Observation of Reform Teaching in Undergraduate Level Mathematics and Science Courses

by

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Abstract

This paper reports on initial results from an ongoing evaluation study of a National Science Foundation project to implement reform-oriented teaching practices in college science and mathematics courses. The purpose of this study was to determine what elements of reform teaching are being utilized by college faculty members teaching undergraduate science and mathematics courses, including a qualitative estimate of the frequency with which they are used. Participating instructors attended summer institutes that modeled reform-based practices and fostered reflection on current issues in science, mathematics, and technological literacy for K-16 teaching, with an explicit emphasis on the importance of creating the best possible learning experience for prospective K-12 science and mathematics teachers. Utilizing a unique classroom observation protocol (the Oregon-Teacher Observation Protocol) and interviews, the authors (a) conclude that some reform-oriented teaching strategies *are* evident in undergraduate mathematics and science instruction and (b) suggest areas in which additional support and feedback are needed in order for higher education faculty members to adopt reform-based instructional methodology.

Observation of Reform Teaching in Undergraduate Level Mathematics and Science Courses

This paper reports on initial results from an ongoing evaluation study of an National Science Foundation project to implement reform-oriented teaching practices in college science and mathematics courses. Participating instructors attended summer institutes and other professional development opportunities that modeled reform-based practices and fostered reflection on current issues in science, mathematics, and technological literacy for K-16 teaching. An explicit emphasis was placed on the importance of creating the best possible learning experience for prospective K-12 science and mathematics teachers. This study of college instructors is part of a larger evaluation study to examine the long-term effects of their teaching on early career science and mathematics teachers.

Background

In August 1997, the Oregon Collaborative for Excellence in the Preparation of Teachers (OCEPT) was funded for 5 years as part of the Collaborative for Excellence in Teacher Preparation (CETP) program of the National Science Foundation. A major focus of the OCEPT grant was to engage science and mathematics faculty members teaching undergraduate courses in institutions across the state in a critical examination of their instructional practices.

Weiss (2001) reported a discrepancy between the objectives high school science and mathematics teachers said they emphasize and the teaching strategies they reported using most often. Teachers reported, for example, that their objective was teaching students to reason mathematically or scientifically. However, their teaching strategies emphasized listening and taking notes, following instructions, and answering questions. Activities that helped students develop communication skills and practice reasoning — such as making presentations, writing reflections, and working on extended investigations — were used far less frequently. These data indicate that many secondary students are not being given the opportunity to learn through reform-based practices. In part this lack of students' experience with reform-based strategies may be due to the fact that their teachers have not had the opportunity to learn science and mathematics content through these practices. The oft-heard maxim "we tend to teach as we have been taught" (Judson and Sawada, 2001; Lortie, 1975) is supported by the experience and data synthesized in three reports (National Research Council, 1996a, 1999; NSF 1996) which suggest that the most common college mathematics and science instructional format is a lecture.

In order to enable all students to reach the goals set forth in the national standards for the sciences and mathematics (American Association for the Advancement of Science, 1989, 1993; NRC, 1996a, 1999; National Committee on Science Education Standards and Assessment, 1993; National Council of Teachers of Mathematics, 1989, 1991, 1995, 2000), the repertoire of instruction and assessment used in related college courses needs to be expanded.

The rationale of the NSF CETP program, in general, and the OCEPT project, in particular, was that prospective teachers who have firsthand experience in learning mathematics and science through reform-oriented strategies will (a) develop a stronger appreciation for the value of the coursework, and (b) use these models for more effective pedagogy when they begin their own teaching.

OCEPT hoped to engender systemic change in colleges and universities throughout Oregon by working with a critical mass of interested science and mathematics faculty fellows from 2- and 4-year public and private teacher preparation institutions and exposing these instructors to a variety of teaching and assessment methodologies. Stipends for release time for course reform and professional development opportunities were provided. Collaboration among these content faculty members, as well as with education faculty members, was encouraged by means of focus groups, electronic communication, and a combination of small group and large group meetings, which were often interdisciplinary in nature. The participating faculty fellows were also encouraged to become leaders in their own departments in order to help their colleagues engage in more reform-oriented teaching methods.

In the final year of the OCEPT project, an evaluation of the effectiveness of this work with college faculty was designed. The purpose of the evaluation was to examine what kinds of instructional strategies were being used in undergraduate mathematics and science classrooms. The evaluation would also assess what types of reform teaching strategies were being used by the student teachers who had taken courses from OCEPT faculty fellows. Did the student teachers feel their teaching was influenced by OCEPT faculty fellows and did the fellows feel their teaching was impacted by their participation in OCEPT activities? Did the observed teaching strategies of both groups reflect reform-based practices? Within these broad evaluation questions, several studies were designed. This current paper reports only on a study of the reform-oriented teaching practices used by college faculty members. A parallel study will report on the teaching practices observed among student teachers and beginning teachers who had taken undergraduate courses from the same faculty fellows (Morrell, Flick, and Wainwright, 2003; Morrell, Wainwright, and Flick, in press; Park, Flick, Morrell, and Wainwright, 2004; Wainwright, Flick, and Morrell, 2002; Wainwright, Morrell, and Flick, 2004). A third aspect of this project will attempt to correlate the strategies used by student teachers and beginning teachers with the strategies modeled in their undergraduate classes, as observed over a 3-year period.

Purpose

The purpose of this particular study is to determine what elements of reform teaching are being utilized by college faculty members teaching undergraduate science and mathematics courses, including a qualitative estimate of the frequency with which they are used. Through observation and interview, (a) methods were identified by which individual faculty members have been successful in incorporating reform teaching elements into their classes and (b) strategies are suggested ways for mathematics and science faculty members to improve their instruction using reform recommendations.

Sample

Although OCEPT was a statewide collaborative that included 34 higher education institutions, the focus of this study was narrowed to five targeted institutions. These core institutions were chosen because they had been consistently involved in OCEPT activities, had a large pool of OCEPT faculty fellows, and together produced a significantly large number of student teachers. They were also representative of the state's universities, including (a) both public and private institutions; (b) rural, suburban, and urban areas; (c) undergraduate and graduate teacher preparation programs; and (d) both teaching and research institutions.

For the set of studies in this research program, the selection of student teachers and faculty fellows as subjects were tightly linked. The goal was to study the teaching practices of faculty fellows who had taught student teachers completing their licensure programs. In order to identify these specific faculty members, the current student teacher cohorts were asked to indicate which faculty fellows had taught them courses. The student teachers who had at least two undergraduate courses from faculty fellows were selected for a separate study. The 12 faculty fellows identified by these student teachers became the subjects of this study.

Methodology

The research team was comprised of four science and/or mathematics education faculty members and three graduate students. In an attempt to select instruments that would be appropriate for this study, a subset of the research team reviewed the literature on observing reform teaching practices. Several CETP projects have studied ways to observe reform teaching in K-16 classrooms. Piburn, et al (2000), for example, working with the Arizona Collaborative for Excellence in the Preparation of Teachers, have made great strides in developing an observation protocol, the Reformed Teaching Observation Protocol (RTOP), that was critically evaluated by our research team. The NSF has sponsored work headed by Lawrenz, Huffman, Appeldoorn and Sun (2002) to develop a set of instruments that could be used by all the CETP projects; these tools were also reviewed extensively. Other projects such as Dana (2000) and Lederman and Schwartz (2001) designed approaches to measure the teaching of scientific inquiry. Professional organizations including the Horizon Research Corporation, Inc. (1999) have also developed observation instruments. All of the scholars working on this task have faced the same difficulty — trying to define exactly what observable behaviors illustrate reform teaching. Coming to an agreement about these behaviors and how these behaviors are exemplified in the field across different types of teaching contexts is not an easy task.

Reform advocates have stressed the need for significant improvement, not only in the translation of content into instruction, but also in positive student-teacher interactions

(NSF, 1996). It is our contention that observations of teachers and students *and* teacher-student interactions are paramount in order to achieve an understanding of the nature of instruction. As Good and Brophy (1997) have noted:

> Observers often try to reduce the complexity of classroom coding by focusing their attention exclusively on the teacher… but it is misplaced emphasis. The key to thorough classroom observation is student response. If students are actively engaged in worthwhile learning activities, it makes little difference whether the teacher is lecturing, using discovery techniques, or using small-group activities for independent study (p. 51)

In addition to the factors mentioned, an instrument that measures the essence of reform-based teaching also needs to be "user friendly" so that a reasonable level of reliability can be established across observers. After carefully examining the observation instruments previously described, we found that none fully met our needs. Some were tedious to use or focused only on the instructor's behaviors or did not produce sufficient reliability when applied by different observers.

Building primarily on the work of Piburn et al (2000) as well as Lawrenz et al (2002), we designed and piloted the OCEPT-Classroom Observation Protocol (O-TOP), found in Appendix A. This instrument captures what needs to be observed (both teacher and student behaviors) and does so in a way that is manageable (comprised of only 10 items), assuming a reasonable amount of training. We also designed an interview protocol (based directly on the O-TOP) as a follow-up instrument in order to validate the observational data and add an in-depth description of the instructor's perspective. (The development of these instruments is described in detail in Wainwright et al, 2003.)

All seven of the team members were associated with the five institutions represented in the study sample. We trained together to be consistent in our application of the observational protocol instrument. In addition, several of the initial observations were done in pairs to further assure reliability with the use of the O-TOP tool. Validation and reliability studies on the O-TOP are reported in a separate article (Wainwright,, 2003).

Faculty fellows were asked to supply the research team with dates and times of their classes. Most of the fellows simply provided their teaching schedules and gave the team unlimited access for classroom observations. This meant that observed lessons were delivered without the explicit expectation that they would be observed. Each fellow was observed teaching at least three class sessions. When possible, the classes were the same as those in which the student teachers had been previously enrolled. Global scan field notes were taken during each observation, and the O-TOP instrument was completed following each class. After the series of observations, the faculty members were individually interviewed using the interview protocol. Typically, the interviews lasted about 30 minutes. The interviews were audiotaped, and the tapes were later transcribed for analysis.

A total of 37 sets of observational field notes, 37 completed O-TOP instruments, and 12 interview transcripts were collected. Of the 12 faculty members, 6 were from science disciplines (18 observations) and 6 were from mathematics (19 observations).

One of the major tasks of this evaluation study was to characterize instruction in college science and mathematics classes. College classes varied dramatically from large lecture classes to smaller recitation sections and laboratory. Within each of these broad categories were significant variations in size and physical arrangement of the classrooms. It was clear from the outset that the O-TOP items, used reliably across observers to mean the same thing, would not produce a single rating or score. Instead the instrument would produce a profile of instruction that could produce a qualitative description of the instructional environment. Because context was a central factor for interpreting classroom observations, our method was driven by a research approach that recognized "qualitative inquiry elevates context as critical to understanding" (Patton, 2002, p. 63). For example, a rating on Item 3: Student Discourse and Collaboration, would not be expected to be as high in a large lecture format as compared to a recitation section, even when delivered by the same instructor.

As an organizer for the data analysis, we used the listing and definitions of types of instructions from Lawrenz et al. (2002, p. 12) to find the one main type of instruction that most closely matched the entire lesson for each of the classroom observations (Appendix B). This categorization was used to aggregate results into meaningful sets.

In order to analyze the large volume of data, the observers wrote a composite for each participant summarizing the field observations, the O-TOP instrument ratings, and a transcribed interview. The composites specifically included the following:

1. A table listing the faculty fellow's O-TOP rating for each item for each observation.
2. A graph displaying the three sets of O-TOP ratings for visual comparisons.
3. A description of the context for each observation:
    - Class type/methodology (e.g. lecture, lab, demonstration) based on Appendix B
    - Discipline (mathematics/science) and topic of the class session
    - Place in sequence of unit (e.g. introduction, ongoing, review) and/or relationship of observations (3 consecutive days, etc.)
    - Description of students and make up of the class (e.g., college majors)
    - Size of class
    - Public vs. private institution
    - Important constraints (e.g., room size, seating arrangement, equipment limitations)
4. A description of the observed behaviors that led to the O-TOP scores for each observation.
5. Patterns and interpretations of the total set of observations, based on context, O-TOP ratings, and interview data.
6. Additional pertinent comments/concerns not otherwise captured.

The faculty members on the research team then analyzed all the composite studies — referring to primary documents when necessary — to see if any patterns generalizeable to the whole were evident, as recommended by Bogdan and Biklen (1998).

Results

Unlike several other observation protocols (for example, MacIsaac and Falconer, 2002) that total the ratings to provide a single numerical score for each class session, the O-TOP is not used to rate any lesson with a single quantitative value. A single quantitative value ignores important contextual issues that can be used to inform collegiate instruction across different kinds of settings. The O-TOP generates a profile of instruction that is expected to look different for different types of classes. Since some aspects of reform teaching will be more evident in some modes of instruction than others (e.g., laboratory settings, group discussions, lectures, and small group sessions). The numerical values on the O-TOP instrument were treated as categorical rather than numerical data. This descriptive profile provides the richness necessary to address the stated research questions: What reform practices have been successfully incorporated into instruction and what does this descriptive data suggest for informing science and mathematics faculty members about how to make improvements to their instruction?

A summary of the focus of the ten O-TOP items follows.

Item	Focus of Individual Observation Items	Abbreviation
1.	Habits of Mind	Habits

2. Metacognition	Meta
3. Student Discourse and Collaboration	Disc.
4. Rigorously Challenged Ideas	Chall.
5. Student Misconceptions	Misc.
6. Conceptual Thinking	Conc.
7. Divergent Thinking	Diverg.
8. Interdisciplinary Connections	Inter.
9. Pedagogical Content Knowledge	PCK
10. Multiple Representations of Concepts	Mult.

To provide some ease in examining the data, we collapsed the five frequency categories into three:

1. Not Observed (N/O on the scale)
2. Infrequent (1 and 2 on the scale)
3. Frequent (3 and 4 on the scale)

The data are provided in Tables 3 - 5. Figures 1 – 4 show charts visually displaying the frequency of each item by content area: Science, Mathematics, and Mathematics for Elementary Teachers (MET). The following results summarize the data; differences are discussed only when the item frequencies differed by at least 20%.

Table 1

Frequency of O-TOP Items Observed During 18 Science Classroom Observations

O-TOP Items	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Habits	Meta	Disc.	Chall.	Misc.	Conc.	Diverg.	Inter.	PCK	Mult.
Not seen	0.22	0.00	0.50	0.17	0.06	0.00	0.06	0.00	0.00	0.06
Infrequent	0.28	0.67	0.06	0.50	0.33	0.44	0.50	0.22	0.00	0.22
Frequent	0.50	0.33	0.44	0.33	0.61	0.56	0.44	0.78	1.00	0.72

Table 2

Frequency of O-TOP Items Observed During 10 Mathematics Classroom Observations

O-TOP Items	1	2	3	4	5	6	7	8	9	10
	Habits	Meta	Disc.	Chall.	Misc.	Conc.	Diverg.	Inter.	PCK	Mult.
Not seen	0.00	0.00	0.30	0.20	0.20	0.00	0.00	0.30	0.00	0.00
Infrequent	0.40	0.30	0.00	0.10	0.10	0.40	0.40	0.50	0.20	0.60
Frequent	0.60	0.70	0.70	0.70	0.70	0.60	0.60	0.20	0.80	0.40

Table 3

Frequency of O-TOP Items Observed During 9 Mathematics for Elementary Teachers Classroom Observations

O-TOP Items	1	2	3	4	5	6	7	8	9	10
	Habits	Meta	Disc.	Chall.	Misc.	Conc.	Diverg.	Inter.	PCK	Mult.
Not seen	0.00	0.11	0.11	0.00	0.11	0.00	0.00	0.44	0.00	0.00
Infrequent	0.33	0.33	0.11	0.33	0.22	0.67	0.56	0.33	0.33	0.11
Frequent	0.67	0.56	0.78	0.67	0.67	0.33	0.44	0.22	0.67	0.89

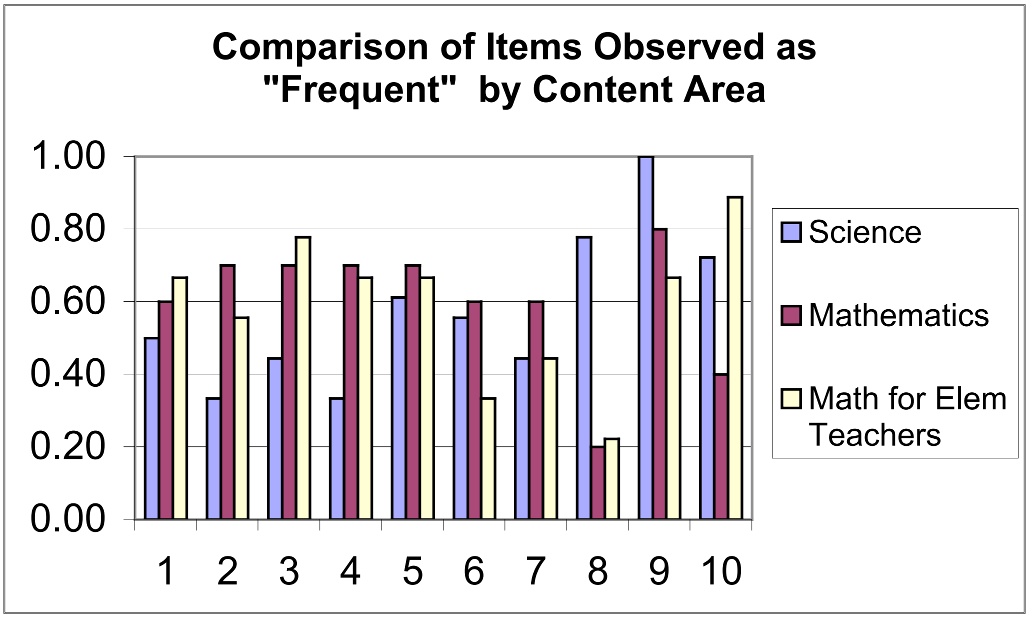
Differences were noted among the disciplines (see Figure 1). Science instruction (18 observations) tended to use different strategies from mathematics, and there were differences between traditional mathematics instruction (10 observations) and instruction in the MET classes (9 observations). Accordingly, these three areas were examined as separate groups.

- When compared to the mathematics classes, science classes more frequently exhibited use of #8-Interdisciplinary Connections, #9-Pedagogical Content Knowledge, and examples of #10-Multiple Representations of Concepts (Figure 1).
- When compared to the MET classes, science classes were noted for more frequent use of #8-Interdisciplinary Connections and #9-Pedagogical Content Knowledge.

- When compared to the science classes, the mathematics courses were noted as having more frequent use of #2-Metacognition Strategies, #3-Student Discourse and Collaboration, and #4-Rigorously Challenged Ideas.
- The Mathematics for Elementary Teachers classes had less frequent evidence of promoting #6-Conceptual Thinking than the traditional mathematics classes. The MET classes, however, did have more frequent use of #10-Multiple Representations of Concepts than traditional mathematics classes. Compared to science, the MET classes were more often typified by items #2, #3, and #4.

Figure 1

Comparisons of percentages of frequently seen items on O-TOP among the three content areas, Science, Mathematics, and Mathematics for Elementary Teachers



There were differences, as might be expected, among the types of instruction and the types of reform-oriented teaching strategies evident within those instructional modes (as identified in Appendix B). Science courses observed tended to be in a lecture format (13 of 18 observations); (see Figure 2). All lecturers, however, were described by the observers as skilled at keeping the students engaged in the lesson. The mathematics faculty members, by contrast, tended to rely on small group discussions more frequently to teach their content (Figure 3). Of the 10 mathematics observations, two were lecture, one was lecture with discussion, and the remaining seven were small group discussion. The MET classes were similar to mathematics classes in many respects; however, no true lectures were observed (Figure 4). Of the nine observations, two were lectures with discussion, one was class discussion, two were hands-on activities, and four were primarily teacher-student interaction sessions. All of the class observations were further analyzed to determine the frequencies of O-TOP items by course content and type of instruction.

- In science, the lecture classes (the primary mode of instruction observed in science) had the lowest frequencies of item #3-Student Discourse and Collaboration (Figure 2a), while the mathematics classes, which used small group work primarily, had frequent use of the same item (Figure 3a). In general, the O-TOP items, which represent elements of reform teaching, were observed far less frequently in the lecture setting than in other contexts.
- Within the three contexts observed in science, making use of #8-Interdisciplinary Connections was most frequently seen in the lecture format (Figure 2a). As a contrast, in the most prevalent context for both the traditional mathematics courses and in the MET courses, where little or no lecture was used, #8-Interdisciplinary Connections were infrequently observed or absent from the classes (see Figures 3a and 4a). In the two classes in mathematics given in a lecture format, #8-Interdisciplinary Connections was also absent (Figure 3b).

Figure 2

Series of graphs showing percentages of frequencies of O-TOP items in science classes by type of instruction

Figure 2a.

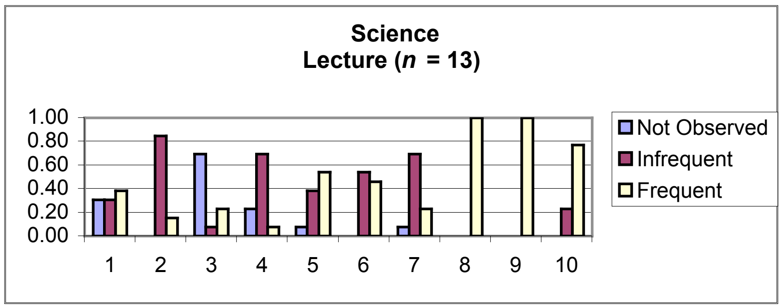


Figure 2b.

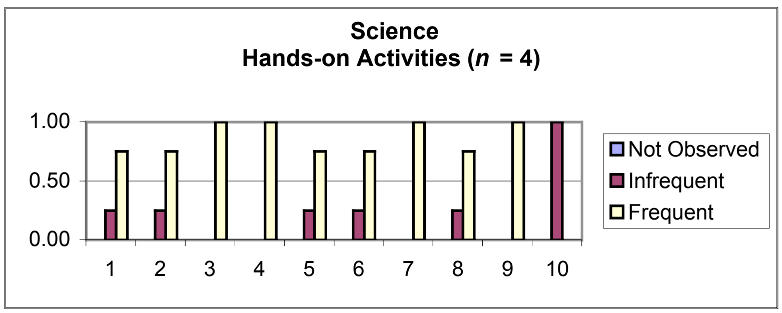


Figure 2c.

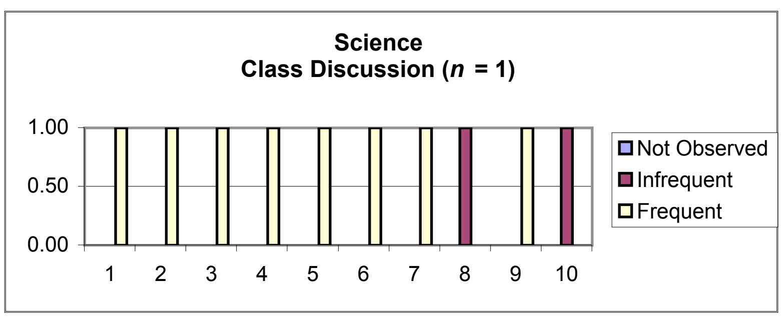


Figure 3

Series of graphs showing percentages of frequencies of O-TOP items in mathematics classes by type of instruction

Figure 3a.

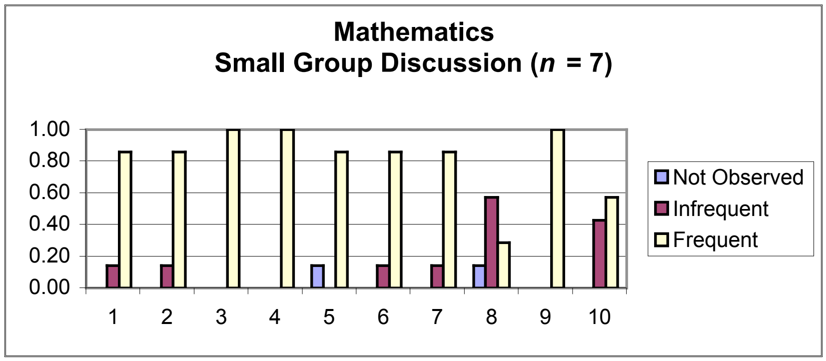


Figure 3b.

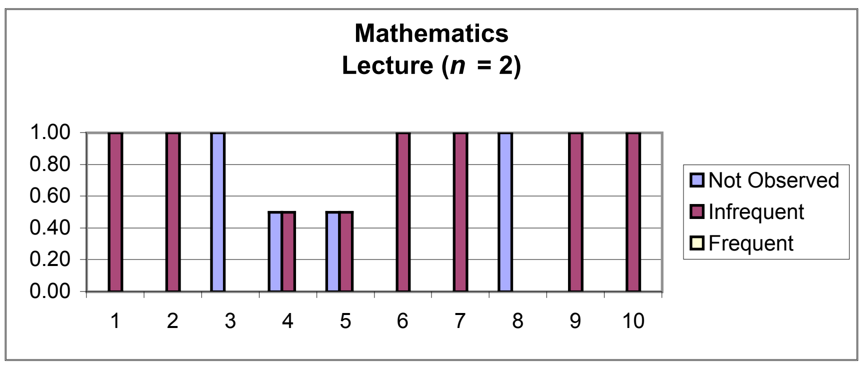


Figure 3c.

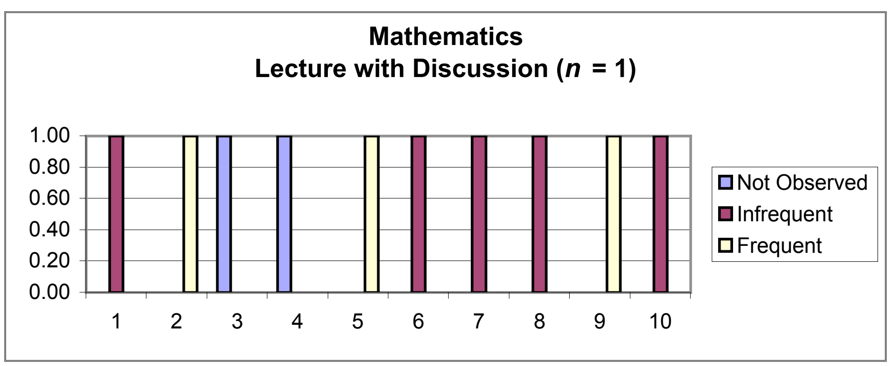


Figure 4

Series of graphs showing percentages of frequencies of O-TOP items in Mathematics for Elementary Teachers classes by type of instruction.

Figure 4a.

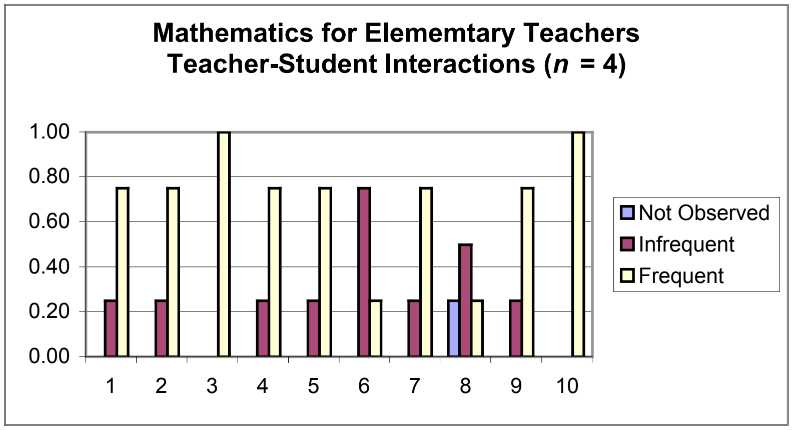


Figure 4b.

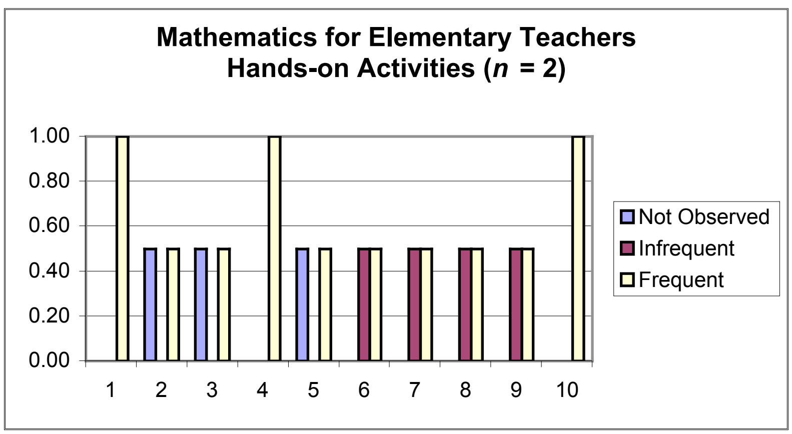


Figure 4c.

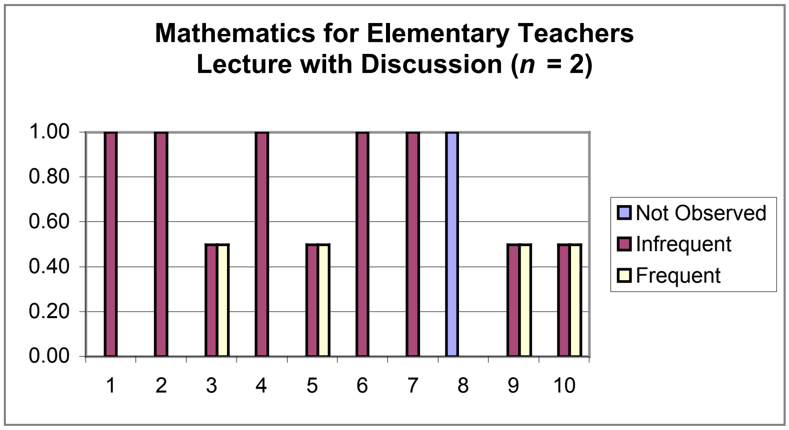
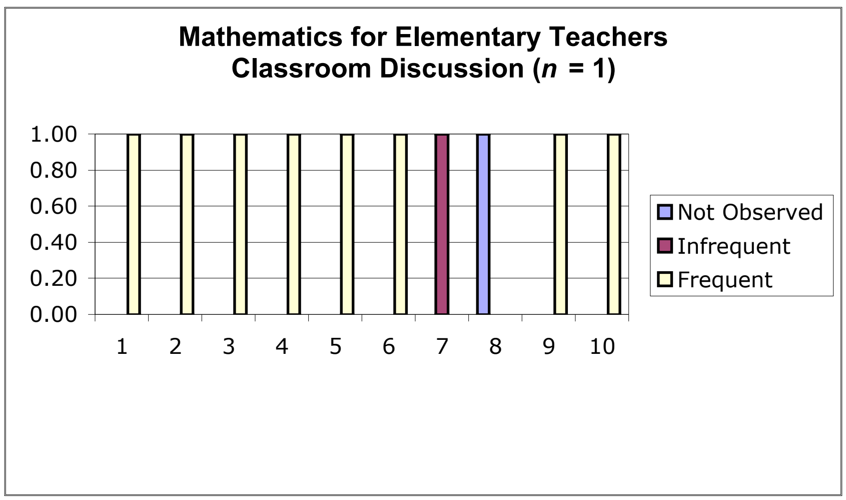


Figure 4d.



An interesting finding emerged from comparing the science lecture classes; the size of the class did not seem to determine the frequencies of reform teaching strategies observed. For example, the classes from the lecturer with 250 students exhibited more frequent use of more of the O-TOP items than did the classes from faculty members with 20 students or less.

During the interviews, several mathematics and science faculty members were vocal about the positives of being involved in OCEPT. Most of the fellows mentioned the networking that occurred with other faculty members as an important and significant component in their professional development. Several noted that the exposure to new teaching ideas was valuable, as was the availability of financial support while trying to implement instructional changes.

Conclusions

The results reported here are from only the first year of this longitudinal study. We will continue this research for 3 more years, observing some of the same faculty fellows while adding new faculty members to our sample, so we will be able to refine and expand upon these early, limited findings. What can be suggested from this initial study is that reform-oriented teaching strategies *are* evident in faculty fellows' science and mathematics courses. Some fellows are doing more reform teaching than others, but not all faculty members started at the same level of comfort with the varied strategies. Although there were not striking differences in the item means of faculty members from primarily research institutions and those that are primarily teaching colleges, the frequencies were higher on all items among the research institution faculty members. Nevertheless, faculty scores on items within the same institution varied widely; the extent of reform teaching one does appears to be an idiosyncratic characteristic.

Observed science classes used a variety of strategies to represent the subject matter. It was typical for science instructors to use a variety of materials with which to demonstrate concepts, in addition to the presentation of graphs, mathematical expressions, and verbal text presented on an overhead projector or written on the board. Instructors also integrated material with other curricular areas and with real-world settings. Perhaps as a result of these connections, science instructors seemed to make the content accessible to students and motivated them to ask questions. Instructors' responses tended to promote more student questions. Mathematics instructors were observed presenting rigorous and challenging content and, in the process, promoted student discourse. Students often collaborated in mathematics classes, shared points of view, and were encouraged to evaluate their own thinking.

Surprisingly, since MET courses are designed to strengthen preservice teachers' conceptual understanding of mathematics, this group of classes had less frequent evidence of promoting #6-Conceptual Thinking than did the traditional mathematics classes.

Given the inherent complexities of teaching, these differences in instructional strategies are likely due to more than one factor. For example, the symbol systems in science and mathematics overlap but there are individual characteristics. The format of the observed science classes was predominately lecture, which affords different instructional opportunities (e.g., allowing the instructor to point out curricular connections and make the presentation more coherent) than do more discussion-oriented formats, which lend themselves to student-student interaction and emphasis on student input.

Lectures are not necessarily ineffective. In this study, there were reform elements, such as making interdisciplinary connections, using multiple representations of concepts, and utilizing strong pedagogical content knowledge, that were more frequently characteristic of a lecture format than any other teaching modality.

Several reform teaching strategies can be identified that occur infrequently more than half the time. Our sample was limited in size and, therefore, we do not propose that this lack of reform elements is cause for concern for all college mathematics and science faculty members; however, this issue is a valid topic for self-reflection among educators.

For the science classes observed, the literature on reform teaching would encourage faculty members to incorporate more collaboration and student discourse into the lecture environments, and we have observed that some faculty members have found ways to do so successfully even in a large lecture hall. Other faculty members may need to be made aware of how this can be done. Science faculty members should also be encouraged to work on ways to incorporate the use of student metacognition into their instruction, to promote the challenging of ideas, and to encourage student discourse and collaboration. At the same time, the use of interdisciplinary connections was observed far more frequently in science classes than in mathematics or in MET classes. Perhaps there are more obvious interdisciplinary connections that can be made in science than in mathematics, or making those connections is a technique the science instructors were either more comfortable with or more aware of than were the mathematics faculty.

In mathematics, particular attention needs to be paid to the use of multiple representations to explain concepts. In addition, mathematics faculty members are encouraged to use interdisciplinary connections so students can see the importance and relevance of what they are learning. The faculty members teaching the MET courses are also encouraged to focus on interdisciplinary connections, as well as on development of conceptual thinking.

Implications for Future Research

This study has provided a profile of teaching within a small set of OCEPT faculty fellows. It has identified frequencies in the use of reform-oriented teaching strategies in college mathematics and science instruction. It has suggested areas in which additional support and feedback is needed to assist higher education faculty in adding these tools to their teaching repertoires. One area of future research then would be to determine the most effective techniques for expanding the set of pedagogical tools utilized by college content faculty in order for them to make use of reform strategies in greater frequency.

The instruments used in this study (particularly the O-TOP) can provide a common language for higher education faculty to use when discussing the structure and delivery of courses for prospective teachers (as well as other courses they teach). The demands of teaching for higher order outcomes, such as promoting understanding of scientific inquiry or problem solving, is resulting in an increased awareness of the value of instructors' interactions with students (NSF, 1996). The O-TOP instrument provides a starting point for reflection on one's instructional practice, as well as the behaviors of students in class as they interact with the instructor and with each other. Increasing faculty interest in reform teaching approaches for upgrading the content knowledge of future and practicing teachers holds the promise of promoting collaborative research efforts between science, mathematics, and education faculty members. It is a starting point for research in designing data-based feedback to professors and graduate teaching assistants for the improvement of instructional practice.

Examining the pedagogical techniques utilized by faculty members who are particularly successful with some particular strategies and observing and reporting on their implementation can prove useful in providing a model for others. For example, one of the OCEPT fellows is adept at using student collaboration and discourse within a large lecture setting. Other faculty members could certainly benefit from learning how this particular fellow is able to implement this strategy. Thus, a line of future research will result in case studies of this individual and other faculty fellows who incorporate frequent use of reform strategies in their instructional design and practice.

Finally, the original premise of OCEPT must be tested. If more reform teaching strategies are incorporated in undergraduate mathematics and science courses, will there be a trickle down effect? If college faculty members make their instructional design decisions explicit to their students, will prospective teachers in those classes be more likely to make use of the modeled reform strategies in their own professional K-12 careers? In tandem with this ongoing study of faculty fellows, we are investigating the reform strategies used by student teachers and beginning teachers through classroom observations and interviews. These findings will be analyzed in light of the practices observed in the undergraduate courses taken by these beginning teachers in order to shed light on the degree of impact faculty members have on their students' choice of instructional techniques.

Ultimately, what needs to be examined is whether school children will experience science and mathematics in a way that encourages them to see the value and joy of these content areas and help to promote the development of a mathematically and scientifically literate society.

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Appendix A

(See PDF file attached)

Appendix B
TYPE OF INSTRUCTION
(based on Lawrenz et al, 2002, p. 12)

L	Lecture/Presentation: Teacher talks almost all the time. If students participate verbally, their interaction is minimal with questions and responses that are either very short or obvious answers.
PM	Problem Modeling: Teacher demonstrating or modeling how to solve a new problem.
SP	Student Presentation: Student lecture, student demonstration
LWD	Lecture with Discussion: Teacher talks *most* of the time. This differs from lecture in that students participate by answering questions that generally require more than a one-word answer. This differs from class discussion in that there is almost no student-to-student communication.
D	Teacher Demonstration: Teacher shows how something works, or how to do something. This differs from Problem Modeling in that it involves the use of some type of equipment or materials.
CD	Class Discussion: Almost all student-to-student talk in full class setting, facilitated by instructor.
WW	Writing Work: Writing individually on worksheets, lab write-ups journal entries, or other writing assignments, or combined with SGD.
SGD	Small Group Discussion: Students (2 or more) engage in conversation with each other about subject matter in small groups.
HOA	Hands-on Activity: Students participate in an activity that involves manipulating materials. This is the typical type of instruction in most science laboratory work.
CL	Cooperative Learning: Structured SGD with individual roles, group accountability, and group processing.
LC	Learning Center/Station: Students working at various stations related to particular topics, generally with a different activity at each station. This may occur in elementary classrooms or in laboratory classes.
TIS	Teacher Interacting with Student(s): Teacher moving among individuals or groups of students and talking to them.
UT	Utilizing Digital Educational Media and/or Technology: Unique use of computers, calculators, videotapes, or other types of technology in which the use of technology is a key focus of the lesson.
A	Assessment: quiz, test, think aloud, problem set.
AD	Administrative tasks: Teacher and students take care of nonacademic business. E.g. taking attendance, collecting homework, etc.
OOC	Out-of-Class Experience: Field trips, interaction with other classrooms, concert, etc.
I	Interruption: e.g., visitor, unexpected announcements, fire drill, student disruption
OTH	Other: (describe)

Note: SGD, HOA, and TIS often occur together.