AN INVESTIGATION OF TEACHING STRATEGY IN THE DISTANCE LEARNING MATHEMATICS CLASSROOM

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Abstract

Distance learning has become increasingly popular among higher learning institutions, and more academic disciplines, such as mathematics, are now being offered at a distance. This experimental study investigated whether an objectivist-based teaching strategy or a constructivist-based teaching strategy yields greater achievement scores for adult students learning mathematics at a distance. A pretest-posttest control-group design was used, with a sample of 35 students. Two researcher-made test instruments, consisting of multiple-choice and brief constructed response/extended constructed response (BRC/ECR) items, were used to measure students' understanding of mathematics topics both before and after the teaching intervention. While the results of t-tests and ANCOVA showed no statistically significant difference in achievement scores between the groups, the findings indicate that both teaching strategies are viable in the distance learning mathematics classroom.

Keywords: objectivism, constructivism, distance learning, mathematics

There has been a recent rise in the use of distance learning among institutions of higher education (Slagter van Tryon & Bishop, 2009). With this increased use, new challenges will inevitably arise. Perhaps the most critical hurdle is how educators can best use distance learning to offer superior and meaningful educational experiences to students.

More specifically, how is this achieved in mathematics courses that are taught at a distance? This study sought to examine the impact of two teaching strategies, derived from different philosophical models of teaching and learning, on student achievement in an online mathematics class.

Many early distance learning studies focused on comparing distance learning and traditional classroom learning. One need only look to Russell's (2001) comparative research text to discover that distance learning has earned its place as a viable alternative to the traditional classroom. More recently there has been a shift away from comparisons of face-to-face and distance classrooms, with studies emerging that attempt to identify which learning models are best suited to distance learning classrooms.

According to Vrasidas (2000) distance learning has historically followed an objectivist philosophy of education, focusing on the belief that knowledge is an objective absolute that is preexisting in nature and can be transferred from the teacher to the student. This model seemed well suited to early distance learning classes that lacked sophisticated technology and instead relied upon one-way communication such as correspondence through the mail or video/audio recordings. Current distance learning classes mimic face-to-face classes in that student-teacher communication is often instantaneous. Rapid technological growth in the field of distance learning, supported by interactive, real-time functionality, calls into question the relevance of an objectivist framework. As the technology that supports distance learning has evolved, the undergirding learning theories should be re-examined.

There is a recent trend in the distance learning literature toward a constructivist-based approach to education (Abik & Ajhoun, 2012; Ashcraft, Treadwell, & Kumar, 2008). Ashcraft, Treadwell, and Kumar note student collaboration and the teacher's role as a facilitator as two key characteristics of constructivist-based learning. Further, research in the area of mathematics at a distance also tends to support constructivist theories (Chinnappan, 2006; Evans et al., 2008; Williamson, 2006; Zhou & Stahl, 2007).

According to many K-12 (Sherman & Thomas, 1986; Williamson, 2006) and higher education (Ben-Jacob & Levin, 1998) researchers, mathematics is best learned in a constructivist-based environment. Research in the field of mathematics education suggests that a constructivist-based approach within the mathematics classroom has a positive effect on students' learning experiences (César & Santos, 2006; Williamson, 2006). Findings indicate that students who work collaboratively are more motivated and feel a higher degree of confidence in their mathematical abilities than those students who work individually (Slagter van Tryon & Bishop, 2009).

There are concerns, however, that stem from the unique nature of the online mathematics classroom. Mensch (2010) suggests that online mathematics students face different challenges, such as higher attrition rates, than those students taking other online courses. Bird and Morgan (2003), Conrad (2002), and Mayes (2011) note that student isolation and anxiety in the online classroom are potential concerns. When coupled with the anxiety that many students feel about mathematics (Hembree, 1990), this concern is heightened. Mayes (2011) further identifies the difficulty of communicating ideas in symbolic and graphical form in the online mathematics classroom. Some research suggests that a constructivist-based model can overcome these challenges.

In a study of adult online mathematics students, Chinnappan (2006) sought to examine the role of discussion in a community of learners. Under the framework of social constructivism, online discussion and collaborative learning were used to support mathematics students' construction of knowledge. Online discussions in a virtual learning community allowed for interactivity among peers and constructive feedback, which resulted in scaffolding of learning.

Similarly, Evans, et al. (2008) found, in a study of rural K-12 teachers, that participation in a community of practice, as framed by constructivist principles, can support mathematics education. As a result of geographic student isolation, Metro College of Denver incorporated a web-based component into its mathematics content course for teachers, which focused on problem-solving skills. With a focus on small group interactions among the students, it was found that, while there were some minor technological hurdles such as variable online connection speed and software functionality, students who were grouped virtually were as successful as those grouped physically in Metro's face-to-face offering of the course.

Likewise, Zhou and Stahl (2007) champion a constructivist-based model in the online mathematics classroom, stating, "We believe students can learn math better and more effectively when they talk about math with their peers. Bringing learners together can challenge them to understand other people's perspectives and to explain and defend their own ideas" (Data Collection and Research Methods section, para 1). In an investigation of middle and high school mathematics students, this study investigated the social interactions among participants as they solved mathematics problems collaboratively through a sophisticated online chat system called Virtual Math Teams Chat (2007). The students were led by a course facilitator, but it was the group's responsibility to negotiate what information was given in the problem and what needed to be determined . It was found that, in an effort to solve the problem, students turned first to the group and, if that was unsuccessful, to online resources. With a focus on social presence and co-presence, Zhou and Stahl noted that a brief moment of socializing in the chat area helped students to establish their identities and develop a sense of co-presence in the online environment. This is a promising finding in that it may help to reduce the isolation that some online students experience.

Even with this emphasis on a constructivist-based approach in the online mathematics classroom, some educators have found that a traditional objectivist-based model is more successful. In one such study, students in an asynchronous university-level mathematics class appeared to have benefitted from this individual approach (Hodges, 2009). Journals, interviews, and artifact collection were used to gather data on seven students' self-regulation strategies. The classroom format required students to improve their organization and time scheduling. Further, Hodges concluded that the participants felt increased learner confidence after taking the course, as well as a responsibility for their own learning. Although Hodges does not provide much detail in the overall format of the class, particularly in terms of instructor presence and role, he does briefly describe some course resources as practice quizzes, a computer lab with instructional assistants, and online lesson pages. It is further noted that most students typically did not need assistance from other students or the instructional assistants, which leads one to believe that the model of this online mathematics class falls squarely within the framework of objectivism. In fact, one student reported, "I'm not afraid to teach a class to myself anymore" (p. 236). This seems to be in contrast to the findings of Chinnappan (2006), Evans et al. (2008) and Zhou and Stahl (2007), who champion an online learning environment that is rich in collaboration and discussion.

Hodges' research suggests that the traditional approach to teaching mathematics online may have merit, despite a movement away from objectivist-based teaching in the distance learning classroom (Ashcraft, Treadwell, & Kumar, 2008). It is, therefore, worthwhile to examine both learning models in the context of mathematics. In light of the conflicting research, this study sought to examine the effect of employing a constructivist-based learning approach versus an objectivist-based learning approach to teaching mathematics online. Teaching strategy effectiveness is linked to student achievement (Ben-Jacob & Levin, 1998); hence, this study examined student achievement to determine the effectiveness by measuring student achievement scores.

Methods

This study investigated whether an objectivist-based teaching strategy or a constructivist-based teaching strategy yields greater achievement scores for adult online mathematics students. The following research question was investigated:

- Do adult distance learners taught by an objectivist-based teaching strategy and those taught by a constructivist-based teaching strategy differ in their mathematics achievement scores?

Participants and Sampling Procedure

The sample consisted of students who were enrolled in the researcher's two online sections of Beginning Algebra. Thirty four students were enrolled in each course section at the beginning of the semester. Using the volunteer process, the resulting sample consisted of 17 participants from one class and 16 participants from the other. The average age of a student at this university is approximately 35, with students representing many different countries, resulting in a globally diverse classroom.

The researcher has been teaching Beginning Algebra online at this university since 2004. In order to receive an undergraduate degree from the university, students must complete the minimum number of credit hours in mathematics. Typically students receive these credits by taking College Algebra. Students take a mathematics placement test to determine which course will best fit their needs. Many are not prepared to take College Algebra and are subsequently enrolled in either Beginning Algebra or Intermediate Algebra, both developmental level mathematics classes. Neither Beginning Algebra nor Intermediate Algebra count toward the required mathematics credit hours.

As adult learners, many students have not taken a mathematics class in years and most express concern for their ability to understand the concepts, a feeling of math anxiety, and, at times, dread for having to take a mathematics class in order to graduate. Even though it is common for students to wait until the end of their degree program to complete the mathematics credits, the researcher has found that, on the whole, students are eager to learn the content. As a result, the retention rate is typically quite high, with an average of 80% of students completing the course.

Measures

Two researcher-made assessments were used as the data collection instruments in this study. The pretest consisted of 25 multiple-choice questions. The posttest consisted of 25 multiple-choice questions and 3 brief constructed response/extended constructed response (BCR/ECR) questions. Both the pretest and posttest contained an even distribution of low, medium, and high difficulty problems. The purpose of the tests was to measure participants' mathematics content knowledge both before and after the teaching intervention. The BCR/ECR questions were reserved for the posttest because the researcher felt that it would be unlikely that students would have the content knowledge to answer these questions at the beginning of the semester. Approval to conduct the study was obtained from both the mathematics program director and the IRB.

Gall, Gall, and Borg (2003) offer five types of evidence for demonstrating the validity of test-score interpretations, one type being content-related evidence. One of the researcher's colleagues who had extensive experience teaching introductory algebra, acted as the content expert to assess content-related evidence of the pretest and posttest.

It is expected that a test that produces scores with a reliability of at least .80 will be considered reliable for use in research, although Nunnaly (as cited in Santos, 1999) believes that a reliability of .70 is considered acceptable for educational research. The reliability of the pretest and posttest multiple-choice scores in this study was computed using Cronbach's alpha. Cronbach's alpha was computed as .779 for both the pretest and posttest multiple-choice items.

The study used analysis of covariance (ANCOVA) as the primary statistical technique. Under ANCOVA, the means of the two groups were compared while using the pretest scores as a covariate. Because the pretest scores were critical in determining if the two groups were statistically equivalent in their achievement levels prior to the implementation of the teaching strategies, ANCOVA, as opposed to other methods, was chosen.

Intervention

The intervention spanned the full 14-week academic semester. Intact classes were used where one section received the constructivist-based teaching strategy, while the second section received the objectivist-based teaching strategy. The same instructor (the researcher) taught both sections, using identical course materials (textbook, online course lectures, etc.), and students in both groups completed the same assignments and assessments (practice problems, quizzes, and final exam). The key differences between the classes were the methods in which students completed the course assignments and the nature and level of interaction with the teacher and other group members.

The students in the constructivist-based section worked on three group projects throughout the semester. The students in the objectivist-based section also completed the same problems during the semester but on an individual basis. The problems were complex in nature, with part of the goal being that students working in a group would be capable of transcending the scope of work that would otherwise be expected of them working individually.

In the constructivist-based group, each project was completed over a span of three weeks. During week one the groups logged into the study groups area of the online classroom to discuss the assigned problem. An entire week was devoted to making contact in the study group and formulating a plan for solving the problem because, especially at the beginning of the semester, some students enter the classroom late. In addition, some students typically drop the course after a few days. It was the hope of the researcher that at the end of week one, all of the group members would be able to check into the study group and begin reading the first problem. At the end of week one, each group submitted a plan for completing the problem. During week two, the groups solved the problem and submitted it for grading. The groups presented their findings for discussion in the conference area during week three. They were asked to create an electronic presentation, which could possibly include a slide show and graphics. The students spent the remainder of the third week reviewing the other groups' presentations and discussing additional techniques for solving similar, yet more advanced, problems.

Each of the three projects was completed by all groups in the constructivist-based class. The groups consisted of three to four participants with a mix of high and low achieving students as determined by the pretest. Working in mixed-ability groups is supported by constructivist theory because students construct their own knowledge in relation to their life experiences. Part of those life experiences, in terms of collaborative group work, include the interactions among the group members.

The traits of constructivism extend well beyond merely working in groups. The researcher approached the constructivist-based group in a manner that she felt supported the underlying tenets of the philosophy. This included not only the types of assessment problems that were selected but also how she interacted with the groups. For instance, each group problem was posted without a set of instructions for solving it. The researcher wanted the group members to come together and discuss possible strategies for solving the problems, similar to the methods found in the work of Chinnappan (2006), Evans et al. (2008), and Zhou and Stahl (2007). Once the groups worked through the problem, they posted their work as a presentation for the entire class. The researcher encouraged students to read and comment on the other groups' postings. In addition, the researcher posed a follow-up question that prompted students to take the concept to a higher level.

Even though the students in the objectivist-based group completed the same three problems during the semester, the researcher's interactions with the students and the course materials was very different. If a student became stuck on a problem, for instance, the researcher told the student what steps to take to solve the problem. In the constructivist-based group, the researcher suggested that the students first turn to the group members for help. Further, the students in the objectivist-based group did not present their findings to the class, as it was noted earlier that there was little room for discourse in an objectivist-based class (Vrasidas, 2000). The students were prompted to take the concept to a higher level, but this was done individually.

The objectivist-based group worked on all assignments individually, as was the current practice within the researcher's classes. Each week the students completed an assigned mathematics problem from the textbook. During three of the weeks, students were assigned the same problem that the students in the constructivist-based learning group were assigned. These three problems were submitted directly to the students' assignments folders, which decreased the potential for students to collaborate on these problems. The remaining weekly assignments were to submit one problem from the textbook for grading. The textbook problems were posted in the weekly course discussion area. Even though all students could see the weekly discussion postings, these assignments were not grounded in constructivist theory. In addition to the assigned weekly problems, the quizzes and final exam were to be completed individually. During week 14 of the semester (which was one week before the final exam), all participants completed the posttest on an individual basis.

Results

Upon collection of the pretest and posttest data, the first step in the data analysis phase was to examine the pretest scores. Eighteen students in the experimental (constructivist-based) group completed the multiple-choice pretest, while 17 students in the control (objectivist-based) group completed the same pretest.

The pretest data revealed a mean score of 13.89 with a standard deviation of 4.96 for the constructivist-based group. The mean score for the objectivist-based group was 15.06 with a standard deviation of 3.70. A t-test was used to compare the two group means. Before running the t-test, three assumptions about the data must be met. First, the data must be normally distributed. To determine this, the researcher used SPSS to run the Shapiro-Wilk test of normality. The resulting statistic of .970 (Sig. = .448) shows that the pretest data are normally distributed. The second assumption is that the observations (or scores) come from independent samples, which is true in this case, as the samples have no effect on each other. In other words, neither the assignment of the students to one of the groups, nor the treatment itself, has any effect on the other group. Third, the two groups have equal variances. Levene's test for equality of variances resulted in a Sig. value of .269, which is greater than the alpha value of .05, therefore the third assumption is supported.

The alpha level was set a priori at 0.05, as is common in educational research. A two-tailed t-test was conducted with $n_1 = 18$ and $n_2 = 17$. Since $n_1 \neq n_2$, the f-statistic was used to test for homogeneity of variance. The Sig. Value (.437) exceeded the alpha level (.05), so it can be concluded that the groups were equivalent in terms of achievement levels prior to the teaching intervention. This is noteworthy because it eliminates the possibility of having one group consist of above-average achieving students, which could bias the final results.

Once the researcher was able to show group equivalence at the beginning of the treatment, ANCOVA could be run. The mean score on the posttest for both groups is 18. This indicates that the average student answered 18/25 items correct (or 72%) on the posttest. The mean has increased from 14/25 and 15/25 for the two groups on the pretest. The ANCOVA reveals that there is a relation between the covariate (pretest) and the independent variable (posttest), $n = 33$, $K = 2$, and alpha = .05. With a critical value of 4.17 and the F value of 7.22 for the pretest, the null hypothesis is rejected and there is a relation between the covariate and independent variable. Further, regarding the ratio of the adjusted between-groups mean square to the adjusted within-groups mean square, the observed F value of .823 does not exceed the critical value of 4.17, hence the null hypothesis of no difference between the “adjusted” mean is not rejected. The conclusion is that the adjusted means do not differ, hence the two teaching strategies do not have different effects on student achievement.

Discussion

The literature is divided in the best approach to teach an online mathematics class. While many champion a constructivist-based approach (Chinnappan, 2006; Evans et al., 2008; Williamson, 2006; Zhou & Stahl, 2007), others support an objectivist model (Hodges, 2009). This study sought to determine if adult online mathematics students had higher achievement levels when taught under a constructivist model than those taught by an objectivist approach.

A limiting factor of the study was the small sample size of 35 students. With such a small sample size, one must be cautious in making generalizations from the findings. In order to increase generalizability, this study could be replicated with a larger sample size. The small sample, however, does not discount the findings, and the results of this study can be added to the existing bank of knowledge on the topic.

Russell's (2001) book *The No Significant Difference Phenomenon* indicates that the vast number of distance education studies have resulted in a "no significant difference" finding, where the majority of these studies have compared face-to-face instruction with instruction offered at a distance. Looking at the findings from another angle, Conger (2005) believes that a "not statistically significant" finding indicates that both elements are equivalent. In the case of this study, the results indicate that both teaching strategies are equivalent in terms of the resulting student achievement levels. This suggests that objectivist-based methods of instruction and constructivist-based methods both lead to equivalent levels of student achievement in mathematics.

One issue arose during the teaching intervention, that of “disappearing” students. The researcher encountered an issue of “disappearing” students in her research project, most notably with the constructivist-based group. The first problem began when she divided the students into groups. It is not uncommon in the online Math 009 course for students to withdraw during the first few weeks of class. This made establishing and maintaining groups difficult. The projects began during the second week of the term, further complicating the researcher’s desire to maintain groups. This issue continued throughout the semester, as at least one student “disappeared” from the class for an extended period of time. What may cause an adult learner in a distance learning setting to “disappear” from the course? What actions could be taken to prevent students from “disappearing” from the distance classroom? One approach is to keep in continual contact with students during the semester. When the student is identified as a name on a screen, it is sometimes difficult to remember that the name belongs to a person, likely an adult with family and career responsibilities. In addition to keeping track of students’ participation in the classroom, checking in may also reduce feelings of isolation and anxiety that Sadik and Reisman (2004) note as a common problem in mathematics classes delivered at a distance.

Conclusion

The purpose of this study was to examine the role of teaching strategy in the online mathematics classroom. Objectivist-based and constructivist-based teaching strategies were employed with two groups of Beginning Algebra students. ANCOVA was used to determine if there was a difference in achievement scores between the two groups. The results indicated that both teaching strategies are successful in the online mathematics classroom. In future studies, replication of this design with a larger sample size could add to the knowledge on this topic.

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