrollment size had been limited by the university and mathematics department and was open only to mathematics and science majors in the College of Natural Sciences who also wished to be certified to teach secondary mathematics and science as part of their degree plan. It must be noted that the researcher taught the experimental content-methods course to the Calculus I treatment group, but did not teach these same students in Calculus II. All treatment students took Calculus II in a traditional setting from other university faculty.

Data Collection and Analysis

Final course grades of all study participants in Calculus I and Calculus II were gathered along with final grades of the comparison group in the College of Natural Sciences taking Calculus I and Calculus II over three university semesters. The hypotheses relating to the research question, "Is there a significant difference in academic achievement, as measured by final grades, of preservice students who took Calculus II after taking an experimental Calculus I content-methods class compared to a control group of students who took a typical university Calculus I and Calculus II class?" were:

> H_0: There is no significant difference in the grades achieved in Calculus II between students in the content-methods treatment group and the control group
>
> H_1: There is a significant difference in the grades achieved in Calculus II between students in the content-methods treatment group and the control group.

A comparison based on subjects' Calculus I and Calculus II grades in each group, was accomplished by using an independent measures *t* test between subjects (Gravetter and Wallnau, 2005). The independent measures *t* test was used to test whether there was any significant difference in performance in the Calculus I and Calculus II course between the two groups.

Results

The first finding of this research relating to the comparison of grades between the treatment group that took the content-methods class and a control group in Calculus I, using an independent measures *t* comparison, was that grades of the two groups differed by an average of M = .1489 on a 4-point scale for grades (A=4, B=3, etc.). Assuming equal variances, the difference in grades between the two groups was not statistically significant $t(92) = .594$, $p > .05$. This result implies that the null hypothesis is not rejected. Therefore, based on this study, one can infer that grades of students in the content-methods Calculus I course did not differ significantly from those of students in the sample control group of students who took the traditional Calculus I course. This was an important outcome in that it provided evidence that the content-methods course was at the same level of rigor as the traditional Calculus I courses offered at the university. Another implication of this outcome was that learning about teaching methodology and the underlying mathematical knowledge and connections of the material presented in addition to learning the full content curriculum of the Calculus I course did not hinder student learning compared to the control group.

A second finding of this study concerned a comparison of grades in Calculus II between the group that took the content-methods Calculus I class then Calculus II and the control group taking a traditional Calculus I course then Calculus II, using an independent measures t comparison, the grades differed by an average of $M = .5162$ on a four point scale for grades (A=4, B=3, etc). Assuming unequal variances, the difference in grades was not statistically significant $t(53) = 1.94$, $p > .05$. This result implied that the null hypothesis is not rejected. Therefore, based on this earlier study, one accepts the null statement and one can infer that grades of students in the traditional Calculus II course after taking the content-methods Calculus I course did not differ significantly from those of students in the sample control group of students who took the traditional Calculus I course and a traditional Calculus II. This was an important outcome in that it provided evidence that the students who took the content-methods Calculus I course were able to perform at least as well as their peers in the next required mathematics course (Calculus II). In fact, the t score for the treatment students was so close to the positive critical t cut-off value for significance (t =1.94 vs. the critical t = 1.96) that an F-ratio test was also performed, and it was found that, when effect size of the two groups was considered, there was a significant difference in the grades of the two Calculus II groups $F(30) = 2.072$, $p<.05$. Therefore, the F-ratio suggested that the null statement could be rejected and treatment group students performed significantly better in Calculus II than those that did not take the content-methods course. In either case, one could reasonably state that students who had taken the Calculus I content-methods course performed at least as well in Calculus II as students who took the traditional university Calculus I course and a traditional Calculus II course.

Table I is a comparison of the percentage of As and Bs earned by treatment students in Calculus I and Calculus II compared to the control group sample in each course. Note that the author taught only the treatment content-methods Calculus I course students. These students then took Calculus II from various other university instructors teaching using traditional methods. The significantly greater frequency of As and Bs achieved by the treatment students in Calculus II provides further evidence that taking the mathematics content-methods Calculus I course did not detract from these students' overall performance in their next mathematics course.

Conclusions and Limitations

It is the researcher's hope that the encouraging and positive results of this research study, in light of the literature cited, inspire some university mathematics departments and teacher certification programs to consider the possibility of implementing a content-methods course such as the one explored in this paper. Of course, this study was only a beginning in justifying the feasibility of the content-methods course. The results of the quantitative study of grades indicated that creating and implementing effective content-methods courses is a realistic possibility. This research implied that both the course content and the development of mathematical underpinnings necessary for teaching secondary mathematics can be taught in a mathematics course that is traditionally just content-based without detracting from the possibility of students performing well in the next required mathematics course in the mathematics degree sequence.

This researcher is not claiming that making content courses into content-methods courses is a good choice for every content course within a teacher certification program. This research was designed largely to discover if the content-methods course could be implemented without hurting students' future performances academically. The results of this research suggested that creating a content-methods course constructed from a traditional content course is at least a viable possibility. One might argue that other factors such as grading rubrics, different instructors, and class size might have influenced the study results, but this is why the researcher only tested to see if subject students could perform at the same level as their peers given the realistic university situation that a typical teacher preparation candidate student encounters. The researcher also acknowledges that as the instructor of the course that was the focus of this research the statistical Hawthorne Effect (Gillespie, 1991) posed a danger in relation to the interpretation of the results of this research in that the researcher was directly involved with that which was being researched. The Hawthorne Effect occurs when the researcher or treatment subjects are acutely aware that they are the subjects of the research. It could be argued that his situation was somewhat held in check by the fact that treatment students were followed (with regard to data collection) into their next mathematics course which was not taught by the author of this research. Even though there were lurking factors involved in influencing the outcome data, this study showed that given that there may be confounding factors in a typical university setting, the content-methods class used in place of a pure content course is a possible option for teacher preparation programs.

Another consideration in implementing a content-methods course is the question of who might teach the course. The researcher, who also taught the content-methods course, possessed the academic background to teach university mathematics courses, while also having over 10 years of secondary mathematics instruction experience. The researcher was hired into a university preparation program as a "master teacher" in the discipline. This is not to suggest that this is the only type of background that someone who teaches a content-methods course must have, but certainly any university mathematics or science department considering implementing a content-methods course must find selected personnel who can effectively convey a depth of content knowledge, an analysis of topics presented, and pedagogical concerns in relation to teaching secondary mathematics.

The social impact that is inherent in this study's research findings is that university mathematics departments and pre-service programs might consider implementing a "best of both worlds" scenario where both content and development of mathematics knowledge for future secondary teachers are combined in one or possibly a few key courses (content-methods courses) within the pre-service student's academic major degree plan. It must be reiterated that these content-methods courses are not the typical content "topics" courses that already exist within teaching certification programs. The hope is that implementing content-methods courses for pre-service teachers will lead, not only to more effective instruction by mathematics teachers, but also to enhanced learning by these future teachers' students. This would then be one possible way of attending to the current crisis in mathematics and science education in the United States.

It is clear that universities can not continue doing the same things that have been done for years in an effort to properly prepare effective mathematics and science teachers. The TIMSS (2003) report offers evidence that with regard to student achievement in mathematics and science current practices are not leading to effective teaching. Borsuk (2003) stated that a recent study of studies concludes that too many mathematics teachers in the United States are deficient in basic skills needed to teach mathematics. The results of the author's research study open the door to a new and innovative way to prepare preservice students in both the content and depth of content knowledge needed for secondary mathematics instruction. While this study was limited in scope, the results were positive enough to suggest serious consideration of creating and further exploring the effect of the content-methods course on teacher preparation.

Table I
Percentage of students receiving either an A or B in Calculus I and II

Grade Distribution for Calculus I					
Percentage					
	A	B	C	D	F
Students who took calculus content-method course	25.5%	29.8%	27.7%	6.4%	10.6%
Control Group	31.9%	23.4%	31.9%	6.4%	6.4%
Grade Distribution for Calculus II					
Percentage					
	A	B	C	D	F
Students who took calculus content-method course	45.2%	35.5%	16.1%	3.2%	0.0%
Control Group	32.3%	29.0%	22.6%	9.7%	6.5 %

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