Developing an Inquiry-Based Physical Science Course For Preservice Elementary Teachers

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Abstract. Preservice elementary teachers should experience science through inquiry in order to be effective in teaching science. In addition, inquiry as a mode of teaching is mandated by Kansas and National Science Education Standards. As a result of the No Child Left Behind Act, teachers also need to be prepared to include basic skills in reading and mathematics in all instruction. To address these issues, Fort Hays State University (FHSU) is adapting and extending the NSF-developed teacher enhancement materials *Operation Primary Physical Science* (OPPS) for use in a physical science course for preservice elementary teachers. This paper presents main features of OPPS, describes advantages of using it as a template in developing desired course material and discusses results collected with students enrolled in the adapted course during 2004/2005 academic year.

Keywords: Teacher training; Physical science; Teaching through inquiry; Course material development
PACS: 01.40.Àd Education; 01.40.Di Course design and evaluation; 01.40.Jp Teacher training;

INTRODUCTION

Experience at Fort Hays State University (FHSU) [1] and elsewhere indicates preservice elementary teachers are not adequately prepared to teach science as an inquiry process and to integrate basic skills in reading and mathematics in all instruction as mandated by the *National Science Education Standards* [2] and the No Child Left Behind Act. Most learning by preservice teachers in general education coursework, such as physical science, occurs through lecture while research has shown that few students learn best in lecture-format classes. [3] Although direct instruction has its place in effective learning [4], extensive research supports hands-on, activity-based learning while preparing teachers to teach science and encourages breaking from the lecture format as the sole means of science instruction. [5-7] Research suggests incorporating group work [8], implementing the learning cycle model [9], incorporating graphic organizers, and using activity-based lessons. Teachers who experience hands-on learning are more inclined to incorporate these strategies in their own classrooms on a regular basis. [10] Based on these findings, a physical science course targeted primarily for preservice K-8 teachers at FHSU was taught using the workshop format tested and developed for *Operation Primary Physical Science* (OPPS), an NSF-funded effort.

GOALS AND RESEARCH QUESTIONS

The overarching goal of this project was to improve preparation of prospective K-8 teachers with respect to content and process knowledge of the physical sciences, as well as pedagogical content knowledge related to teaching science. A missing component identified for achievement of this goal was preservice teachers' lack of experience with exemplary content/pedagogical models starting with foundation courses. Therefore the key college science course for prospective K-8 teachers (Physical Science) was modified to utilize teaching strategies that have been shown successful in learning science at the elementary level. For this purpose *Operation Primary Physical Science* (OPPS) [11], an exemplary teacher enhancement project [12], was adapted and extended. This material was developed at Louisana State University under the leadership of Gayle Kirwin. OPPS is closely aligned with the National Science Education Standards and consists of nearly a dozen modules. Modules are organized by topics and content is concentrated on real-world situations as authentic

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learning contexts. The OPPS utilizes a five-step variation of learning cycle model [9] with the following elements:

Elicit - identify students' prior knowledge,
Explore – allow for and provide experiences to challenge their prior knowledge and mentally prepare them to learn new material,
Inquire - expand student knowledge with directed and self-directed investigations,
Reflect - reach closure on what has been learned, and
Assess - determine if students have acquired mastery of the concepts being studied.

Through these steps, the model uses and promotes cooperative learning and peer instruction.

Two main research questions during the course implementation were (1) whether students learn content in this modified course and (2) what are their attitudes toward the modified teaching setting.

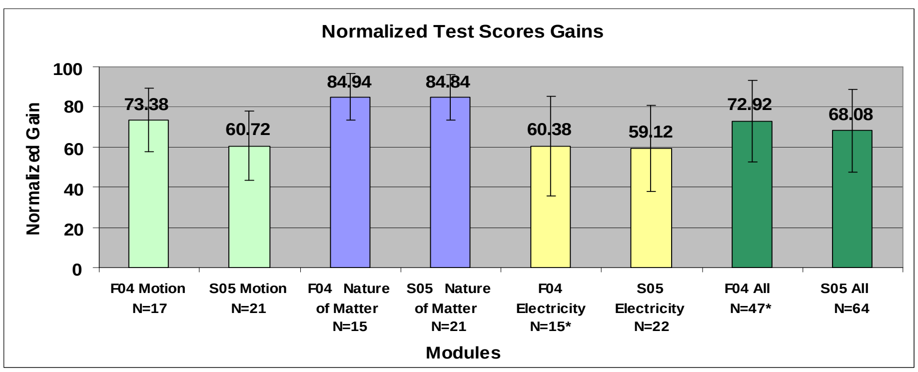
METHODOLOGY

After adaptation, selection, and refinement of OPPS materials in summer of 2004, the modified Physical Science course was offered during Fall 2004 (F04) and Spring 2005 (S05). Based on results and experience in this deployment phase, materials are currently being modified into their final form to be tested during Fall 2005. Achievement of project goals was monitored and assessed through content knowledge gains to address research question 1. To address research question 2 related to student attitudes, several instruments were used: focus group interviews for their general impressions, the CLASS survey [13] for their attitudes about learning science and the CLES survey [14] about constructivist learning environment. The same instructor was teaching the modified course in both semesters (F04 and S05).

FINDINGS AND DISCUSSION

Pre- and Post- Instruction Testing

Learning gains in content knowledge were measured for each module through pre- and post-instruction tests earlier developed by authors of OPPS. These tests target conceptual knowledge and simple experimental design ability. Normalized gain is the percentage gain achieved divided by the total possible percentage gain or: Normalized Gain = (post-test% - pre-test%) / (100% - pre-test%). Hake [3] argues that a normalized gain is an accurate measure of the effectiveness (or non-effectiveness) of a particular presentation style. Learning gains are shown in Figure 1 (where N represents number of students).



* One outlying data point eliminated

FIGURE 1. Normalized Content Knowledge Gain Scores for Modules and Semesters.

All pre-post gains in test scores shown in Figure 1. are significant at the .01 level on a two–tailed t-test. In Figure 1, an outlier was eliminated from one module but gains are significant at the same level even with this data point included. This outlier was removed because it gives a false impression of the gain and the St. Dev. associated with the respective module.

Focus Group Interviews

Focus group interviews were conducted at the middle and end of each semester. Results varied between these points in that students' comments were more positive at the end of the both semesters than in the middle. A difference also existed between the two semesters; F04 was more positive than S05. Students in both semesters spoke positively about the class methodology, opportunities for experimentation, group learning, and the support they received during activities from the instructor and TAs. Students welcomed technology and considered it helpful for learning and interaction (e.g., Classroom Response System, DVD demos, animated PowerPoint, and CBL-probeware). They indicated that peer learning took place in the classroom. Students concerns consisted of the timing for activities (either too long or too short), level of scaffolding during activities (sometimes perceived as insufficient - especially at the beginning of inquiry activities), the relatively small number of modules covered and the lack of frequent use of the textbook. They requested better coordination between the class, the lab and the textbook. Below are several representative comments about the class and the methodology:

F04 (mid semester): "… He asks us the question and then we all figure [it] out.… I don't know that he explains stuff. I think he makes us do it."

F04 (end of the semester): "I wish more elementary ed. teachers would take this because we learned in here exactly how they are learning it out there."

S05 (mid semester): "…it's just kind of fun to do experiments so it keeps everyone involved and I don't know if we take it as serious as we probably should"

S05 (end semester): "Yes, I have actually been more excited to learn in this class because it was really hands on …."

Results of CLASS Survey

The Colorado Learning Attitudes about Science Survey (CLASS) [13] was used to gauge students' pre- and post instruction attitudes about learning science. This instrument measures changes in terms of favorable and unfavorable shifts in several categories listed in Tables 1 and 2. Desirable changes are positive for favorable changes and negative for unfavorable.

TABLE 1. Comparison of Students' Attitudes about Learning in the modified Physical Science Course Before and After Instruction as per CLASS Survey.

MODIFIED COURSE	Fall 04, N=14		Spring 05, N=20	
Category Shift (%)	Favorable	Unfavorable	Favorable	Unfavorable
Overall	1.84	-7.17	-6.08	3.11
Understanding Physics	7.14	-13.27	-2.33	1.76
Math	2.86	-2.86	5.58	-1.11
Sense Making/Effort	0.00	-4.76	3.46	-2.85
Real World Application	7.14	-12.50	-0.72	3.09
Personal Interest	12.50	-17.86	-8.75	9.17

TABLE 2. Comparison of Students' Attitudes about Learning in the Traditional Physical Science Course Before and After Instruction as per CLASS Survey.

TRADITIONAL LECTURE COURSE	Fall 04, N=42		Spring 05, N=16	
Category Shift (%)	Favorable	Unfavorable	Favorable	Unfavorable
Overall	1.18	0.97	2.74	-7.10
Understanding Physics	6.35	-3.63	2.68	-8.93
Math	2.14	-3.45	-1.25	-2.50
Sense Making/Effort	-4.60	4.60	-2.08	-1.04
Real World Application	5.47	-2.41	3.13	-9.38
Personal Interest	3.57	-1.79	-4.69	-10.94

Tables 1 and 2 show that changes during F04 semester in the modified course were uniformly desirable which was not the case for the same course during S05 or for the traditional course in either semester. Significance of these changes was determined through paired two sample t-test for means. It was found that during F04 semester in the modified course desirable change was significant (at the .05 level on a two–tailed test) in 3 different categories ("overall", "understanding physics" and "personal interest") and during S05 in one category ("sense making"). However, the overall category for the modified course in S05 was significant but in undesirable direction. Traditional lecture had significant changes in only one category (understanding physics, F04) and this one was in a desirable direction. All other changes, desirable or not, were not significant in lecture format.

Results of CLES Survey

The Constructivist Learning Environment Survey (CLES) [14] was administered to students at the end of the two semesters in the modified course. Results of this instrument are measured in terms of 6 categories: The "Personal relevance" scale is concerned with the extent to which students perceive the school science relevant to their out-of-school lives. "Scientific uncertainty" determines students' perceptions of science as a fallible human activity. "Critical voice" describes students' ability to exercise a critical voice about the quality of their learning activities. "Shared control" concerns students' involvement in the management of the classroom learning environment. "Student negotiation" deals with students' mutual interaction. The "Attitude" scale provides a measure of the concurrent validity of the CLES. The attitude scale has been used extensively and has an established reliability [14]. CLES was administered only at the end of each semester in the modified course only because lecture courses typically do not aim toward these constructivist goals. Results in Table 3 show that modified course classroom in both semesters was perceived as highly but not exclusively constructivist. This concurs with separate observations of the classroom by one of the other authors (Adams).

TABLE 3. Results from CLES Survey

Scale	Fall 04	Spring 05
Personal Relevance	76.07%	75.36%
Scientific Uncertainty	72.14%	66.34%
Critical Voice	78.75%	73.04%
Shared Control	54.11%	55.78%
Student Negotiation	78.93%	75.53%
Attitude	76.43%	71.18%
Overall	72.74%	69.54%

CONCLUSIONS

Students do learn course material as shown by significant learning gains in both semesters. Learning gains and also students' perception of the classroom environment (CLES) did not vary between semesters. Students' overall attitudes toward the class (as found during focus groups) were positive, especially at the end of the each semester. This shows that the methodology was well accepted, but students were typically not initially used to it. However, focus group attitudes and students' learning strategies (CLASS survey) were more favorable in F04. Because the same instructor was teaching the course both times, with equal attitude, and covered the same content, it seems that non-curricular factors, such as students' expectations, interpersonal dynamics and communication skills may affect students attitude (focus group) and approach toward learning in the course (CLASS). Other possible sources of differences were size of the group (smaller in F04) and students' comfort with expressing opinions (more outgoing group in F04). Because student interaction and engagement play crucial role in this course, it is very helpful to spend first 2-3 classes at the beginning of the semester getting students to know each other and building their team work skills through group activities not related to the course content. At this time, it is also necessary to thoroughly describe the methodology and expectations from students. After very positive experience during the F04 semester, the instructor in this study may have overlooked some of these factors while introducing the course at the beginning of S05. These ideas are being implemented in the F05 course offering. Overall, this project showed the utility and transferability of excellent teacher enhancement materials (OPPS) to preservice teacher preparation. A possible broader impact of this finding is providing the starting point for similar innovations in other college science courses.

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