A Two Semester Observational Study of Teaching Practices and Interactions in Multi-Section Undergraduate Mathematics Courses

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This project was conducted as an attempt to answer the questions "are there teaching behaviors that exist in undergraduate core mathematics classrooms that correlate to better student performance?" and if so, "what are some of these behaviors and how can they be recorded?" Being able to record teaching behaviors that are influential in student performance can be used as the first step in finding a way to increase the implementation of such practices, thus improving student performance. This project focused on the identification of possible teaching behaviors that have an effect on student success; future work will focus on the recording and development of these practices. This paper reports on the correlation of specific teaching practices, suites of teaching practices and interactions in the classroom to student success. The data was gathered during two semesters of classroom observations of multi-section undergraduate mathematics courses at a large research university in the Southwestern United States.

Introduction

This study looks at specific teaching practices in undergraduate mathematics courses and whether they impact student success in an attempt to answer the question "Are there teaching behaviors that correlate to better student performance?" This report will describe findings from analysis of both qualitative and quantitative data collected through classroom observations of undergraduate mathematics courses over two semesters at a large research university. Classes observed were qualitatively categorized based on the overall amount of interactions present in the classroom. Detailed quantitative data on teaching practices, student actions and instructor-student interactions were also gathered using systematic classroom observation. All data were compared to student performance and to the performance of students in sections of the same courses that were not observed.

Background

Research has shown that what instructors believe should be done in a classroom and what they do may be inconsistent (Raymond, 1997; Cooney, 1985). Additionally, many instructors are not always aware of the nature of their interactions with individual students (Doyle, 1979). Classroom observation is one of the most fundamental ways we can collect data on actual instructional practices in a naturalistic setting.

Systematic classroom observation is a quantitative method of measuring classroom behaviors from direct observations of pre-specified behaviors (Medley, 1992). This system requires observers to assign the recorded events into previously defined categories. Much observational research in education tends to be more ethnographic in nature. However, systematic classroom observation is gaining in popularity in educational research (Waxman, Tharp, & Hilberg, 2004), in part because it yields more easily to quantitative analytical methods. Systematic observation is a well-known methodology used in the social sciences, and some of our most robust theories of human interaction come from this type of research (Bakeman & Gottman, 1986). While there is an extensive literature base regarding the use of systematic classroom observation in K-12 settings and more limited literature on its uses in higher education, the literature on its use in undergraduate mathematics classrooms is very limited.

Much of the research relating student achievement to teaching behaviors, known as process-product research, has been conducted in the venue of elementary classes. Researchers conducting these studies have been successful in identifying teaching behaviors that are associated with student achievement (Evertson, Emmer & Brophy, 1980; Fey, 1970; Good & Grouws, 1977). Research (at the elementary and secondary levels) indicates identifiable differences in 'effective' and 'ineffective' classrooms and schools (Teddlie, Kirby & Stringfield, 1989; Teddlie & Stringfield, 1993; Teddlie, Stringfield, Wimpelberg & Kirby, 1989; Waxman, Huang, Anderson & Weinstein, 1997). Much of the research in this area identifies classroom-level characteristics present in effective teaching. Some primary predictors of effective teaching include time on task, review of previous learning, and interactive teaching (Rosenshine, 1983; Stringfield & Teddlie, 1991; Teddlie, Kirby & Stringfield, 1989).

Conceptual Framework

As early as 1916, researchers recognized that education is a student-centered social process requiring a close relationship between teacher and student (Dewey, 1916). Communication in the classroom has especially gained momentum in mathematics education. Through communication, ideas become objects of reflection, refinement, discussion, and amendment (NCTM, 2000). Through in-class dialogue, misconceptions can be identified and addressed. By carefully listening to, and thinking about the claims made by others, students learn to become critical thinkers about mathematics (NCTM, 2000). Problem-solving behaviors and ways of thinking can be developed within classrooms that support reflective discourse (Cobb, Boufi, McClain & Whitenack, 1997). Students who are involved in classroom discussions in which they justify their solutions will gain a better mathematical understanding as they work to convince their peers about differing points of views (Hatano & Inagaki, 1991). An added benefit of classroom discourse is that it reminds students that they share responsibility with the teacher for the learning that occurs in the lesson (Silver, Kilpatrick & Schlesinger, 1990). The teacher's role in establishing the context for mathematical development is of particular importance in the success of building a discursive classroom.

Researchers have noted relationships between academic achievement and the discussion of academic material by group members such as giving and receiving explanations (Peterson, Swing, Stark & Waas, 1984; Webb, 1988). Also, students in schools classified as effective/efficient (efficiency classification measures the relative degree of efficiency with which the school has used it resources to improve test scores) were seen interacting with their instructors on average about 70% of the time, while students in ineffective/inefficient schools only interacted with their instructors on average approximately 47% of the time (Waxman, Huang, Anderson & Weinstein, 1997). The amount and quality of teacher/student academic interactions are two of the most important education variables that promote student outcomes (Wang, Haertel & Walberg, 1994).

Friedman and Stomper (1988) studied effective teaching of basic college mathematics and concluded that more effective instructors spent a large percentage of their class time involved in discourse with their students. They found that the effective mathematics instructors in their study used a more interrogative format in their class while ineffective instructors used a more declarative teaching style (Friedman & Stomper, 1988).The effective instructors in these classes, among other things, dominated the instructional process by initiating 94% of the pedagogical moves, whereas the less effective instructors determined the course of instruction only 78% of the time and the students in those classes initiated 22% of the pedagogical moves, though the exact definition of a ‘pedagogical move’ in this study is unclear. Shapiro & Levine (1999) also stated the importance of faculty-student interactions in success in college, though this was not specific to mathematics.

Methods

To investigate the effect of specific teaching practices on student success in undergraduate mathematics courses, data was collected over two semesters through classroom observation. Data collection took place during three unannounced visits to each classroom during the first semester, and only one unannounced visit the second semester. The participating instructors were 22 Graduate Teaching Assistants (GTAs) during the first semester, and 23 participants of various levels the second semester (10 GTAs, 10 Part-Time Instructors, 2 Lecturers and 1 Faculty member). The classes were all multi-section core classes where all sections take the same cumulative final exam. Each semester contained a mixture of College and Intermediate Algebra, Pre-calculus, Elements of Calculus I and II, and Introductory Statistics.

For the qualitative analysis, after three visits to each class, the classes were categorized as ‘highly interactive’, ‘minimally interactive’, or as having an ‘average’ amount of interactions. This categorization was based on the overall amount of discourse present in the classroom. In classes categorized as ‘highly interactive’, the students asked many questions and questioned statements made by the instructors or other students on a regular basis. The instructors asked many questions of the students regarding the academic material being taught and requested input from the students when solving problems, and usually got a response. However, if the instructor asked a question and got no response initially, he or she called on students by name (these instructors seemed to know the majority or all of their students by name fairly early in the semester) to elicit a response. If they saw a student off task, they would call on them by name to get their attention and to get them back on task. These instructors tended to at least attempt to involve their students in the learning process more by creating a more active classroom. The students in these sections spent more time working individually and in groups on assigned problems than did students in other sections.

In the classes categorized as 'minimally interactive', instructors maintained a classroom where there were very few interactions, and occasionally there were none. There were more students off task in these classes, and less effort by the instructors to get them back on task. Instructors tended to present materials and problems with very little input from the students. Students were generally not engaged in the material, and sometimes the instructor seemed unable to help students. Many of the instructors of these classes gave no corrective feedback during class, and the students rarely interrupted the instructor when he/she was working problems for clarification, though they did occasionally talk among themselves.

While these different categorizations of highly and minimally interactive were made based on many different behaviors observed and not observed in the classes, the amount of instructor-student interaction was the single most identifiable measurable difference between these classes. Classes that appeared to be average, where there were some instructor-student interactions, but not an overwhelming number, were categorized as 'average'. During the second semester, the same qualitative classifications were used, but after only one visit to each class. The majority of students taking these classes were in sections that were unobserved, and thus categorized as Unknown. This large group of students was assumed to perform ‘average’.

For the quantitative portion of the study, course observation protocols were used during classroom observations each semester. During the first semester, course coordinators used a trial observation protocol and time sampling to record approximately how much time instructors spent on previously defined instructional activities, what students spent time doing during class and how many verbal instructor-student interactions occurred during class. A total of eleven observation forms were used, based on observations of instructors teaching either College Algebra or Pre-Calculus. There were a total of 361 students in these classes. Instructional activities included items such as lecture, working examples, administering a quiz, etc. Student activities included listening to lecture, working problems in groups/individually, taking a quiz, etc.

During the second semester, the researcher recorded the actual amount of time spent on the same instructional and student activities in the classes with the aid of classroom observation software, as opposed to the approximations of the amount of time spent on each item gathered through time sampling. The researcher also recorded the number of interactions that occurred as well as the type of interaction, and whether it was student- or instructor-initiated.

All the detailed data, as well as the qualitative classification was analyzed using logisitic regression to determine the effect any of these variables would have on student success. A success was considered a grade of C or better in the class, since that is the grade required at that institution to advance to the next course. A grade lower than a C (including a C-), withdrawal from the course or an incomplete were considered unsuccessful.

Results

Qualitative Data

The results of the qualitative data the first semester were promising. Students in a class categorized as highly interactive were expected (by the researchers) to perform better than their peers in their math class. Those in a class considered minimally interactive were expected to perform poor compared to their peers. The results of the analysis supported these expectations. More specifically, the results indicate that with all other variables held constant, the odds of a student passing a math class in a section rated as High were 1.463 times that of a student in an unknown section. The odds of a student passing in a section rated as Low were 0.4927 that of a student in an unknown section. The odds of a student passing in a section ranked as average were virtually identical to a student in a section ranked unknown, i.e. 0.9551. The qualitative classifications of highly interactive and minimally interactive were significant predictors of whether a student in this analysis passed their math class or not. The following table shows the results from the logistic regression analysis, including the odds-ratio and its associated *p*-value.

Section Classification	**Odds-Ratios**	***p*-Value**
Highly Interactive	1.463	.039
Average	.9551	.8
Minimally Interactive	.4927	.000

Table 1 First Semester Qualitative Data Results

The results from analysis of the qualitative data gathered during the second semester were not as statistically significant. The same categorizations were made after only one visit to each classroom. The categorization of a class as highly interactive during the second semester was again statistically significant. These values indicate that with all other variables held constant, the odds of a student passing a math class in a section rated as High were 1.259 times that of a student in an unknown section. The predictions of students to perform Average and Low compared to other students were not statistically significant predictors of student success during this semester.

Section Classification	**Odds-Ratios**	***p*-Value**
Highly Interactive	1.259	0.067479
Average	.8681	0.123982
Minimally Interactive	.9015	0.492123

Table 2 Second Semester Qualitative Data Results

Quantitative Data

The items monitored by course coordinators during the first semester of this study that were determined to be significant predictors of student success were the amount of time the instructor spent working examples and the amounts of interactions, both instructor- and student-initiated. However, both instructor- and student-initiated interactions were only significant predictors of student success if the variable representing the proportion of class involved in classroom discussion is also considered in the model. This variable was rated using a likert scale of 1 to 5 with a 1 indicating no students were involved in the class discussion and a 5 indicating that most students were involved in the classroom discussion. When all three are included in the model, all three returned significant parameter estimates. The results from the analysis follow:

Variable	Estimate	Standard Error	Z-Value	P-Value
GPA	0.708002	0.182108	3.89	.000
Working Examples	-1.51718	0.547170	-2.77	.006
Proportion of Class Involved in Discussion	-1.40130	0.233577	-6.00	.000
Instructor-initiated Interactions	0.117748	0.0218048	5.40	.000
Student-initiated Interactions	-0.406280	0.0873173	-4.65	.000

Table 3 Coordinator Observation Analysis Results

During the second semester of this study, the researcher gathered detailed data regarding the amount of time spent on instructional activities, student activities, and a detailed count of interactions that occurred during the classes observed. Of all these items, the statistical model returned three types of interactions that were deemed to be significant predictors of student success. No teaching practices were deemed to be significant by the model. The interactions included student-initiated (SI) logistic interactions, and both instructor- (II) and student-initiated (SI) academic interactions requiring a mathematical explanation. These interactions had low *p*-values, suggesting that interactions with the instructor are indeed crucial to the success of an undergraduate student in these core courses. This finding is consistent with other studies of the general relationship between instructor-student interactions such as those by Friedman and Stomper (1988) and Shapiro and Levine (1999).

The interactions that were most indicative of student success in the current study included students initiating interactions with regards to logistics of the course. This category includes students asking questions about what material will be on an upcoming exam or quiz, when the next quiz will occur or homework assignment will be due, what page from the book the instructor is working off of, or what problems are due on the next homework assignment.

The second type of interaction that was determined to be significant was academic in nature and required a mathematical explanation. This includes questions such as an instructor asking students "Why is the second derivative positive here?", or "What does it mean if a system of equations can be solved by only a single point?" These questions require mathematical reasoning to answer. Another example of an interaction in this category would be a student asking the instructor to explain something that was just presented to the class in more detail. Many times this type of interaction, both student- and instructor-initiated, occurred after an instructor had asked for and received input on the next step of a solution.

The values of the parameter estimates returned from the logistic regression, the associated *p*-values and the significance levels follow.

Variables	Coefficients	Exponentiated Coefficients	P-Values	Significance Level
Logistic SI Interaction	0.090330	1.0945	0.03519	< .05
Academic, Explanation, II	0.041426	1.04229	0.03825	< .05
Academic, Explanation, SI	-0.090824	0.91318	0.06426	< .1

Table 4 Researchers Structured Observation Analysis Results

Conclusions

The qualitative description of a class as highly interactive in this study was statistically significant throughout both semesters. The classification of minimally interactive was significant when made after three observations to the class, but not significant when decided after only one visit to each class. The classification of having an average amount of interactions was not significant for either semester, suggesting students in those sections had statistically similar odds of passing their class as the students in the unobserved sections. Since the majority of sections were unobserved we should expect student success in these sections to be close to the overall average, which lends credence to the theory that the sections labeled “Average” were, indeed, average. Since none of the categorizations based on overall interactions in the class were as significant the second semester, this provides us with some information about how many observations must be performed to get an accurate picture of a classroom environment. The number/length of observations needed to describe teachers’ typical/consistent classroom behavior patterns are not well documented (Tollefson, Lee & Webber, 2001) and this is an area for future investigation.

While we cannot yet describe in complete detail the fundamental components of this ‘highly interactive’ style of teaching in minute detail, there are some behaviors and practices observed in those classes that appear to be influential in student performance. Instructors whose classes were categorized as highly interactive knew their students by name, interacted with them on a personal level and asked many more questions of them on the academic material than instructors whose sections were classified as minimally interactive. Students also asked more questions in these classes, both of the instructor and of each other. These instructors involved the students more in the classroom by having them work on problems during class, and occasionally having them present the work at the board. They worked on problems during class both individually and in groups more often than their counterparts in Average or Low sections.

Instructors whose sections were classified as minimally interactive spent the majority of their time presenting material to students, as opposed to having students work on material at their desks or at the board. There were very few interactions between the instructor and the students in these classes. There were occasionally classes with no verbal instructor-student interactions in them at all. Some instructors were not attentive to their students asking for help, or seemed unable to help them. These instructors tended not to ask for input from students when working at the board, and students were less likely to interrupt these instructors with questions than in sections classified as High.

In the limited previous research of undergraduate mathematics using systematic classroom observation to evaluate effective teaching, researchers found that the effective mathematics instructors used a more interrogative format in their class while ineffective instructors used a more declarative teaching style (Friedman & Stomper, 1988). These basic descriptions accurately portray what researchers in this study saw in the classroom as well. Many behaviors believed to be components of the 'highly interactive' teaching style were not found to be significant in the models. This suggests several changes in the data collection and/or the analysis. For example, instructors in highly interactive classroom clearly knew their students by name, but time spent taking roll was not deemed significant in the model.

For the quantitative data, the results from the coordinators observation forms serve as a support of the researchers' idea that interactions play an important role in the classroom. The results of this analysis are limited in that the observation protocol was newly revised and the course coordinators were not 'trained' to use it. Thus, the level of interobserver agreement is unknown. The number of instructor- and student-initiated interactions was significant only when considered with the overall proportion of students involved in the classroom discussion. It is unclear what each of the coordinator was measuring when looking at the proportion of students involved in the classroom discussion. It is possible they were measuring an 'average' proportion of students involved in each interaction with the instructor, or totaling up the proportion of students involved at the end of the class. Future work with this type of protocol would necessitate the training of observers.

For the analysis of the second semester of quantitative data, several specific types of interactions were deemed statistically significant predictors of student success.

One of these interactions is student-initiated logistic interactions, which were positively correlated with student success in the core classes observed. This might suggest that students in a section of one of these courses where there are at least some students that are more attentive to what is required and expected of them will perform better in the course than others in a section where none of the students are vocal during class about these details. Another possible explanation is that there are instructors who create classroom environments in which students are comfortable and motivated to ask these kinds of questions. That is, there could be combinations of both "classroom environment" factors and "instructor characteristics" that explain this finding. It would be important in future work to design studies that might describe these characteristics and tease apart the relative importance of and interactions between characteristics of the group vs. characteristics of the instructor.

The other interactions that turned out to be significant predictors of student success in this study were both instructor- and student-initiated interactions requiring a mathematical explanation. This type of interaction includes questions such as “why did you take the derivative here?” or “what do the critical points of a function represent when looking at the graph?” These questions require more than a simple yes or no answer. Both the instructor-initiated and student-initiated interactions in this category returned parameter estimates that were significant, although the former was positive and the latter was negative.

Previous research has shown a positive correlation between the proportion of questions asked that called for an explanation from students and student achievement (Evertson, Anderson, Anderson & Brophy, 1980). Other research on instructor-student interactions has shown that instructor-initiated questions that require students to draw conclusions rather than just recall data were found to be effective in soliciting responses from students (Atkinson, 1999). Since only interactions that received a verbal response were counted in this study, the significance of the instructor-initiated interactions in this category and the positive correlation associated with it are in agreement with these earlier findings.

Many times during these classroom observations, this type of interaction followed the interaction that represented an individual (usually the instructor) requesting the next step of a solution of a problem. So, either a student or the instructor would supply a step of a solution, and again either a student or the instructor would ask for an explanation of that step. Research has shown that teaching behaviors consistently correlated with student achievement gains include the instructor asking probing questions as follow up to initial questions (Rosenshine, 1971), and the finding from this study suggests support of this previous result. This result can be explored further with the use of sequential analysis, taking into account not just the types and amounts of interactions, but also the sequence in which they occur.

The results of this study were that instructor-initiated interactions of this type were positively correlated with student success, and that student-initiated interactions of this type were negatively correlated with student success. This data suggests that classes where instructors ask the students to explain the material more often may have higher success rates. This also suggests that success rates are lower in classes where students must ask for more clarification of the academic material. It could be that in these classes where students must ask for clarification that the explanations given by the instructor are not clear. Further investigations into this type of interaction could inform us of the characteristics of ‘clear explanations’ in mathematics, and the impact of clear explanations on student achievement.

This study has provided specific types of interactions and patterns of interactions whose impacts on student success can be further explored in the context of undergraduate mathematics classes. Two ways to do this in future work include sequential analysis and Hierarchical Linear Modeling. This study also informs us on the amount of time needed to get an accurate picture of an instructors’ typical classroom and adds to the very limited literature on systematic classroom observation in undergraduate mathematics courses.

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