THE OCCURRENCE OF REFORM TEACHING PRACTICE IN UNDERGRADUATE MATHEMATICS AND SCIENCE CLASSES: THE STUDENTS' PERSPECTIVE

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Introduction

It is a widely accepted adage that teachers teach the way they were taught [1]. Lortie states that what pre-service teachers experience in classrooms has a strong impact on the pedagogical choices they make as they move into their own classrooms [2]. Thompson, focusing on mathematics teachers, concurs, believing that after years of receiving traditional instruction, it is very difficult for teachers to conceptualize teaching mathematics differently [3]. If we want mathematics and science to be taught in public schools in a more meaningful way, then pre-service teachers need to be exposed to the teaching of these areas in a more meaningful way.

Reform of both science and mathematics curricula and classroom practice has been a focus of many groups for over a decade. Related to science teaching, various initiatives present a common series of suggestions for reformed approaches in science teaching: Project 2061; Scope, Sequence, and Coordination of Secondary School Science of the National Science Teachers Association; the National Research Council; and, the National Committee on Science Education Standards and Assessment [4-8]. Similar work in mathematics has been generated by the National Council of Teachers of Mathematics and initiatives funded by the National Science Foundation [9-13]. Uniformly, the suggested approaches are more constructivist in nature and demonstrate a need for students to reflect on their own learning. Coble and Koballa outline recommendations for reform in order to improve teaching, stressing the areas of learning facilitator, assessor of learning, reflective practitioner, and pedagogical content knowledge expert [14].

Research has shown that pedagogical knowledge may be more important than pure content knowledge in being an effective mathematics or science teacher. This demonstrates the need to focus attention to Schulman's concept of pedagogical content knowledge in both mathematics and science education [15].

The Journal of Mathematics and Science: Collaborative Explorations Volume6 (2003) 153- 164

Helping pre-service teachers move in reform directions remains problematic. For reform to occur, students need to see improved teaching practices at all levels of their education, particularly during their college experiences. Some evidence is appearing that training of college level content faculty may have a positive impact on the instructional strategies selected by first year teachers coming from those programs [1].

In August 1997, the Oregon Collaborative for Excellence in the Preparation of Teachers (OCEPT) was funded for five years as part of the Collaborative for Excellence in Teacher Preparation (CETP) program of the National Science Foundation. The main goal of the program was to strengthen teacher preparation in science, mathematics, engineering, and technology. One major way OCEPT identified to achieve that goal was to engage faculty currently teaching undergraduate science and mathematics courses in a critical examination of their instructional practices. As the reform movement entered the consciousness of college-level instructors, OCEPT sought to assist the change of teaching methodologies. Through a variety of interventions, OCEPT hoped to encourage among these faculty members the use of particular kinds of instructional practices advocated by various state and national educational reform reports.

Purpose

The purposes of this study were two-fold: 1) to measure the degree to which pre-service teachers perceive reform classroom practices occurring in their undergraduate college mathematics and/or science courses; and, 2) to determine if there has been a shift in these perceptions over time (pre-1990 to the present).

Methodology

Instrument — To gather information about the mathematics and science backgrounds of students entering teacher preparation programs in Oregon, a survey was developed by a group of college math, science, and education faculty involved in the OCEPT program. A portion of that instrument was designed to measure students' perceptions of the instructional strategies they experienced in undergraduate science and mathematics classrooms.

The Classroom Experience section consists of twelve items that describe reform teaching and assessment practices (see Appendix A). The items were designed based on the national mathematics and science standards for teaching, instruments used by other CETP projects, and an instrument developed by the American Association for the Advancement of Science Project 2061 [5,7,9-11,16]. Students were asked to indicate how frequently they experienced each of the items in their undergraduate mathematics and science classes using a rating of 1 (not at all) to 5 (often).

The instrument was piloted across the state of Oregon (n=330) in 1997. After the initial administration, some questions were reworded for greater clarity. Content validity of the instrument was determined by a panel of college mathematics, science, and education faculty familiar with national and state mathematics and science reform efforts. A factor analysis on the items demonstrated a high degree of correlation among eleven of the twelve items, indicating a single factor represents approximately 50% of the variance among the items. The only item not correlated with the rest is "used computer technology in ways that enhanced my ability to learn." This is the sole item of the twelve that is dependent on outside resources (e.g., equipment), which may influence if and how frequently this classroom experience is used. To gain some measure of reliability, a group of eighteen post-baccalaureate, pre-service students were given the survey twice over the course of a month. Paired t-tests showed no significant differences in the students' responses [17].

Besides the twelve classroom experience statements, additional items were included on the survey instrument for the students to indicate in what time period they completed the majority of their mathematics and science undergraduate course work. The choices were: before 1990, between 1990 and 1994, and between 1995 and the present. These time divisions were chosen to represent the periods prior to the push for the current mathematics and science teaching reforms, the initial widespread dissemination of the NCTM, NRC, and AAAS guidelines for reform, and closer to the inception of the OCEPT project.

<u>Sample</u> — There are sixteen institutions of higher education in Oregon which have teacher preparation programs. In Fall 1998, 1999, 2000, and 2001, copies of the questionnaire, instructions for administration, and informed consent forms were sent to all sixteen institutions. Faculty members were asked to administer the survey to all students admitted to teacher education programs between June and December of the corresponding year; that is, undergraduate seniors and post-baccalaureates. Over the course of the four years of administration, 2,141 surveys were collected. Because not all institutions participated in the

survey administration, we do not have the data needed to determine what proportion of the total population is represented in our findings. Sampling data are presented in Table 1.

Table 1

Number of Completed Student Questionnaires and Number of Institutions Responding to the Survey for Each of the Four Years of Administration

Year	Number of Student Responses	Number of Participating Institutions
1998	503	14
1999	624	13
2000	421	11
2001	593	12

Analysis — The data from all surveys were analyzed using *StatView*. Means and standard deviations were calculated for each item, by content area and by time period. Analysis of variance was run for the aggregate data for each item, using the item rating as the dependent variable and the time block the courses were taken as the independent variable. A Scheffe post-hoc analysis was performed when indicated.

Mathematics Results

The means and standard deviations of the student responses to twelve items concerning their perceived experiences in mathematics classrooms are listed in Table 2. The data are reported by the time period block that students completed the majority of their mathematics coursework. Also indicated on the table are the time periods for each item that had significant differences between the reported perceptions. Table 3 shows the corresponding data concerning science classroom experiences.

Table 2

Means and Standard Deviations and Results of ANOVA Analyses for each Item Indicating Students' Perceptions of Mathematics Classroom Experiences (Rating Scale of 1 "not at all" to 5 "often")

Item	Pre-1990 Mean (SD) N=280	1990-1994 Mean (SD) N=337	Post-1994 Mean (SD) N=1,408	Significant Differences ($p<.0001$)
Encouraged me to work on problems and projects with others	2.1 (1.2)	2.7(1.3)	3.5 (1.3)	1,2 2,3 1,3
Used a variety of approaches to help me and other students learn (group work, lecture, field-based work, hands-on labs, demonstrations, etc.)	2.1 (1.2)	2.5 (1.2)	3.3 (1.3)	1,2 2,3 1,3
Provided a variety of ways for me to demonstrate what I learned	1.9 (1.1)	2.2 (1.2)	2.9 (1.3)	1,3 2,3
Helped me to make connections between the course material and the "real world"	2.2 (1.2)	2.4 (1.2)	3.2 (1.2)	1,3 2,3
Provided frequent feedback on my work that helped me improve my learning	2.6 (1.2)	2.7 (1.3)	3.4 (1.2)	1,3 2,3
Made learning goals very clear	3.1 (1.3)	3.2 (1.2)	3.7 (1.1)	1,3 2,3
Emphasized my understanding of "big ideas" or concepts rather than isolated facts and information	2.4 (1.2)	2.7 (1.2)	3.3 (1.2)	1,3 2,3
Expressed the belief that I could learn and be successful in their classes	2.7 (1.2)	2.9 (1.3)	3.6 (1.2)	1,3 2,3
Provided opportunities for me to "be" a mathematician (posing my own questions, investigating problems, analyzing data, developing theories)	1.9 (1.1)	2.1 (1.2)	2.9 (1.3)	1,3 2,3
Used computer technology in ways that enhanced my Ability to learn	1.5 (1.0)	1.8 (1.1)	2.3 (1.3)	1,3 2,3
Required me to reflect on my learning through writing, journaling, etc.	1.3 (0.9)	1.4 (0.9)	2.2 (1.4)	1,3 2,3
Shared with the class their reasons for choosing their teaching strategies	1.5 (1.0)	1.7 (1.1)	2.4 (1.4)	1,3 2,3

Table 3
Means and Standard Deviations and Results of ANOVA Analyses for each Item Indicating Students' Perceptions of Science Classroom Experiences (Rating Scale of 1 "not at all" to 5 "often")

Item	Pre-1990 Mean (SD) N=280	1990-1994 Mean (SD) N=337	Post-1994 Mean (SD) N=1,408	Significant Differences (p<.0001)
Encouraged me to work on problems and projects with others	2.9 (1.3)	3.4 (1.3)	3.6 (1.1)	1,2 2,3 1,3
Used a variety of approaches to help me and other students learn (group work, lecture, field-based work, hands-on labs, demonstrations, etc.)	3.0 (1.2)	3.4 (1.2)	3.7 (1.6)	1,2 2,3 1,3
Provided a variety of ways for me to demonstrate what I learned	2.4 (1.2)	2.8 (1.2)	3.0 (1.1)	1,2 2,3 1,3
Helped me to make connections between the course material and the "real world"	3.0 (1.2)	3.4 (1.2)	3.6 (1.5)	1,2 1,3
Provided frequent feedback on my work that helped me improve my learning	2.7 (1.2)	2.9 (1.2)	3.2 (1.2)	2,3 1,3
Made learning goals very clear	3.2 (1.2)	3.4 (1.0)	3.6 (1.0)	2,3 1,3
Emphasized my understanding of "big ideas" or concepts rather than isolated facts and information	2.9 (1.2)	3.2 (1.1)	3.4 (1.1)	1,2 2,3 1,3
Expressed the belief that I could learn and be successful in their classes	2.9 (1.3)	3.1 (1.2)	3.5 (1.6)	2,3 1,3
Provided opportunities for me to "be" a mathematician (posing my own questions, investigating problems, analyzing data, developing theories)	2.5 (1.2)	2.9 (1.3)	3.2 (1.3)	1,2 2,3 1,3
Used computer technology in ways that enhanced my Ability to learn	1.6 (1.0)	2.0 (1.2)	2.5 (1.3)	1,2 2,3 1,3
Required me to reflect on my learning through writing, journaling, etc.	1.7 (1.0)	1.9 (1.2)	2.2 (1.3)	2,3 1,3
Shared with the class their reasons for choosing their teaching strategies	1.6 (0.9)	1.8 (1.0)	2.2 (1.3)	2,3 1,3

Students tended to keep their ratings in the middle of the 1-5 scale. No items had a mean rating of 4 or above; several items were rated below 2. Three items were rated consistently as the lowest, and these were the same for both the mathematics and science classrooms; namely, use of computers to enhance learning, reflecting on one's learning, and sharing reasons for choosing teaching strategies. The frequency of occurrence, as perceived by the students, increased significantly from prior to 1990 to 1995 and the present ($p<.001$) for each of the items in both content area classrooms.

Discussion

Looking at the comparisons between time periods, most striking is that science and mathematics instruction is perceived by students to be significantly more in alignment with new standards of teaching than it was just seven years ago. The differences are even more pronounced with a comparison of perceived instruction of twelve or more years in the past. Considering the conservative nature of change in education, this represents an encouraging trend.

Several items were rated at 3.5 or higher in the most recent time block. Three were common to both content area classrooms. All students felt that mathematics and science instructors had clear learning goals and felt they could be successful in the classes. Additionally, group work was a frequently used strategy. In science classrooms, students additionally felt the instructors used a variety of instructional approaches and helped to make the course content relevant.

Less encouraging is the number of items in the most recent time category with means at or below the midpoint of the response scale (2.5). In both mathematics and science, these practices are: "used computer technology in ways that enhanced my ability to learn," "required me to reflect on my learning through writing," and "shared with the class their reasons for choosing their teaching strategies." Mathematics had two additional items: "provided a variety of ways for me to demonstrate what I learned" and "provided opportunities for me to be a mathematician."

The item on technology may reflect a number of issues. The availability of technology in science and mathematics classrooms is not uniform in the institutions participating in the study. Low scores may reflect that the technology simply was not available. Alternatively, the question was worded to begin to address technology as a generative learning tool, and respondents may have been unable to imagine the technology they did use as enhancing their ability to learn [18].

Apparently, using written reflection is one of the strategies least likely to have made its way into college level math and science courses as an instructional tool. As noted above, in all classes group work was used frequently. By its nature, discussion among peers often requires revisiting learning, and collaboration may be providing experience for this kind of reflection. College faculty may not be familiar with journaling, may not have experienced it first-hand, and/or may feel it is an unnecessary time burden for themselves and/or their students. A substantial literature base now identifies reflection as necessary in knowledge construction. We need to determine whether it is truly being omitted in these college level courses or whether it is just not required in a formal manner.

Sharing reasons for choosing teaching strategies is the only item that represents a need related to the discipline of education. All the other items are effective strategies to enhance learning in the fields of math and science—and most others. Openly articulating instructional reasoning is necessary to help students move toward enhanced teaching rather than enhanced abilities within math or science. Because most content courses are not geared just to pre-service teachers, and because most instructors (those in teacher education included) are not in the habit of vocalizing their thinking processes about planning and executing a lesson, it is understandable that the scores for this item do not indicate frequent use.

Particular to mathematics classrooms, students felt they infrequently experienced a variety of assessment techniques. Traditionally, mathematical assessments have consisted of solving closed problems, where one applies the correct algorithm(s) to arrive at the correct answer. Broadening mathematical thinking to include conceptual understanding necessitates a broadening of assessment techniques. It may be possible that college level instructors do not yet feel comfortable designing alternative assessment tools and/or do not have a variety of these tools readily available for their use.

Another item rated as experienced infrequently in mathematics classrooms is being provided with the opportunity to be a mathematician. Again, this is not surprising as most people have no concept of what a mathematician is or what a mathematician does.

Conclusions and Implications

The data collected indicate that undergraduate instruction in mathematics and science classes is moving toward the models recommended by the teaching reform movement. Basic teaching principles, such as providing clear learning goals and helping students feel they can be successful, are being implemented with more regularity. Group work is frequently being used in the classroom. Some areas are still weak (e.g., written reflection), but all reform-based teaching practices are being utilized more often than they have been in the past.

Although there is no direct evidence to connect this positive trend to the efforts of the OCEPT project, it would appear that the types of interventions used by OCEPT should continue. College-level instructors need an organized way to be introduced to a variety of teaching and assessment methodologies. Collaboration and coordination among mathematics and science faculty and education faculty need to be encouraged and facilitated. Many instructors have already tried a variety of presentation and assessment strategies, and dialogue needs to occur as to what works, what has not, and to brainstorm future endeavors. College faculty need to be made aware of national, state, and local standards and be introduced to resources that are available to assist them in strengthening their instruction. They need to know (beyond the scope of their course evaluations) what students perceive as encouraging and impeding their learning. In addition, they also need to realize that non-majors and majors alike may eventually become our future teaching force.

There are several major limitations to this study that must be considered. The first is that not all institutions of teacher preparation participated in this study and data are not available to calculate a response rate. We made the assumption that the sample is representative of the population. Another concern is we are relying on students' memories to describe their content classes' classroom experiences. The time lapse between when they completed the coursework and when they completed the questionnaire may certainly have affected the ratings. Also, the students are giving one rating for all mathematics or science classes. It is hard to give one rating to a number of classes, and those most recent classes or classes with strong memories may have influenced the final score. Finally, as is the case with many Likert-type scales, the ends are defined, but the middle rankings are more nebulous. It is unlikely that all students viewed a score of 2, for example, in the same manner.

If we accept the premise that we teach as we have been taught, it is reasonable to assume that as we implement reform in college level mathematics and science classes, these changes will begin to be implemented in the lower grades, as well. Two questions are raised by this research. How accurate are the students' perceptions of the classroom experiences in their college courses, and will changing college level teaching actually affect how pre-service teachers will teach once they are in their own classrooms? The answers to these questions will help to focus where efforts should be most effectively directed in promoting science and mathematics literacy for all.

Acknowledgments

The writing of this paper was supported by WRITE ON! a writing retreat facilitated by the Oregon Collaborative for Excellence in the Preparation of Teachers (OCEPT), and funded by National Science Foundation grant DUE-9653250. ■

References

[1] E. Judson and D. Sawada, Tracking Transfer of Reform Methodology from Science and Math College Courses to the Teaching Style of Beginning Teachers of Grades 5-12, Arizona Collaborative for Excellence in the Preparation of Teachers, ERIC ED 445208 (2001).

[2] D. Lortie, Schoolteacher, University of Chicago Press, Chicago, IL, 1975.

[3] A.G. Thompson, "Teachers' Beliefs and Conceptions: A Synthesis of Research," in D.A. Grouws (ed.), Handbook of Research on Mathematics Teaching and Learning, Macmillan Publishing Co., New York, 1992.

[4] Science for All Americans, American Association for the Advancement of Science, Washington, DC, 1989.

[5] Benchmarks for Science Literacy, American Association for the Advancement of Science: Project 2061, Oxford University Press, New York, 1993.

[6] B.G. Aldridge, "Essential Changes in Secondary School Science: Scope, Sequence, and Coordination," NSTA Reports, (Jan/Feb 1989) 4-5.

[7] National Science Education Standards, National Research Council, Washington, DC, 1996.

[8] National Science Education Standards: An Enhanced Sampler, National Committee on Science Education Standards and Assessment, National Research Council, Washington, DC, 1993.

[9] Curriculum and Evaluation Standards for School Mathematics, National Council of Teachers of Mathematics, Reston, VA, 1989.

[10] Professional Standards for Teaching Mathematics, National Council of Teachers of Mathematics, Reston, VA, 1991.

[11] Assessment Standards for School Mathematics, National Council of Teachers of Mathematics, Reston, VA, 1995.

[12] Principles and Standards for School Mathematics, National Council of Teachers of Mathematics, Reston, VA, 2000.

[13] D.A. Grouws, and K.A. Schultz, "Mathematics Teacher Education," in J. Sikula, T.J. Buttery, and E. Guyton (eds.), Handbook of Research on Teacher Education, Macmillan Publishing Co., New York, NY, 1996.

[14] C.R. Coble and T.R. Koballa, Jr., "Science Education," in J. Sikula, T.J. Buttery, and E. Guyton (eds.), Handbook of Research on Teacher Education, Macmillan Publishing Co., New York, NY, 1996.

[15] L.S. Schulman, "Knowledge and Teaching: Foundations of the New Reform," Harvard Educational Review, **57**(1) (1987) 1-22.

[16] Rocky Mountain Teacher Education Collaborative (RMTEC) website, 1996, Internet: http://www.rmtec.org

[17] P.D. Morrell, M. Kinnick, and R. Webb, "Who Will be Teaching Mathematics and Science: A Profile of Pre-Service Teachers in Oregon," Oregon Collaborative for Excellence in the Preparation of Teachers, 1998, Internet: http://www.mth.pdx.edu/OCEPT/

[18] R. Osborne and M.C. Wittrock, "Learning Science: A Generative Process," Science Education, **67** (1983) 489-508.

Appendix A
Items Found on Survey Relating to Classroom Experiences

Encouraged me to work on problems and projects with others

Used a variety of approaches to help me and other students learn (group work, lecture, field-based work, hands-on labs, demonstrations, etc.)

Provided a variety of ways for me to demonstrate what I learned

Helped me to make connections between the course material and the "real world"

Provided frequent feedback on my work that helped me improve my learning

Made learning goals very clear

Emphasized my understanding of "big ideas" or concepts rather than isolated facts and information

Expressed the belief that I could learn and be successful in their classes

Provided opportunities for me to "be" a mathematician (posing my own questions, investigating problems, analyzing data, developing theories)

Used computer technology in ways that enhanced my
ability to learn
Required me to reflect on my learning through writing, journaling, etc.

Shared with the class their reasons for choosing their teaching strategies