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Editor
Micheal Kamen
Electronic Journal of Science Education
Education Department
Southwestern University
P.O. Box 770
Georgetown, Texas 78627-0770
Telephone: 512-863-1948; Email: ejse@southwestern.edu

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A Commitment to Open Access

Michael Kamen
Southwestern University

It is interesting to note that some of the *unique* early features of the Electronic Journal of Science Education have become commonplace. I recall John Cannon and David Crowther (the founders and first editors) being very excited that they set up a review process that was completely electronic. This facilitated a more efficient review process and certainly was a sign of things to come. I can't recall the last review I did from a hard copy. A second groundbreaking feature was that the journal was set up to be *open access*. There was no fee and anyone with a web browser and internet access was a subscriber.

I am proud to be affiliated with EJSE and the forward thinking of John and David. There are now a growing number of open access journals supporting the distribution of scholarly writing including research findings, position papers, theoretical discussions, and discussion of research methods. EJSE has been part of that movement and maintains a commitment to open access. This seems more important than ever as the world is shrinking and budgets are tightening. Journals affiliated with professional organizations often have financial, political, and contractual constraints to be able to publish an open access journal. I see the EJSE serving an important role in both the dissemination of research and in pushing the agenda for open access.

As an unfunded journal, everyone working to publish each issue does so as an added job responsibilities. A priority is to give thoughtful and helpful reviews that will aid the authors in their research whether ultimately published in the EJSE or elsewhere. And of course the biggest priority is to maintain high standards and publish quality manuscripts that add value to the knowledge base of the science education community. I encourage you to consider supporting this effort. I invite published authors interested in joining the editorial review board to submit their vita and a brief letter of interest to EJSE. We would welcome additional reviews to help facilitate a quick review time, provide quality feedback, and support the implementation of a peer-reviewed open access journal in science education.

The articles in this issue reflect the diversity that is possible in an open access international journal. Keil, Haney, and Zoffel report on research about a teacher professional development program to help middle school teachers design and implement a problem-based environmental health curricula. This paper adds to the discussion about how teachers navigate the tension between supporting a problem-based instructional model and preparing students for a content-driven state exam.

The second manuscript brings us to issues of cultural learning environments in Brunei. The importance of culturally sensitive curriculum and teacher preparation is highlighted by Harkirat Dhindsa and Khadija-Mohd-Salleh. Their exploration of cultural learning issues from Brunei will help science educators from around the world gain perspective of similar issues in their own country.

Jonathan Way presents a research study on the implementation of a unit on Coyote behavior. This thoughtful and creative paper presents a case from two classrooms that will have utility for others implementing a similar curriculum. It also continues the discussion on the inclusion of state standards into a highly motivating unit of study. In addition the description of the research methods and the author's role as teacher/researcher/scientist will serve others navigating the complexities of these combined roles.

In another article relating to environmental issues, Meagher uses a quantitative analysis of concepts maps drawn by community college students to document students' growth in understanding environmental science content. This article will provide help to anyone wanting to use concept maps in a systematic way to gain insight into students' understandings. The author provides significant insight into a sophisticated use of concept mapping and some of the benefits and constraints of this approach.

Bhattacharyya and Bhattacharya report on a qualitative study to integrate a technology-integrated project-based approach into a graduate elementary methods class. Some very interesting results relating to the atmosphere during the class and the role of *banter* emerged during the study.

Del Carlo and Bodner also discuss the social relationships and community building as an important element in science learning. The social interactions which could be perceived as "off task behavior" is reported as being a positive factor in the classrooms studied. This article prompts additional thoughts and questions, along with Bhattacharyya and Bhattacharya's findings about the value and range of social interactions in a classroom setting.

And finally, Reis and Galvao report on a case study of a teacher who enthusiastically includes discussions on controversial issues in her biology class. The case is made that the teacher's conviction about the value of this approach adds to the success she had.

These articles together speak to the importance of thinking about what is happening for the students we teach. From their engagement with Coyotes to joking with friends to debating about the merits of stem cell research, how we allow students to engage with each other and the content does matter.

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Improvements in Student Achievement and Science Process Skills Using Environmental Health Science Problem-Based Learning Curricula

Chris Keil
Bowling Green State University

Jodi Haney
Bowling Green State University

Jennifer Zoffel
Bowling Green State University

Abstract

Project EXCITE, a seven-year federally funded teacher professional development program prepared middle grade teachers to design and implement integrative, problem-based, environmental health curricula with over 1600 students. This article examines how this program, through the developed and implemented curricula, impacted both state-based, proficiency test scores and process skills test scores. Analyses of proficiency and performance scores indicate positive effects for both measures, offering educators further support for the use of integrative problem-based environmental health science curricula.

Correspondence should be addressed to Chris Keil, 216 Health Center, Bowling Green State University, Bowling Green, OH 43403, ckeil@bgsu.edu

Introduction

The Environmental Health Science Context for Learning

In 1998 the State Education and Environmental Roundtable (SEER) report (Lieberman & Hoody, 1998) described how using the environment as a context for learning broadly impacts student achievement. Since then, others have described the same effect and advocated the expanded use of environmental topics in schools. A study by the National Environmental Education and Training Foundation (Glenn, 2000) reported that environmentally based education:

- Improved reading and math scores
- Improved performance in science and social studies
- Developed student abilities to transfer knowledge to new contexts
- Enabled students to “do science” rather than just “learn about science”
- Decreased classroom discipline problems and
- Provided all students with the opportunity to learn at a higher level.

Environmental *Health* Science (EHS) explicitly links environmental conditions to personal and public health. This emphasis can enhance student engagement and topic relevancy even beyond what can be achieved with ecologically linked environmental science. The indoor and residential environments in urban, rural, and suburban settings, provide near-at-hand opportunities for EHS explorations whereas these same settings may not have diverse and accessible outdoor environments to explore. In recognition of this, the National Institute of Environmental Health Science funded programs for the development of school-based environmental health instructional materials, teacher enhancement and development, and most recently, the Environmental Health Science as an Integrating Context (EHSIC) program aimed at combining effective EHS instructional materials with high quality professional development and classroom implementation.

Project EXCITE (**E**nvironmental health science e**X**plorations through **C**ross-disciplinary and **I**nvestigative **T**eam **E**xperiences) was one of the EHSIC grant programs. The EHSIC goals included: developing EHS curricula, deepening student learning outcomes and motivation to learn across the disciplines using EHS as an integrative context, facilitating teacher development of best practices, and fostering student awareness of EHS as both a viable career opportunity and as an essential understanding needed for socially responsible citizenship. One specific set of goals for students included: enhancement of critical thinking skills, increased competence in identifying problems, ability to assemble relevant data, improved solution building, development of inquiry process skills and better performance on standardized tests.

Project EXCITE met these program goals by working with three cohorts of teachers over a two year period (over 160 contact hours for each cohort member) to develop and implement multidisciplinary, problem-based learning (PBL) units addressing locally pertinent EHS issues in the middle grades (4th – 9th). These PBL units, called Odysseys, span topics such as:

- indoor air quality in schools
- a proposed natural gas electric generation facility in a rural village
- the safety of household chemicals
- community and environmental impacts of school construction projects
- pest management practices in a rural village
- the spread of communicable diseases in schools
- water quality and distribution in small and middle size cities and
- food health and safety in a school cafeteria.

The EXCITE-brand of PBL provides rich opportunities for students to develop critical thinking, problem solving, and service learning through a four phase Odyssey experience: *Meet the Problem, Inquiry and Investigation, Build Solutions, and Take Action* (see Figure 1). During the *Meet the Problem* phase, students are presented with a semi-structured and developmentally appropriate local problem to investigate. After the students have outlined what they currently know and what they need to know about the problem, they identify possible resources for learning and generate a beginning hypothesis (an inference regarding the nature of the problem). Students then devise a plan to guide them through the next learning phase, *Inquiry and Investigation*. In this phase, students design and conduct tests to find answers to research questions and use process skills (observation, inference, measuring, data collection and organization, data analysis, data presentation and discussion, among others). Students revisit the problem by sharing findings from others, revise their original ideas/hypotheses, and summarize what they now understand to be true. When students have unraveled the problem and have constructed deeper understandings of the related content they *Build Solutions*. They then use critical thinking skills to weigh the positive and negative outcomes associated with each possible solution in order to establish a best-fit solution. After students decide upon a best-fit solution, they develop a plan to *Take Action*, thus encouraging active citizenship and social responsibility. Action projects consist of creating informational products to communicate their newly constructed knowledge, designing and constructing models or prototypes, developing action-oriented projects, or organizing a program or event. During this final phase, service learning is actuated, as students apply newly acquired knowledge, skills and dispositions outside the classroom to better society. Student reflection is emphasized throughout the Odyssey as students are given frequent opportunities to respond to questions in a daily reflection log.

All of the EXCITE Odysseys are interdisciplinary. They promote both deeper understandings of content and the acquisition of skills related to science, mathematics, language arts, social sciences and health. Because they are framed by real problems that face real people, they provide opportunities for students to examine, discuss, and clarify the ethical issues related to the problem at hand. Each EXCITE Odyssey is framed by national and state educational standards spanning across the curriculum.

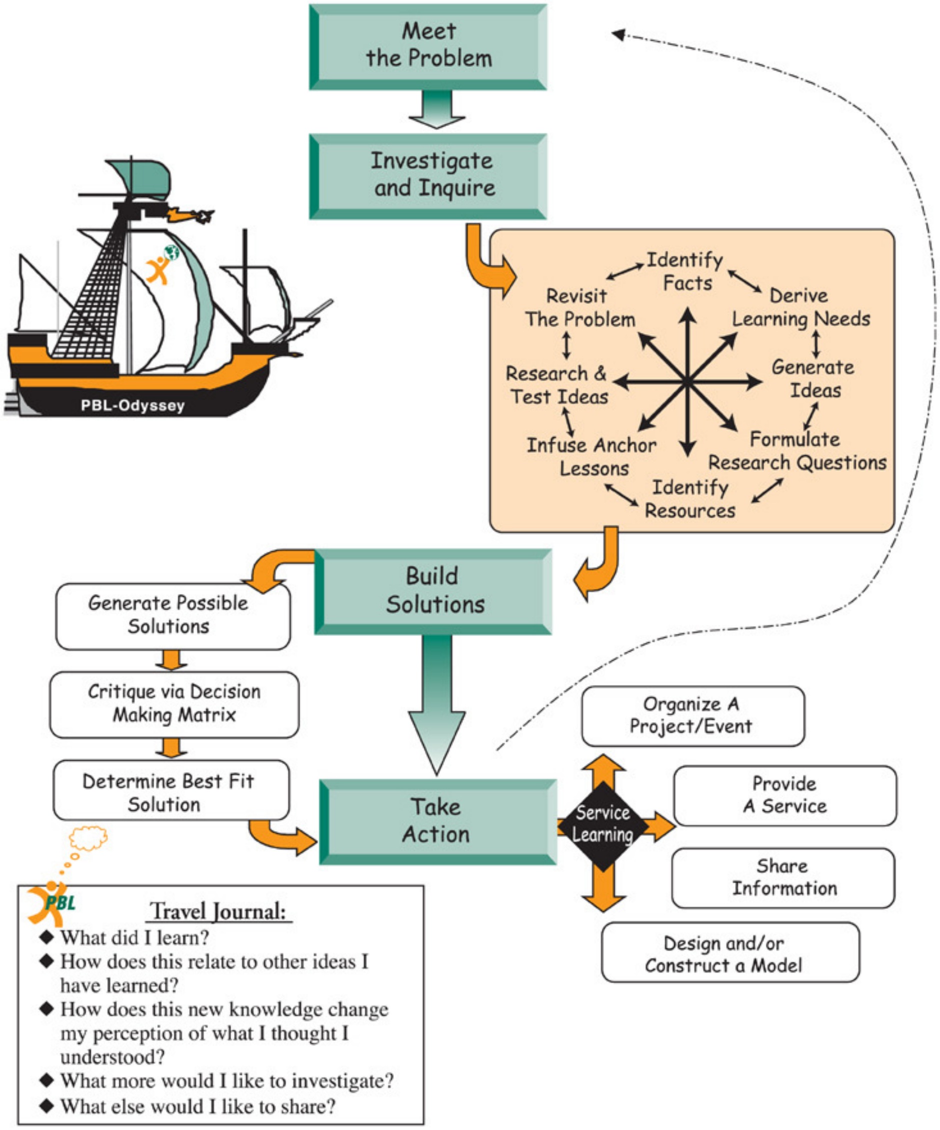

Figure 1. Project EXCITE PBL Odyssey Model

Science Process Skills

Science process skills are inseparable from the practice of science and play a key role in both formal and informal learning of science content. Padilla's (1990) essay defined these skills as "transferable abilities, appropriate to many science disciplines, and reflective of the behavior of scientists." He re-emphasized that science processing includes both basic and integrated skills. Basic processing involves: observing, inferring, measuring, communicating, classifying, and predicting. Integrated science process skills require controlling variables, defining terms operationally, formulating hypotheses, interpreting data, experimenting, and formulating models. Both basic and integrated skills are needed to be scientifically literate. Science process skills are not only important for those pursuing careers in science, but most jobs in this new millennium involve using these skills (Rillero, 1998). While an exhaustive knowledge of science content is impossible, mastery of science process skills enables students to understand, at a much deeper level, the content they do know and equips them for acquiring content knowledge in the future. Assessing process skills is not as common as assessing content knowledge, but it can be done (Harlen, 1999).

Driven by the pressure of performance on high-stakes testing, many science curricula unfortunately often over emphasize content knowledge. But just as a quality literacy program equips children with the basic tools of reading literacy: code breaking, text use, participation in the text and analysis of text, science literacy should also provide the tools required for all forms of scientific knowing (Colvill & Pattie, 2002). Moreover, it is believed that content knowledge is acquired more efficiently and understood at a deeper level when obtained via inquiry using the fundamental tools of science, the process skills (National Research Council, 1996). Not only do science process skills improve science content knowledge, but they also improve language arts and mathematics skills (Ostlund, 1998) (Lieberman & Hoody, 1998).

So a challenge exists. Students need improved science process skills for their long-term academic and personal success. At the same time, given the current policy climate, performance on high-stakes tests should not be jeopardized. Meeting this challenge is one goal of Project EXCITE. The EXCITE Odyssey four-phase PBL model provides frequent opportunities for students to develop both the basic and integrated process skills using environmental health as a context for learning. These same basic and integrated skills are found in middle grades science state and national science standards.

Research Questions

Our first research question was whether student participation in a time-intensive interdisciplinary curriculum such as Project EXCITE produces a measurable difference in state achievement (proficiency) test scores. This question was driven by both the goals of EHSIC and the perception among teachers and administrators that innovative curricula like Project EXCITE jeopardize student preparation for these standardized tests. Our hypothesis was that dedicating instructional time to EXCITE, which is not “test-driven” but is standards-aligned, would not negatively affect proficiency test scores when compared to similar, non-EXCITE schools and in fact might increase scores due to the interdisciplinary approaches of EXCITE resulting in better (deeper and transferable) subject learning.

Our second, research question was whether participation in Project EXCITE improved students’ science process skills. This question was examined for differences among demographic variables including: gender, student performance level, and school. Our hypothesis was that the inquiry based EXCITE approach would indeed improve science process skills.

Methods

Treatment

Participating students were in classes taught by teachers that have undergone professional development though Project EXCITE. These teachers participate in Project EXCITE as a multidisciplinary team and undergo over 160 hours of professional development over a two-year period. This professional development includes two summer institutes and academic year meetings. Teachers are trained in: problem-based learning (PBL), the design and development of PBL units, core concepts and processes of environmental health science, approaches to inquiry learning, strategies to assess PBL, and classroom management techniques needed for conducting PBL units.

All EXCITE students first participate in the ZoOdyssey, an introduction to PBL and EHS in the form of a simulated investigation into an illness outbreak following a trip to the zoo. This Odyssey was developed by EXCITE faculty and staff and aims at teaching the process of PBL (described earlier) over three to five hours of instruction. Following ZoOdyssey, the students go through the Odyssey developed by their teachers focusing on a local EHS issue. The local Odysseys units were implemented over a period from one to four weeks (30 – 90 hours of instructional time). The mode of delivery varied based on instructional decisions about implementation made by the participating teachers. Some schools devoted multiple class periods a day to the unit over a period of one or two weeks. Other schools experienced their Odysseys a few class periods a week over a longer period of time. However all Odysseys incorporated strict adherence to the four-phase EXCITE model.

Participating Schools

Interdisciplinary teacher teams from twelve EXCITE schools have been through the complete two–year professional development and Odyssey implementation cycle of Project EXCITE. Six schools participated from 2001 – 2003 as “Cohort 1” and six schools participated from 2003 – 2005 as “Cohort 2”. All 12 of these schools represented separate school districts. The schools represented a wide diversity in demographics. Table I summarizes information about the EXCITE schools.

Two non-EXCITE middle schools, DON and GLN in the same district as an EXCITE school (FIN) were used as control groups for proficiency test analysis. Six non-EXCITE classrooms identified as MAU and SMS were used as control groups for science process skills testing. These classrooms were in the same school building as EXCITE teams, MGW and SRG respectively. But were used as controls in years subsequent to EXCITE being implemented in those schools and with teachers who had not participated in the EXCITE program. The demographics for the proficiency testing and process skill control groups are also included in Table I. Ethnic and economic data were obtained from state department of education reports. Economically disadvantaged status is based on eligibility for free or reduced cost lunches.

Table I

Demographic Data for Participating Schools

School	Cohort	Public or Parochial	Participating Grade Level	School Grade Levels	School Population	% Non-White	% Economically Disadvantaged
BGR	1	Public	8	7-8	500	11.5	15.6
MGW	1	Public	7	6-8	700	9.0	N/A
SRG	1	Public	6,8	6-8	890	21.0	21.8
ATW	1	Public	7	7-8	590	3.4	N/A
RSF	1	Public	8	7-8	330	6.7	32.3
YNG	1	Public	4,5	K-5	760	44.5	80.7
ARC	2	Public	7	K-12	620	3.8	18.1
LBC	2	Public	6	5-8	400	5.0	18.4
NBL	2	Public	7,8	7,8	130	3.9	15.0
SPX	2	Parochial	5,6	K-8	240	N/A	N/A
FOS	2	Public	8	6-8	490	33.1	59.0
FIN	2	Public	6	6-8	490	16.2	27.7
DON	Prof-C	Public	6	6-8	460	6.5	27.1
GLN	Prof-C	Public	6	6-8	440	15.1	41.2
MAU	POPS-C	Public	7	6-8	670	10.5	13.3
SMS	POPS-C	Public	6,8	6-8	950	24.1	26.0

N/A: Not available
Prof-C: control group for proficiency test comparisons
POPS-C: control group for science process skills test comparisons

Proficiency Testing

In Ohio students are tested on their proficiency in reading, writing, math, citizenship and science. In each subject area student proficiency levels are classified as “advanced”, “proficient”, “basic” or “below basic”. “Advanced” and “proficient” are considered passing levels. Obtaining student or even classroom specific proficiency test data was extremely difficult. Many schools were unable to access and provide the needed test data and information in the format needed. Privacy laws prevented the schools from providing student-level data without coding the information first and schools refused to allow us to code the data as needed. Some schools were able to provide partial information. Results for an entire grade level were available on the state department website for each school, but in most cases an entire grade level did not participate in Project EXCITE during the same year proficiency tests were given. However, in one EXCITE school (FIN) an entire 6th grade level participated in Project EXCITE before they took the proficiency test that year. This school was in a district with two other middle schools (DON and GLN) that had no exposure to Project EXCITE. The percentage of students passing the five subject areas and the percentage of students scoring "below basic" was compared for the year immediately prior to FIN beginning Project EXCITE (2003) and after their second year in the project (2005). Results from 2005 were considered because at that point FIN teachers had experienced the full professional development program and developed experience with both PBL and EHS.

Science Process Skills Evaluation Instrument

Students' scientific process skills were evaluated using the 21 question Performance of Process Skills test (POPS) (Mattheis & Nakayama, 1988). This is an instrument developed to evaluate integrated science process skills such as: experimental design, use of variables, and data presentation and interpretation. The POPS was previously tested for validity and had a total test reliability of 0.75 using the Kuder-Richardson formula 20 for this study.

EXCITE students took the POPS test before participating in the ZoOdyssey. Following the local Odyssey, EXCITE students took the POPS test again. Time between the pre- and post-test ranged from 3 to 29 weeks depending on when the ZoOdyssey and local Odysseys were implemented during the school year. Ten weeks was the median interval. Valid pre- and post-test scores were available for over 1600 students.

In the control groups the POPS test was given three times to look for changes in science process skills due to standard instruction and changes that might occur by simple maturation. The period between the first and second test was a period with "normal", non-EXCITE instruction that ended shortly before the winter holiday break. The interval between the second and third tests began before the winter holiday and concluded a few weeks after the winter holiday. This interval represented a period of time with more "limited" non-EXCITE instruction due to the wind down before break, the break itself, and the gearing up after break. This period was intended to see if maturation of the students over a period of weeks might account for any gains in science process skills seen in the treatment groups. The length of the non-EXCITE normal instruction interval, ranged from 4 to 6 weeks. The period of limited instruction, was 5 or 6 weeks. Overall the span of time between the initial and final POPS test administration for the control group ranged from 9 to 12 weeks which brackets the median pre/post test interval (10 weeks) for the treatment groups. Three valid and reliable tests were administered and data were collected for over 100 non-EXCITE students (see Figure 2).

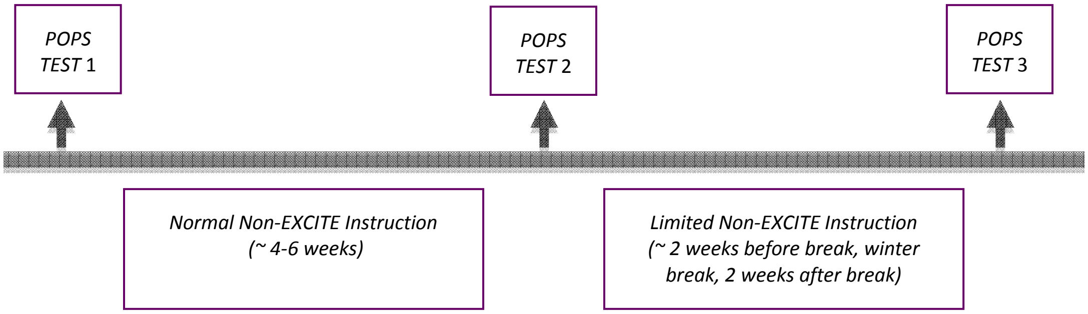

Figure 2. Control Group Testing Periods for POPS

POPS Data Analysis

Matched pair one-tailed t-tests were completed to test for an increase in POPS scores. Though data is interval (number correct), the range is wide enough (0-21) that if a normal distribution of scores is exhibited, parametric tests can be done.

Students with scores lower than 4 on either the pre or post-test were eliminated from the analysis (i.e. on several answer sheets there was evidence that there was not a genuine effort to complete the test and were described as non-efforts). These represented 3.1% (52 out of 1661) of the EXCITE students who completed both pre and posttests. No student scored less than 4 on both pre and posttest. The non-effort rates across the twelve schools were non-normally distributed. The pre test non-effort rate averaged 1.3% (range: 0% - 5.9%) with a median of 0.7% and a 95% confidence interval on the median of 0% - 4.8%. The post test non-effort rate averaged 1.5% (range: 0% - 5.6%) with a median of 0% and a 95% confidence interval on the median of 0% - 4.3%. The POPS control groups non-effort rates was not statistically different than the EXCITE group.

The comparisons were completed for various groupings of students. These groupings were:

- All EXCITE students
- All EXCITE students by gender
- Each school
- By pretest performance level (quartiles)

Results and Discussion

Proficiency scores

The proficiency test performance analysis is for the one EXCITE school (FIN) in which an entire grade level (6th grade) of students participated in Project EXCITE during a year the proficiency test was given. This school also completed their EXCITE Odyssey prior to taking the proficiency test. Proficiency test scores for two schools in the same district were used for comparisons. This was to see whether the school that dedicated the time to the EXCITE curriculum did at least as well as the non-EXCITE schools and did not suffer from their participation.

The changes in pass rates from the year immediately before Project EXCITE to the results after two years of Project EXCITE are presented in Table II. Also presented is the standard deviation of the pass rates in each subject area for the 5 years prior to EXCITE. Though the sample size, 5 years, is too small to make full use of parametric statistics, the standard deviation is presented as a measure of typical year-to-year variability.

Table II
Change in Pass Rates from 2003 – 2005

	Subject Area (change, standard deviation)				
School	Reading	Writing	Math	Citizenship	Science
FIN	+10.5 (5.5)	+3.8 (3.3)	+13.3 (6.1)	+10.4 (4.4)	+2.2 (5.1)
DON	-2.8 (8.0)	-3.5 (4.8)	+12.5 (6.3)	+2.8 (3.6)	+1.5 (8.4)
GLN	+19.3 (6.2)	-3.2 (8.3)	+4.1 (13.9)	+11.1 (6.6)	+9.9 (12.4)

After the two years in which FIN participated in EXCITE, pass rates were higher in all subject areas than the year immediately prior to beginning EXCITE. For reading, writing, math and citizenship (four of the five subject areas), the increase was greater than the annual variability for the preceding five years as measured by the standard deviation.

Over the same period DON had decreased pass rates in two subjects and increased pass rates in three subjects. Only the increase in the math pass rate was larger than the annual variation as measure by the standard deviation (one of five subject areas). GLN had pass rate increases in reading, math, citizenship and science. The increase in pass rates in reading and citizenship were greater than the measure of annual variability (two of five subject areas).

Qualitative observations as well as the science process performance results presented later in this paper suggest that "lower performing" students may benefit more from participation in Project EXCITE. This may be due to the non-traditional problem-based approach to learning or the use of "real-world" environmental health contexts, or a combination of both. For this reason we looked for changes in the number of students in the "below proficient" results category. Table III presents the change in the percentage of students scoring "below proficient" along with the standard deviation in the percentage of students in that category in the previous five years. A negative value indicates a decrease in the number of "below proficient" students, the desired result.

Table III
Change in Percentage of Students Scoring "Below Proficient"

	Subject Area (change, standard deviation)				
School	Reading	Writing	Math	Citizenship	Science
FIN	-10.2 (3.2)	-2.0 (1.8)	-10.4 (5.2)	-12.4 (4.9)	-1.9 (2.9)
DON	+0.4 (2.9)	+5.6 (3.9)	-5.6 (4.9)	-0.3 (4.0)	+1 (5.2)
GLN	-6.7 (4.7)	+1.7 (6.6)	+0.0 (11.2)	-7.7 (5.9)	-4.7 (10.9)

After two years of EXCITE participation, a smaller percentage of FIN students performed at a "below proficient" level in all subjects compared to the year immediately prior EXCITE. For reading, writing, math and citizenship the change was greater than the standard deviation of the percentage of students at that level over the preceding five years.

Over the same period, DON had a smaller percentage "below proficient" students in math and citizenship. This difference was greater than the measure of annual variability for math. DON had a larger percentage of "below proficient" students in reading, writing, and science. The difference was greater than the measure of annual variability for writing. GLN had a smaller percentage "below proficient" students in reading, citizenship and science. This difference was greater than the measure of annual variability for both reading and citizenship. GLN had a larger percentage of "below proficient" students in writing and no change in math.

To summarize, the EXCITE school (FIN) had increases in pass rates greater than the standard deviation in four out of the five subject areas while GLN showed similar increases in only two areas and DON in one. Similarly FIN had students move above the "below proficient" category at rates greater than the standard deviation in four out of the five subject areas while GLN showed improvements greater than the standard deviation in only two areas and DON in one.

State proficiency performance appears to be enhanced during the periods of EXCITE implementation. Though the sample size (only 5 years of data before EXCITE) precludes formal statistical testing, this data suggests that participation in Project EXCITE did not negatively affect standardized test pass rates and may in fact have improved pass rates and decreased the percentage of students at a “below proficient” level. Notably, the only sustained teacher professional development across the district during these years was Project EXCITE in the FIN school. Therefore, it is plausible to attribute this success to the EXCITE program and not some other professional development program or district initiative.

A primary goal of the NIEHS EHSIC program was to enhance student achievement in all subject areas using EHS as an integrative context for learning. Although additional data was not available to make greater use of inferential statistics (requiring teacher and/or student level data), the overall evidence suggests that for the FIN EXCITE students, proficiency performance during the years of EXCITE was improved across subject areas compared to years prior to EXCITE.

Keeping in mind that the average Odyssey implementation period was roughly 2 weeks (or 60 total hours of instructional time across disciplines), these gains become even more notable. Ironically, when interviewed and/or surveyed, many EXCITE teachers felt that although the EXCITE Odyssey experience was motivational for students and evoked deep understanding of local EHS problems, they felt uncomfortable spending so much time on a unit not perceived to be directly supporting test preparation. The majority of EXCITE teachers conveyed that they would continue to use EXCITE Odysseys/PBL in the future, but would need to limit the amount of time spent on the unit to leave time for test preparation. Furthermore, many teachers worried that although they believed students were developing critical thinking and higher order skills, and although they knew first hand that these curricular materials were standards-aligned, they were concerned that the Odyssey experience may not foster student achievement on the state tests.

It should also be noted that the science proficiency test scores did not notably improve in the FIN EXCITE school. At the time of testing, only a small fraction of this test measured process skills (under a broader category of the nature of science). Since then, a new achievement test is in place in Ohio aimed at increasing the emphasis on assessing scientific processing skills. For this very reason, the POPS test was also administered, as a more direct and valid measure of the impact of the primary goals of Project EXCITE.

Scientific Process Skills

Scientific process skills improvement was assessed using the POPS test. Table IV summarizes the changes in POPS test scores for all students that had valid pre and post tests. Significance of change was determined by matched pair t-test. These data were further analyzed based on their pre-test performance (quartile) and by gender. The sample size was smaller for the gender specific analysis because gender data was not provided for some of the students. A one-way ANOVA analysis shows that the gains were not different based on gender (p = 0.11).

Table IV
Change in POPS Test Performance for EXCITE Students

Group	Pre-test Quartile	Pre-test average	Post-test average	Average gain	p	n
All students	All	13.1	13.9	0.6	<0.001	1609
	1st	7.2	9.2	2.0	<0.001	367
	2nd	11.6	13.0	1.4	<0.001	445
	3rd	15.1	15.7	0.6	<0.001	392
	4th	18.3	16.4	-1.9	<0.001	405
Males	All	13.6	14.2	0.6	<0.001	588
	1st	6.4	9.2	2.8	<0.001	123
	2nd	10.4	12.0	1.6	<0.001	170
	3rd	14.0	15.1	1.1	<0.001	129
	4th	17.7	16.9	-0.8	0.002	166
Females	All	13.4	14.2	1.0	<0.001	612
	1st	7.7	9.6	1.9	<0.001	154
	2nd	12.0	13.2	1.2	<0.001	134
	3rd	15.2	15.6	0.4	0.041	165
	4th	18.3	17.9	-0.4	0.048	159

Table IV presents aggregate data for all EXCITE students in both cohorts. The same pattern of greater improvement in lower quartiles can also be seen when considered by cohort, year and school.

When analyzed by cohort, the Cohort 2 (2003 – 2005) students exhibited a greater average gain in POPS test scores, +1.1 compared to Cohort 1 (2001 – 2003) students who had an average gain of +0.5. ANOVA revealed that this difference was statistically significant (p <0.001). This may be due to the overall maturation of the EXCITE program. The project staff initially assumed that participating teachers did not need us to overemphasize how to do inquiry. During the first cohort training period, we spent more time deepening teacher EHS content knowledge and helping teachers with teaming structures and interdisciplinary planning. However, the POPS scores posted by Cohort 1 students and feedback from the teachers provided us with valuable information that we used as we refined our program. During teacher professional development, we subsequently spent a significant amount of time having EXCITE teachers participate as learners in designing and enacting controlled investigations and other inquiry and research methodologies. We also created anchor lessons that teachers could use with their students aimed at developing needed process-oriented inquiry skills such as graphing, controlling variables, planning research and communicating findings.

Within each cohort there was no statistical difference in the gain in POPS tests scores between students participating in the first year and students participating during the second year. In general, there was no statistical difference in the magnitude of the increase in POPS tests scores between the EXCITE schools. The average increase at SPX, however, (+1.7) was statistically greater than the increases in other schools in that cohort, BGR (+0.4), SRG (+0.4), ATW (+0.5) and FOS (+0.5).

The magnitude of the increase in average scores and the degree of statistical significance is highest for students that performed in the lowest (first) quartile on the pretest. The difference in scores by quartile is statistically significance for all quartiles. The statistically significant decrease in the scores for students performing in the top quartile on the pre-test is likely due to a ceiling effect of a 21 question test instrument.

The question remained whether the increase in POPS scores could have been: a) a result of simple maturation of the students or b) achieved with typical, non-EHS non-PBL instruction. In order to claim an “EXCITE effect”, we aimed to rule out these alternative explanations to the increased scores. We looked at the first question using an internal control group and at both questions using an external control group.

At one EXCITE school (NBL) some of the students who participated in EXCITE as 7th graders also had the same teachers in 8th grade and participated in EXCITE a second year. These students had demonstrated a statistically significant increase in POPS tests scores administered before and after EXCITE during the school year. The next year they took the POPS test again as a pre-test for their 8th grade participation. If maturation, the time over summer break, affected student’s scientific process skills, improved POPS scores at the beginning of 8th grade might be expected. There was no statistically significant increase in their POPS scores. This suggests that simple maturation does not contribute to improved science process skills as measured by the POPS test.

We also recruited six non-EXCITE classrooms from two schools to explore these alternative explanations of increased process skills test scores. Non-EXCITE control group classrooms took a POPS pre-test and then two follow-up tests, one after a period of normal instruction and then again after a holiday period with limited instruction, but also large periods of vacation. Table V presents data on significant changes in test scores between administrations of the POPS test to the control groups. There is little significant positive change in average POPS test scores in the control group. Notably, the lowest quartile of pre-test performers showed no significant change at all. This same group in the EXCITE schools exhibited the greatest gains in POPS test scores. The significant increase from test 1 to test 3 that was observed in MAU was driven by the performance of one quartile. Further analysis showed that it was the performance of the second quartile students from a single classroom driving the significance of the increase.

Table V
Change in Average POPS Test Score for Control Group Students.

	1	2	3	Δ 1 - 2	Δ 2 - 3	Δ 1 - 3	n
All	15.4	15.9	15.7	+0.5*	-0.2	+0.3	102
1st	9.8	10.2	10.2	+0.4	+0.0	+0.4	22
2nd	13.6	14.6	14.6	+1.0	+0.0	+1.0	28
3rd	17.8	18.2	18.0	+0.4	-0.2	+0.2	29
4th	20.0	20.0	19.4	+0.0	-0.6*	-0.6*	23

*: significant at $\alpha = 0.05$

Student science process skills, as measured by the POPS test, appear to be enhanced through participation in Project EXCITE Odysseys. As shown in Table IV, the EXCITE schools made regular improvements in process skills scores. These improvements are most notable at the lowest quartile students, yet are statistically significant for the entire group. Moreover, improvements were found in both male and female students. Table V shows that in non-EXCITE schools process skills do not appear to be developed by “normal” instruction (test 1 – test 2 timeframe) or maturation alone as examined during “limited” instruction (test 2 – 3 timeframe). POPS scores for the control groups remained stable (or sometimes decreased) at periods of time with normal instruction, limited instruction and/or extended breaks from instruction.

It is makes sense that Project EXCITE Odysseys promote student attainment of these process skills. The EXCITE PBL model infuses inquiry-based instruction throughout the Odyssey experience. When students first meet the problem, they are required to access and organize available information as they identify relevant facts, derive related learning needs and make initial hypotheses and assumptions. They use process skills throughout the inquiry and investigation phase of the Odyssey experience, as they use the inquiry process to gather additional information and data needed to better understand the problem. During the solution-building phase, students again use process skills to analyze solutions in light of the strengths and weaknesses of each solution and ultimately generate a best-fit solution based on their analysis. Finally, students synthesize the newly constructed knowledge to both plan and enact a community-based action project to improve upon the problem. Again, the entire Odyssey experience averages two weeks or 60 total instructional hours, yet even in this limited time period, science process skill improvement was possible.

Implications

This study examined two research questions: whether participation in a time intensive interdisciplinary curriculum such as Project EXCITE produces measurable differences in state achievement (proficiency) test scores and whether participation in Project EXCITE improved students' science process skills. Data indicate that both were enhanced during the EXCITE Odyssey experience.

We believe this data offers further justification for using PBL and EHS as an integrative context for learning. Proficiency gains were noted across subject areas. As such, we believe that the inquiry skills infused throughout the PBL Odyssey experience enhanced the EXCITE learners' data organization, data analysis, and written communication skills and these skills were measured by the state proficiency tests in mathematics and writing. Similarly, EXCITE learners repeatedly designed procedures, controlled variables, and organized and interpreted data, as documented by the increase on the POPS test that measures these skills. However, only modest gains on the state proficiency test appear for science. This implies that state science proficiency improvement may not correlate well with science process skills performance. This appears to be the case for FIN students who made similar significant gains as other EXCITE students on the POPS test, but posted only modest gains in science proficiency test scores during the EXCITE experience.

Teachers perceive that the state science proficiency test is content-oriented and are concerned that spending time on the EXCITE Odyssey experience would not be justifiable. Considering that students improved their process skills performances, but only showed modest gains in their science proficiency test scores, there may be some truth to this thinking for science proficiency testing at least. It is our hope that the newly revised Ohio state achievement tests will more equally balance science content and science processes, so that students who are gaining process skills will also post similar improvements on the state science achievement tests. Given that process skills were not effectively assessed on the Ohio 6th grade state proficiency test, we were unable to document improvements in middle grade students' overall scientific literacy. In relationship to the evaluation of innovative curriculum, such as Project EXCITE Odysseys, state achievement test scores often only measure a fraction of the knowledge gained by the students as a result of the curricula. We believe this is one very good justification for the use multiple assessments when examining the impact of an inquiry-based professional development project on student achievement.

Given the positive impacts found in this study, we advocate that a problem-based interdisciplinary EHS curriculum lasting longer than 2 weeks or 60 contact hours would further develop student achievement and scientific process skills. Additional investigation regarding the relationship between length of implementation and impact on student learning is therefore warranted. We believe that as more data are available documenting the positive and significant impact of integrative and problem-based learning, it is imperative that we clearly and swiftly communicate this relationship within educational communities so that teachers will know that these innovative ways of teaching and learning can help them succeed and survive in an accountability driven era. More data-driven studies examining student performance on both state achievement tests and other valid and reliable assessment measures, like the POPS test, are needed to help make the case for a problem-based, EHS curriculum. We hope this investigation provides significant contributions in doing so.

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Cultural Learning Environment of Non-Government Secondary Science Students in Brunei

Harkirat S. Dhindsa
Universiti Brunei Darrusalam

Khadija-Mohd-Salleh
Universiti Brunei Darrusalam

Abstract

The aims of this research were to cross-validate the Cultural Learning Environment Questionnaire (CLEQ) in the local context of Brunei and to evaluate culturally-sensitive factors (gender equity, collaboration, deference, competition, teacher authority, modelling and congruence) in secondary science students' learning environments. Data were collected from 1417 secondary science students enrolled at non-government schools in Brunei and their 49 science teachers by administering the CLEQ (Fisher & Waldrip, 1997). Factor, validity and reliability analyses supported the instrument's suitability to evaluate the culturally-sensitive factors associated with the cultural learning environment of these students. The students generally believed that both genders are treated equally and that they are independent learners, although, to some extent, they were reluctant to give their independent views in their classes. The perceived, predicted and observed mean values by students, teachers and researcher, respectively, were comparable for all these scales except for teacher authority and modelling scales, where differences were highly significant. The data revealed no gender, regional, or grade level differences in students' perceptions. However, perceptions of students from different race groups were different. Implications of the research are discussed.

Correspondence should be addressed to Prof. Dr. Harkirat S. Dhindsa, hdhindsa@shbie.ubd.edu.bn

Introduction

Human cognition is shaped by the socio-cultural interactive processes (Vygotsky, 1978). All cultures have well developed theories about how the physical world operates without studying formal science (Bullivant, 1981; Ingle & Turner, 1981; Jordan 1985, & Quinn 1987). Science is therefore a cultural artifact and it is embedded in and influenced by society and culture (Aikenhead, 1997). Science teaching is also a cultural activity and cultures influence the teaching and learning process at large (Jegede, 1999; Santagata & Stigler, 2000).

The studies on the effects of cultures on educational systems suggest that classroom teaching and learning processes are influenced by the cultural values of both the teacher (Delpit, 1988; Santagata & Stingler, 2000) and the students (Fisher & Waldrip, 1997, 1999; Jegede & Okebukola, 1991). The research literature on science learning highlights that cultural background of a learner may have a greater effect on education than does the subject content, especially in relation to students making observations in science classes. (Jegede & Okebukola, 1991). Whenever the pupils enter the world of school science, they bring with them their existing cultures it soon becomes evident to them that science too is another culture with which they have to interact. Moreover, students soon feel confused as a result of need for the border crossing not only from knowledge gained at home to school, but also between subjects (Aikenhead, 1996; Jegede, 1999). This problem is not only faced by students from non-western countries who are learning western science but also by students from western countries (Cobern & Aikenhead, 1998; Ogawa, 1995).

Research on the influence of teacher culture on classroom teaching suggest that Taiwanese teachers consider academic achievement (Aldridge, Fraser & Huang, 1999), Chinese teachers consider clarity in explaining and showing enthusiasm in their teaching (Steven & Stigler, 1992) and American teachers consider sensitivity and patience as the most important attributes of a good teacher and teaching. The research studies from USA reported that classroom management strategies (Grossman, 1995) and classroom communication techniques (Delpit, 1988) of white American teachers were inappropriate for children from other cultures, especially for black students. There are also studies that show that practising teachers from different cultures hold both scientific and traditional thoughts about scientific concepts. The traditional thoughts are often culturally oriented misconceptions about the scientific concepts. Many teachers were not aware that they are bringing cultural bias to their teaching by defining a concept using a non-scientific traditional knowledge (Lawrenz & Gray, 1995; Ogawa, 1995).

The sheer complexity and cultural variety that we often find in multicultural classrooms provide a stiff challenge for any teacher (Thomas, 2000). To deal with this challenge, it is apparent that today’s teachers need to fully understand their own cultural beliefs, individual student’s culture and the world view so that learning can be made more meaningful for all students (Lee, & Fradd, 1998). Moreover the complexity of the challenge is further heightened as a result of rapid human migration within and between countries as the world is progressing towards a borderless society. The schools are becoming increasingly culturally diverse in their scope and clientele. For example in 2001, there were about 80,000 (about 23% of the total population) temporary workers from many countries employed in Brunei. A considerable fraction of these workers are teachers and the children of these workers attend schools in Brunei. This population adds to the existing cultural diversity in the national population. According to the Government of Brunei Darussalama (GBD), the population (357,800 as estimated for 2004) of Brunei Darussalam consists of 52% male and 48% female. On the basis of race, there are 66.3% Malay, Kedayan, Tutong, Belait, Bisaya, Dusun, and Murut, 11.2% Chinese, 6% Iban, Dayak and Kelabit, and 11.8% other races (GBD, 2007). Moreover, there are also other subcultures within each culture such as rural, urban, water village, gender, language and socioeconomic status.

All these cultures and subcultures have dimensions that influence the teaching and learning processes differently. It is however, important to select some important dimensions that can be targeted to improve upon the overall classroom practices. The material, social, cognitive, affective, linguistic, and ecological dimensions of culture have also been highlighted in the literature (Leavitt, 1995; Stairs, 1995). The literature also reports three contrasting styles of learning: dependent–independent, competitive–collaborative and avoidant–participant that are influenced by cultural values of a learner (Grashna, 1972). Hofstede (1984) identified power-distance, uncertainty avoidance, individualism, and masculinity/femininity as the important cultural dimensions of the unique environments of multicultural organisations. Moos (1979) reported relationship, personal development, system maintenance and system change as cultural dimensions. Schwartz (1992, 1994) reported that individualism and collectivism could supply valid explanations about cultural differences in cultural values in a society. Fisher and Waldrip (1997) proposed gender equity, collaboration, competition, deference, congruence, modelling, communication, and teacher authority as culturally sensitive factors. This study concentrated on these dimensions because they are widely accepted as significant and cover the dimensions, proposed by Moos (1979) and Hofstede (1984) (for details see Fisher and Waldrip, 1997). Moreover, these dimensions are important in a classroom setting and valuable information on these dimensions can be collected, which can guide the teachers to optimize their teaching in multicultural classes. Furthermore, these dimensions have been established to associate with classroom practices in the existing literature. For example association between these dimensions and students' (i) academic achievement (Waldrip, Fisher & Dorman, 2005), (ii) attitudes to science (Waldrip, Fisher & Dorman, 2005), and (iii) interaction with teachers (Fisher & Waldrip, 2002) has been reported in the literature. Fisher and Waldrip (2000) reported that the perceptions on these scales of metropolitan, provincial, rural and mining community students were statistically significantly different. Moreover, the availability of a well established valid and reliable instrument also to some extent guided the selection of these dimensions.

In addition to the above, these dimensions have been evaluated in the Bruneian context to investigate the cultural learning environments of (i) secondary science students in government schools (Dhindsa, 2005), and (ii) pre-service teachers (Dhindsa & Fraser, 2004). Additional research on these dimensions in the Bruneian context suggests (i) low level statistically significant gender differences in perceptions of these factors of students from government schools (Dhindsa, 2005), significant differences in perceptions of these dimensions of Bruneian students studying at international, private and public schools (Khadija-Mohd-Salleh & Dhindsa, 2005) and significant variations in means values of these factors in populations comprising of lower secondary, upper secondary and tertiary students (Dhindsa, 2008). Moreover, Khadija-Mohd-Salleh (2004) compared the perceptions of students from four race groups in Brunei and found significant differences in these groups of science students' perceptions of cultural learning environments. In Brunei, a father's race is considered as the race of the child and it is a common practice in this country to ask for an individual's race on government forms. However, the cultural learning environment of students studying at non-government schools has received very little attention. These students come from a subculture of the society which is to some extent economically better off than those members of society who cannot afford to pay high fees to send their children to non-government schools.

This study mainly concentrates on using CLEQ to study the cultural learning environment of secondary science students enrolled in non-government schools in Brunei. The authors have not come across research in the non-government schools representing a subculture based on the affordability to pay fees especially in Brunei. It is important and timely to investigate the cultural learning environment of science students in non-government schools. The study is extended to investigate if the teachers are able to predict their students' mean perception on the CLEQ scales. In order to predict students' behaviour on these dimensions, the teachers should (a) know the make-up of the community, (b) select the important dimensions of culture that need to be addressed in a given curriculum, (c) know the existing influence of these dimensions on the classroom practices so that certain behaviours that can lead to successful teaching and learning can be targeted for modification and (d) be able to predict students' perceptions of the cultural learning environment in their classes (Brislin & Yoshida, 1994; Dhindsa, 2005).

Educational context and rationale

According to the Brunei Ministry of Education (MOE) statistics there are 31 government, 16 non-government, and 3 international secondary schools in Brunei. Education in Brunei Darussalam government schools is free, non-government and international schools charge moderate to high fees (MOE, 2005). The non-government schools follow the Bruneian curriculum. Nine of these schools are situated in Brunei–Muara district and seven schools in Belait District, there are no non-government schools in the Tutong and Temburong districts of Brunei. Brunei though small in size with only four districts, the cultures of residents in these districts are clearly distinct. The total number of students enrolled in the non-government schools increased by 10.5 % from 4881 to 5453 in the year 2004 (MOE, 2005). An increase in the number of students in the schools is the result of an expected increase in the total populations in Brunei Darussalam.

The parents select schools for their children. Those who can afford to pay moderate to high school fees are likely to choose a non-government school because the students in non- government schools get better grades in national examinations as compared to students in government schools. During 2003, the Pass rates for government and non-government schools for a national lower secondary examination (Penilaian Menengah Bawah – PMB) were 77.3% and 95.5% respectively and for GCE O-level examination were 70.4 % and 91.8% respectively (MOE, 2005). The higher percentage of passes in both these national examinations could influence parents' decisions to send their children to non-government schools. Moreover admission to and the selection of, A-level subjects is based on the GCE-O level results. The student population in these schools represents children of expatriate workers who came from various cultural backgrounds from many countries and also from various local cultures especially from families that can afford to pay the school fees. The population feeding these schools represents a subculture based on the ability of families to pay school fees (economic factor). Furnham (1992) identified several powerful sub-groups that influence student's understanding about science: the family, peers, the school and the mass media, as well as groups associated with various physical, social, and economic environments. Furnham further stated that each subgroup has a culture, which we designated as a "subculture" to convey an identity of a subgroup.

It is important that teachers are able to predict the students' behaviour in a classroom situation to avoid students completing the questionnaires which may require students' learning and teachers' teaching time. Moreover, the processing of these data takes time and teachers have to wait for some to react to the survey results. Furthermore this process adds to the teachers' responsibility. These issues can be tackled by training teachers to predict students' related desired variables to a fair degree of accuracy. An alternative to this could be that teachers are able to observe and record students' behaviours accurately so that they can help each other without losing classroom teaching and learning time. Therefore this study decided to compare associations between students' perceived, teachers' predicted, and researchers' observed data on the scales CLEQ.

Aim

The aim of this study was to evaluate the cultural learning environment of secondary science students in non-government schools in Brunei. More specifically the study concentrated on the following research questions.

a. How suitable was the CLEQ instrument in collecting the data on cultural factors of the learning environment of students in non-government schools?
b. What were the magnitudes of the cultural learning environment factors, covered in the instrument, in the science students' classes in non-government schools?
c. Were the teachers able to predict their students' perception of these factors?
d. How did the observation data compare with students' perception and teachers' prediction data?
e. How were these cultural factors influenced by respondents' gender, district, grade level and race?

Methodology

Student Participants

The participant*s* of this study consisted of 1417 [753 in Form 3 (Grade 9) and 664 in Form 4; (Grade 10)] students enrolled at non-government schools. There were 963 respondents from Brunei-Muara district and the remaining 454 were from Belait district. When the sample was grouped on the basis of respondents' race, it was found that there were 443 Malays, 685 Chinese, 65 Indigenous and 131 Others. The respondents under Others were mainly from India and Pakistan. There were 673 males and 673 females in the sample. Of the participants 93 and 71 did not disclose their race and gender respectively. The age range of the respondents was between 13 and 17 years with the median ages for Form 3 (Grade 9) as 14 years and Form 4 (Grade 10) as 16 years.

Teachers Participants

The study also included 49 teachers whose students participated in the research. These included 22 male and 20 female teachers (7 teachers did not disclose their gender). Twenty eight teachers were from Brunei-Muara district and 21 from Belait district. Sixteen teachers taught Form 3 (Grade 9) and the remaining 33 taught Form 4 (Grade

10). There were 4 Malay, 6 Chinese and 33 Others and 6 teachers did not disclose their race in this sample.

Instrument

The instrument (CLEQ) used in this study was empirically developed by Fisher and Waldrip (1997). The selection of CLEQ instrument for the present study was based on its successful use (reliability and validity in collecting data) in previous learning environment research (Dhindsa, 2005, 2008; Dhindsa & Fraser, 2004; Fisher & Waldrip, 1997, 1999). Moreover the development of this instrument was guided by the anthropology, sociology, psychology, management, and cultural factors research (Hofstede, 1984, Moos 1979; Stull & von Till, 1994). Furthermore, the instrument is considered salient by teachers and students as well as it is economical in time and money as it contains a relatively small number of reliable scales, each containing a small number of items i.e. 5 items per scale. The overall 35 item instrument contains seven scales: Gender Equity, Collaboration, Deference, Competition, Teacher Authority, Modelling, and Congruence. Each item written in simple English was responded to on a five-point scale with the extreme alternatives varying from Strongly Disagree to Strongly Agree. The respondents were asked to indicate to what extent they agreed to that each item described their classroom. The higher the score for a given scale the more prominent is the behaviour. The instrument is easy to modify. The items were modified to get prediction and observation data from the teachers and a researcher respectively without changing the theme of the scale and the content of the item. These changes are reported in Table I along with the description of the scales. In this way three instruments for students (CLEQ-S), teachers (CLEQ-T) and researcher (CLEQ-R) were designed.

Table I

Descriptive Information for Each Scale of the Cultural Learning Environment Instrument

Scales	Description	Sample item
Gequity	The extent to which students perceive males and females are treated equally.	S. I feel that comments in class by male and female students are equally important. (+) T. I think that my students feel that comments in class by male and female students are equally important. (+) R. Students feel that comments in class by male and female students are equally important. (+)
Collabo-ration	The extent to which students perceive they collaborate with other students rather than act individually.	S. I feel it is important for the class to work together as a team. (+) T. I think that my students feel that it is important for the class to work together as a team.(+) R. These students feel that it is important for the class to work together as a team. (+)

Deference	The extent to which the students feel they defer to the opinions of others.	S. I try to say what I think the teacher wants rather than give my own opinion. (+) T. I think that my students try to say what they think the teacher wants rather than give their own opinions. (+) R. These students try to say what their teacher wants rather than giving their own opinions. (+)
Competition	The extent to which the students are competitive with each other.	S. I like to compete against the other students. (+) T. I think that my students like to compete against other students. (+) R. These students like to compete against the other students. (+)
Teacher Authority	The extent to which the students perceive the teacher has authority in the classroom.	S. It is OK for me to disagree with the teacher. (-) T. I think that my students think it is OK for them to disagree with teachers. (-) R. These students feel that it is OK for them to disagree with their teacher. (-)
Modelling	The extent to which the students expect to learn by a process of modelling.	S. I like teachers to show me what to do. (+) T. I think that my students like teachers to show them what to do. (+) R. These students like their teacher to show them what to do. (+)
Congruence	The extent to which the students perceive learning at the school matches their learning/ application at home.	S. What I learn at school helps me at home. (+) T. I think that my students feel that what students learn at schools help them to do things at home. (+) R. These students feel that what they learn at school helps them to do things at home. (+)

Gequity=Gender equity; Collabo=Collaboration; Defer=Deference; Compet=Competition; Teacheraut=Teacher Authority; Modell=Modelling; Congrue=Congruence

Procedure

The Cultural Learning Environment Questionnaire-Students (CLEQ-S) was administered to the students in their classes. The instructions written on the instruments were repeated verbally and students' questions were answered before they started to answer the CLEQ-S. The teachers' questionnaire (CLEQ-T) was administered to all the Form 3 and Form 4 science teachers who were currently teaching the targeted classes. The items in the CLEQ-T evaluated teachers' awareness of their students' mean perceptions of the culturally sensitive factors in their classes. Teachers were also asked to respond to each question on a 5 pointed scale. One of the researchers observed 10 classes of participant teachers and graded the CLEQ-R items. All the respondents marked each item on a 5 pointed scale. The completed response sheets were collected, and, data were then coded and processed using the SPSS program. The significant differences were further evaluated by computing effect size for each comparison. The effect size data was scaled as low (0.2), medium (0.5) and high (0.8) based on Cohen's classification (Cohen, 1969).

Results and Discussion

In this section, the results are discussed under three headings: (a) instrumental variables (b) culturally sensitive factors of students' learning environment, and (c) the effects of gender, grade level, race, and region on culturally sensitive factors of students' learning environment.

Table II

Factor Loading for Items in the 35 Item Version of the Personal Form for Individual Students as the Unit of Analysis (n= 1417)

Item	Gequity	Collabo	Defer	Competition	Teacheraut	Modell	Congrue
1	0.70						
2	0.74						
3	0.70						
4	0.74						
5	0.74						
6		0.58					
7		0.72					
8		0.72					
9		0.76					
10		0.74					
11			0.63				
12			0.73				
13			0.61				
14			0.67				
15			0.74				
16				0.78			
17				0.69			
18				0.68			
19				0.48			
20				0.76			
21					0.64		
22					0.63		
23					0.54		
24					0.67		
25					0.61		
26						0.69	
27						0.75	
28						0.68	
29						0.62	
30						0.48	
31							0.44
32							0.49
33							0.55
34							0.59
35							0.60
% variance	7.16	4.54	7.14	7.85	6.56	9.71	7.19
Eigen value	2.50	1.59	2.50	2.75	2.30	3.40	2.52

Gequity = Gender Equity, Collabo = Collaboration, Teacheraut = Teacher Authority, Modell = Modelling. Cut off point = 0.3. Note: See the text of these items in Fisher & Waldrip, (1997).

Instrumental variables

The suitability of the instrument for collection of data was evaluated by analyzing the students' data using factor analysis, internal consistency and discriminated validity. The teachers' and researcher's data were only processed for some of these coefficients due to small sample sizes.

Factor Analysis. The purpose of factor analysis was to examine the internal consistency of scales within the 35 items instrument. The determinant value of 1.275E-04, Bartlett's test: p =0.000 and KMO value of 0.813 suggested that data were suitable for factor analysis. Principal components analysis with varimax rotation was used to generate orthogonal factors with eigenvalue of one or more by omitting the factors loading less than 0.3. In this way 9 factors were obtained that explained 56.2% of the variance in students' data explained by 35 items if they were not grouped into factors. This produced two factors each with two items and some other items contributed to more than one factor. Since the instrument was conceptually designed for seven factors, therefore it was decided to reanalyze the data to get a seven factor solution. Table II shows the factor loadings for seven factors obtained from this analysis using the individual students as the unit of the analysis. Scree plot test also justified these seven factors. The percentage variance extracted and eigenvalue (rotation sum of squared loading) associated with each factor are also recorded at the bottom of each scale. The 35 items when extracted into seven factors accounted for 50.0% of the variance in students' responses explained by these items if all were kept independent. The percent variance explained in this study was comparable to the variance 52.7 % and 51.1% for seven and six factors reported by Fisher and Waldrip (1997) and Dhindsa, (2005) respectively.

Table III
Cronbach Alpha Reliability Coefficient and Discriminant Validity for Student Data for CLEQ Scales

Scales	No. of items	Alpha Reliability	Discriminant Validity
		Students (n=1417)	
Gender Equity	5	0.65	0.08
Collaboration	5	0.74	0.10
Deference	5	0.58	0.17
Competition	5	0.82	0.13
Teacher Authority	5	0.72	0.06
Modelling	5	0.68	0.11
Congruence	5	0.77	0.11
Instrument	35	0.81	-

Reliability. Cronbach alpha coefficient was used as a measure of the reliability of the CLEQ. It was computed for the seven factors as well as for the 35 items scale (whole instrument). Table III shows the alpha coefficient for the whole instrument was 0.81 for students' and 0.86 for teachers' responses. The students' data in the table also shows that the alpha coefficients ranged from 0.58 to 0.82 for different scales. These data suggested that CLEQ scales have acceptable reliability, especially for scales containing a small number of items except for deference data. The range of alpha reliability values for the seven scales were comparable to range (0.69 to 0.86) reported by Fisher and Waldrip (1997). Dhindsa (2005) using the same instrument reported the alpha reliability values in the range of 0.68-0.81 for the six scales for data from secondary science students in government schools in Brunei Darussalam.

Discriminant validity. The discriminant validity was measured as the mean absolute partial correlation of a scale with other scales. This procedure was used as a convenient measure of independence of the CLEQ scales. The mean correlation of a scale with other scales (discriminant validity) ranged from 0.06 to 0.17 for students' data and from 0.12 to 0.24 for teachers data for CLEQ scales (Table III). These low values of discriminant validity suggest that the raw scores obtained in CLEQ scales measured relatively distinct aspects of the cultural learning environment. Moreover, the independence of CLEQ-S scales is attested by the factor analysis results. The range of correlation coefficient values (discriminant validity) for seven constructs in the present study was consistent with the ranges: 0.04 to 0.23; 0.09 to 0.18, (Fisher and Waldrip, 1997, 1999) and, 0.11 to 0.18, (Dhindsa, 2005) reported in literature.

Table IV
Scales, Scale Item Mean, Standard Deviation, ANOVA, and Effect Size Data for Students, Teachers and Researcher

Scales	Students (S)	Teachers (T)	Researcher (R)	Comparisons		
	(n=1417)	*(n=49)*	*(n=10)*	SvsT	SvsR	TvsR
	Mean ± SD	Mean ± SD	Mean ± SD	p-value/ES*	p-value/ES	p-value/ES
Gender Equity	4.11 ± 0.62	4.21 ± 0.46	3.92 ± 0.29	0.26	0.33	0.06
Collaboration	4.13 ± 0.67	4.11 ± 0.55	3.76 ± 0.65	0.84	0.08	0.08
Competition	3.69 ± 0.86	3.70 ± 0.80	3.62 ± 0.29	0.94	0.80	0.76
Deference	3.46 ± 0.66	3.24 ± 0.83	3.70 ± 0.47	0.02/0.33	0.25	0.10
Teacher Authority	3.01 ± 0.82	2.62 ± 0.67	2.10 ± 0.83	0.00/0.48	0.04/0.74	0.00/1.11
Modelling	3.51 ± 0.71	3.74 ± 0.58	4.26 ± 0.42	0.03/0.33	0.00/1.06	0.01/0.92
Congruence	3.55 ± 0.73	3.78 ± 0.71	3.42 ± 0.67	0.03/0.32	0.57	0.15

*Effect Size (ES) data for significant differences only

Culturally Sensitive Factors of Students' Learning Environment

Scale item mean, standard deviation, ANOVA and effect size data for students, teachers and researcher are reported in Table IV. ANOVA analysis revealed that mean data for students, teachers and researcher for gender equity, collaboration and competition scales were statistically non-significantly different. Whereas for deference and congruence scales the researcher's data when compared to that for teachers as well as for students, the differences were statistically non-significant. These results suggest that students' and teachers' perceptions and the researcher observation were in agreement with each other for these five scales except for students' and teachers' perception data on deference and congruence scales. The comparison of students' and teachers' data for deference and congruence scales revealed that students perceived statistically significantly higher level deference and lower level congruence than that what their teachers predicted. The effect size values close to 0.3 suggest that the differences are marginal and are of little educational importance. These differences may be the result of large variations in sample sizes for two groups of data. However, p-values less than 0.05 for all the comparisons for the remaining two scales (Teacher authority and Modelling) suggest that the mean values for the three groups were statistically significantly different. The researcher observed significantly higher teacher authority and modelling compared to what students and teachers perceived. Moreover, students perceived significantly lower modelling and lower teacher authority than that what their teachers predicted. The effect size values in the range of low to high for all these comparisons suggest that these differences are of educational importance. While considering all these comparisons reported in Table IV it was concluded that the three sets of data were comparable for all the scales except for Teacher authority and Modelling. For these scales perceived, predicted and observed mean data for students, teachers and researcher respectively were different. Additional details for each scale are discussed below.

Gender equity. Table IV shows that the average scale item mean for gender equity was 4.11, which suggests that students believed both male and female students were treated equally in their classes. They also believed contributions from both genders in the classes were equally valuable. Researcher's classroom observation value (3.92 ± 0.29) also supports high gender equity in these classes. Moreover, the mean values of 4.21 reported by teachers suggest they also perceived a high value and were able to predict students' perception of gender equity in their classes. Average scale item mean values of 4.13 and 4.53 for gender equity were reported for secondary science students in government schools in Brunei Darussalam (Dhindsa, 2005) and Australia (Fisher & Waldrip, 1997) respectively. The comparable mean and standard deviation values for Bruneian government (4.13±0.63) and non-government (4.11±0.62) school students support the previously published data on government schools on this dimension of the local culture. Since the same instrument was used in Brunei and Australia, therefore the differences in mean student data for gender equity in these countries suggest that the instrument was able to pick up the cultural differences in the two countries. Brunei is a country where Malay culture, Islam religion and Islamic values are highly respected, whereas Australia represents a multicultural society with western culture as the majority culture. The results obtained in this study on gender equity suggest that the Bruneian society value women education. At present there are more female than male students enrolled at the institutions of higher education (Dhindsa, 2008). The gender equity in the classroom situation in the non-government schools in Brunei was comparable to that found in some developing and developed countries (Shumba, 1999), but different from the reports which indicated that in some cultures even in the classroom setting, genders were treated differently (Barber, Chadwick & Oerter, 1992).

Tobin and Gallagaher (1987) reported that unfair engagement opportunities provided to male and female students as well as the selection procedures used by teachers encourage inequity in a classroom situation. Teachers can play a vital role to maintain or improve gender equity by providing equal opportunities to both male and female students in their classes. Tobin and Gallagher (1987) also reported that gender inequity is also enhanced by the students' seating orientation in a the classroom. It can put them in a position to be involved more or less in classroom interaction that might contribute towards gender inequity. In Bruneian schools, male and female students sit in different rows. This certainly affects the seating orientation in a classroom. However, there is no research in the Bruneian context on the effects on gender equity of separate seating arrangements for male and female students in classroom, which is recommended. Fisher and Waldrip (1999) reported that the gender equity is enhanced by teachers who were helping/friendly, but retarded by too much freedom. Nurdiyanah (2006) reported that Bruneian lower secondary students perceived their teachers to be highly helping/friendly (mean value 2.5 out of 3). A high mean value on this factor suggests that science teachers' personal behaviour could have helped the lower secondary students perceive higher gender equity in their classes despite students sitting in different rows with limited freedom to mix with the opposite sex. Teacher educators can target to improve upon these behaviours of teacher trainees with a view to improve gender equity in science classes. The curriculum department can contribute towards increasing gender equity by improving upon the teaching materials. Elgar (2001) reported unfair representation of gender in favour of males in the lower secondary science textbooks recently published by MOE. Curriculum materials influence students' perceptions in general. The unequal representation of the two genders in the Bruniean science textbooks could also have contributed to the lower mean score on gender equity scale at lower secondary level.

Collaboration and Competition. The *collaboration* scale item mean value of 4.13 suggested that the students perceived a high degree of collaborative learning occurring in their classes (Table IV). Teachers reported an almost matching value of 4.11 for students' perception, whereas the researcher reported a relatively lower value of 3.76 ± 0.65. The non-significantly lower mean value for researcher might be due to the small number of classes observed where differences in schools' culture and teachers' practices have occurred. The scale item mean value of 4.13 is comparable with the mean values of 4.24 and 4.08 obtained using the same instrument in Bruneian (Dhindsa, 2005) and Australian (Fisher & Waldrip, 1997) secondary science classes.

The *competition* scale item mean value of 3.69 in Table IV shows that the students to some extent liked to compete with each other in their classes. The teachers' predicted value of 3.70 for their students' perception of competitive learning in their classes matched almost exactly. The researcher's observation mean value (3.62 ± 0.29) also supports the students' perception in this regard. The mean value of 4.16 for Bruneian students in government secondary schools suggest that students in non-government compared to those in government schools perceived their classes to be less competitive. Fisher and Waldrip (1997) using the same instrument reported the mean scale item score of 3.03 for Australian students. The differences in the mean values could be due to the difference in cultural make up of students and teachers' teaching styles in these two types of schools, as well as in the two countries.

A comparison of collaboration and competition data revealed that students in non-government schools perceived science learning in their classes to be more collaborative than competitive. These results are different from what was observed in government schools. In government schools, the students perceived equal extent of collaborative (4.24) and competitive (4.16) learning occurring in their classes (Dhindsa, 2005). However, the results of this study are in line with (i) trend reported by Fisher and Waldrip (1997) in Australian data and (ii) the general practices observed in most western countries. According to the observed practices, collaboration and competitiveness are inversely related to each other. Bruneian students come from a collectivist society in which collaboration is highly valued, therefore this factor appears to elevate the mean score for them (Thomas, 2000). According to Thomas (2000), although collaboration is a key element in a collectivist society and constructivist learning, however, schools are designed for competition. This inherent characteristic of the school system might have contributed towards the relatively high value on the competition scale.

Since the mean scores for the competition and collaboration scales were less than the maximum possible values, there is scope for optimisation of these culturally sensitive factors. Fisher and Waldrip (1999) reported that collaboration is more likely to occur when teachers showed leadership, were admonishing or strict. They also stated that when teachers showed leadership, were strict or uncertain or gave students' responsibility, competition was enhanced. Teachers from developing countries including Asia have been reported to be directive and strict (Coll, et al., 2002; Gidding & Waldrip 1993). Bruneian teachers, as reported by Nurdiyanah (2006), showed leadership (mean value 2.8 out of 3) and were also strict (mean value 2.2 of 3). This behaviour of teachers might have contributed to the higher mean values on collaboration and competition scales. However, further improvements to these factors can be achieved by modifying the teachers' specific behaviours. Teacher educators during pre-service and in-service training should emphasize these behavioural aspects of teacher trainees to optimize competition and collaboration in science classes.

Deference. The scale item mean of 3.46 for deference in Table IV, which is greater than 3, suggest that the Bruneian students in non-government schools, to some extent, were unwilling to give their opinions in their classes. Teachers predicted a similar value (3.24) however the researcher observed a higher value of 3.70 ± 0.47. The researcher's data are based on observation of 10 classes only. It could have been a chance factor that the researcher observed classes where teachers provided very little opportunity for students to air their opinion. Dhindsa (2005) reported slightly higher mean value (3.63) for Bruneian secondary science students in government schools and Fisher and Waldrip (1997) reported a lower value (2.98) for Australian secondary science students.

The results of this study are in line with previous classroom observation studies (Monaliza, 2001; Norlina, 2002) which reported that in actual classroom situations, students are generally reluctant to air their views. The results of this study appear to be consistent with the Bruneian culture. People of Bruneian society highly respect hierarchical order. This means that the teacher occupies a higher place in hierarchical series than the students and the students are expected to agree with their teachers and thus not to air their contradictory views.

Moreover, language appears to be another barrier that may hinder students from expressing their own views. English is students' second or third language and their proficiency in it is low. According to Heppner, Heppner, and Leong (1997), less than 15% of Bruneian Form 6 (USA 12th grade) students could read independently at USA 9th grade level, and more than half were reading at the frustration level on the USA 7th grade material. The English text reading level of Bruneian students is about six years lower than their counterparts in English-speaking countries. However, in schools the lessons are conducted in English. Those students who are unable to communicate effectively often fear a loss of identity (Beebe, 1983). The university students' risk-taking behaviour (Ely, 1986) and sensitivity to rejection (Naiman, Frohlich, Stren, & Todesco, 1978) were positive predictors of students' voluntary classroom participation. Dhindsa (2005), based on government schools students' data, concluded that Bruneian students feel that they are confident in their ability to embrace risk-taking even if it might cost them stress in relationship however, their actions appear to be limited by language deficiency and by the superior hierarchical status of the teacher. The results of this study also reflect a very similar situation.

A lower average scale item mean value for students at non-government (3.46) compared to government (3.63) schools suggests that these students were more open to air their views in their science classes. This difference in mean scores was expected because the command of the English language of students in non-government schools is relatively better as reflected by O-level English results. According to these results the pass percentage ranges of students from 2004 to 2006 were 14-15.6 % and 52.2-59.5% for government and non-government school students respectively (unpublished statistics, Ministry of Education, Brunei)

Teacher Authority. For this scale a higher average scale item mean value reflects lower teacher authority. The scale item mean value of 3.01 for teacher authority suggests that the students at this level were undecided on whether they like to follow what the teacher says or do things by themselves. Teachers predicted (2.62) that their students will perceive a higher level of teacher authority in their classes as has been observed by the researcher (2.10 ± 0.83). The average scale item mean value of 3.01 for Bruneian students in non-government schools was close to Australian data (3.02) reported by Fisher and Waldrip (1997).

The results of this study suggest that the students did not see their teachers as highly authoritarian as has been observed by the researcher and felt by the teachers. Dhindsa (2005) highlighted that there are items on the scales that start with "I feel...″ and require students to reflect on their feelings not actions. Based on their feelings the students appear to have scored high on this item, thus increasing the scale mean score. However, teachers and the researcher concentrated on the actions and did not appear to have seen the actions in the classes.

According to Thomas (2000), mostly high power/distance (a dimension of culture that is associated with emotional distance between teacher and students) and collectivist culture go hand in hand, and the strong hierarchical feature of high power/distance dimension will mitigate against the group decision. In most developing countries cultural systems are still typified by a top-to-bottom approach, which favours high power/distance including between teachers and students. Thomas's view supports the authoritarian nature of teachers in Asian cultures, especially where teaching involves traditional approach, is well known. This factor might have prompted the students to record teachers as more authoritarian. In Brunei, the hierarchical superiority of teachers in the social set up gives them authority. Since the data were collected in the presence of class teachers, the presence of a teacher might have helped to increase the average score for the students. Moreover, the Bruneian culture is very considerate and does not encourage speaking against others. This inherent cultural characteristic might also have elevated the students' mean data to some extent. Thomas (2000) also stressed that where there are strong goals, in this case teaching and learning in a classroom setting, participative practices are likely to become part of system. The students and teachers are part of a common system and have strong common goals therefore this factor could have helped students to see teachers as less authoritarian.

Modelling. The scale item mean value of 3.51 for modelling suggests that the students perceived that modelled learning was occurring in their classes and hence they were, to some extent, dependent learners. The traditional teaching styles and examination oriented teaching in Bruneian secondary schools appear to have contribute towards this factor. Teachers predicted a comparable mean value of 3.74, however, the researcher reported the observed value to be 4.26 ± 0.42. According to the researcher's data, learning in the students classes was highly modelled, which might be the result of observing a small number of classes and selected teachers' teaching style. However, this value is slightly lower than 3.76, the value reported by Dhindsa (2005) for students in government schools but higher than 3.10 reported for Australian students (Fisher & Waldrip, 1997). These results suggest that the students in the non-government schools perceived that they were marginally more independent learners in their classes during science lessons than students in the government schools. Since many of the science teachers teaching in non-government schools are expatriate teachers from developing countries, their teaching styles might have contributed towards the mean value for this factor. Some of the teachers in non-government schools are not trained and also their teaching is results oriented. Their survival in the job is based on the percent pass rate in the examination. Furthermore, the mean value might also have been influenced by educational backgrounds of high achieving foreign students especially from India and Pakistan as well as the local Chinese students attending the non-government schools in Brunei. Most of these students attend extra classes outside school (take tuition) in science subjects and their exposure to different teaching and learning styles at school and tuition can influence this value.

In a collectivist society with a high power/distance dimension, like the Bruneian society, students like to be told what to do (Thomas, 2000), hence, teachers are more directive and students follow the directives. The research studies from developing countries, including from Asia, also show that the teachers in these countries are directive with high values for helping/friendly behaviour, admonishing behaviour, and low values for freedom and responsibility (Coll, Taylor & Fisher, 2002; Gidding & Waldrip 1993). Examination oriented educational systems, and, students' pass rates in traditional examinations taken as a measure of teacher efficiency, often forces many teachers to exhibit the above stated behaviours. These characteristics of teachers encourage modelling (Fisher & Waldrip, 1999). These authors reported that modelling tended to occur when the teacher was admonishing and strict. Moreover, with helping and friendly teachers, students favoured modelled learning.

Congruence. The scale item mean value of 3.55 for the congruence scale suggested that the students perceived that what they learn at school, to varying extents, was associated with the environment at home. Teachers predicted higher (3.78) and the researcher observed lower (3.42 ± 0.67) mean values which are nevertheless close to the mean value for students. However, the average scale mean item value of 3.55 was lower when compared to government schools (3.85) reported by Dhindsa (2005) but higher than 3.43 reported for Australian students by Fisher & Waldrip (1997).

Congruence is a key element in teaching and learning as the students are motivated to learn the topics that are useful and relevant to their lives (Jegede & Okebukola, 1991; Waldrip & Taylor, 1994). For many children around the world the educative experience in schools is clearly not consonant with their home experience and the schools do not emphasise what students' homes do (Bishop, 1999). In non-government schools, teaching is result oriented as teachers are preparing students for GCSE–O level external examinations that are set and conducted by UK authorites. Excellence in this examination helps these schools to attract good students. The overall teaching is examination oriented with less emphasis on the aspect of congruence. Therefore, students appeared to have scored a low value on this scale. Since some teachers in these schools are untrained, they lack ability in making science learning at school consonant with home experience. Most of the teachers in these schools are relatively low-paid expatriates. Their limited knowledge of local culture and environment could have been a limitation of their teaching that is picked up by the students while they were responding to this scale. The origin and nature of their teachers' training as well as long successful teaching experience with students from a wide range of cultural backgrounds appears to play a vital role in helping to improve congruence in the secondary science classes. For example, leadership in teachers helps to improve congruence (Fisher & Waldrip, 1999). These authors also reported that students who were more likely to see congruence between what they learn at school and home tend to have teachers who displayed leadership, were friendly and helpful or strict. Moreover, the congruence between what is learned at school and its usefulness in a social setting can be enhanced by relating classroom teaching to students' daily life.

Comparison of Culturally Sensitive Factors of Various Groups of Students.

Under this heading, comparisons of culturally sensitive factors of students grouped on the basis of gender, location (district), grade level and race are reported. Teachers' predicted and researcher's observation data were not processed due to small sample sizes.

Table V

Scale Item Mean Values, Standard Deviation Data and Significance Levels for Male and Female Subjects on Seven CLEQ-S Factors

Scale	Items	Male	Female	Male vs. Female	
		N = 673	N= 673	p-values	Effect size
Gender Equity	5	4.10± 0.64	4.12±0.58	0.522	
Collaboration	5	4.12±0.71	4.16±0.61	0.317	
Deference	5	3.42±0.69	3.51±0.63	0.015	0.14
Competition	5	3.62±0.86	3.78±0.85	0.001	0.19
Teacher Authority	5	3.04±0.83	2.96±0.80	0.088	
Modelling	5	3.49±0.74	3.53±0.68	0.282	
Congruence	5	3.53±0.77	3.57±0.69	0.274	

N = number of respondents; 71 respondents didn't disclose their gender; Effect size data for significant differences only.

Cultural Learning Environment: Male and Female Students

Table V shows that the scale item mean values for all the seven scales for male students ranged from 3.04 to 4.12 and for the female students from 2.96 to 4.16. The male and female students' perceptions on gender equity, collaboration, modelling, teacher authority and congruence were statistically non-significantly different. However, on deference and competition scales the differences were statistically significantly in favour of females. The low effect size values of 0.14 (deference) and 0.19 (competition) show that these significant differences are of little educational importance. These differences might have been due to large sample sizes. It was therefore concluded that there were no gender differences in male and female students' perceptions on deference and competition scales. Based on the overall analysis of the data on gender differences it was concluded that there were no gender differences in students' perceptions of the cultural learning environments of secondary science classes at non-government schools in Brunei. Dhindsa (2005) reported no gender differences in culturally sensitive factors data for government school students. Openness in Bruneian culture and emphasis on female education may have contributed to these results. The Bruneian results are different from the ones reported by Parker, Rennie & Harding, (1995). According to them (a) females prefer a science classroom that is cooperative rather than competitive in nature and (b) females receive less attention than boys from their teachers in the classroom and that would foster gender inequity.

Cultural Learning Environment: Brunei-Muara and Belait Students

Table VI shows that the scale item mean values on seven scales ranged from 2.97 to 4.14 for Brunei-Muara district, and 3.05 to 4.17 for Belait district students. The analysis of students' data from the two districts revealed that the scale item mean values on the collaboration, deference, modelling, teacher authority and congruence scales were statistically non-significant different and hence comparable in both districts except for gender equity (p=.004) and competition (p=.024). However, the low effect size values for gender equity (0.07) and competition (0.13), suggested that these differences are of little educational importance. Based on the above data, it was concluded that there were no differences in students' perceptions on seven cultural factors of learning environment evaluated using CLEQ-S in the Brunei-Muara and Belait districts.

Table VI

Scale Item Mean Values, Standard Deviation and Significance Levels for CLEQ Scores for Subjects from Brunei-Muara (BM) and Belait (B) Districts

Scales	Items	Districts		Comparisons	
		Brunei-Muara.	Belait	BM vs B	
		N=825	N=592	p-values	Effect Size
Gender Equity	5	4.07 ± 0.65	4.17 ± 0.64	0.004	0.07
Collaboration	5	4.14 ± 0.68	4.12 ± 0.64	0.536	
Deference	5	3.45 ± 0.90	3.48 ± 0.65	0.430	
Competition	5	3.64 ± 0.90	3.75 ± 0.80	0.024	0.13
Teacher Authority	5	2.97 ± 0.83	3.05 ± 0.81	0.083	
Modelling	5	3.50 ± 0.72	3.51 ± 0.70	0.724	
Congruence	5	3.53 ± 0.75	3.58 ± 0.71	0.204	

N = number of respondents; Effect size data for significant differences only.

These results are in line with those reported by Dhindsa, (2005) for government schools in four districts of Brunei. His data for Brunei-Muara and Beliat suggest that mean data for all the culturally sensitive scales were comparable despite a wider range in students' ability and parents' economic status in government schools than in non-government schools. Brunei though small in size, the development of its four districts varies at large. Based on regional developmental status of four districts, Brunei-Muara and Beliat, where non-government schools are located, rank first and second respectively. Moreover, the expatriate population is high in these districts. These two factors appear to have contributed towards minimising the regional variations in the students' perceptions in these districts. However, these results are different from those reported by Waldrip and Fisher (2002). They have reported variations in some culturally sensitive factors between urban, rural and mining populations. Their study covered a large regional area in Westren Australia, where variations in regional developmental and economic status of parents appeared to be significant, which could have influenced their results.

Table VII

Scale Item Mean Values, Standard Deviation and Significance Levels for CLEQ-S Scores for Form 3 and Form 4 Subjects

Scales	Items	Form		Form 3 vs Form 4	
		Form 3	Form 4	Significance	
		N=779	N=638	p-values	Effect Size
Gender Equity	5	4.15 ± 0.60	4.07 ± 0.63	0.013	0.13
Collaboration	5	4.18 ± 0.64	4.06 ± 0.69	0.001	0.18
Deference	5	3.50 ± 0.67	3.41 ± 0.65	0.009	0.14
Competition	5	3.75 ± 0.84	3.61 ± 0.88	0.003	0.16
Teacher Authority	5	2.93 ± 0.82	3.09 ± 0.81	0.000	0.20
Modelling	5	3.52 ± 0.72	3.49 ± 0.71	0.491	-
Congruence	5	3.64 ± 0.73	3.44 ± 0.72	0.000	0.28

N = number of respondents; Effect size data for significant differences only

Cultural Learning Environment: Form 3 and Form 4 Students

Table VII shows the ranges of average scale items mean values are 2.93 - 4.18, and 3.09 - 4.07 for Form 3 and Form 4 respectively. For these two groups of students, all these differences were statistically significant except for modelling. However, the effect size values for these differences (0.13 - 0.28) were low and of little educational importance. It was therefore concluded that Form 3 and Form 4 students' perceptions on these factors of cultural learning environments were comparable. The scale item mean values for Form 3 on all the scales were higher than for Form 4 students except for teacher authority which was lower. These significant differences might have been contributed by the large sample sizes. Moreover, it was observed that Form 3 students were more serious with their studies because they were preparing to sit for a national examination, whereas Form 4 students are evaluated by the class teachers. Students' achievement at the national level examination is important for them to select the area of their choice to study at upper secondary level. Dhindsa (2005) compared Form 4 and Form 5 data on the culturally sensitive factors and reported that mean values for all the scales except for collaboration and deference were comparable. The differences in means for these two scales were also at marginal for deference and moderate for collaboration.

Cultural Learning Environment: Malay, Chinese, Indigenous and Other Students

Table VIII shows the range of scale item mean values from 3.05 to 4.23 for Malay, 2.96 to 4.08 for Chinese, 3.03 to 4.35 for Indigenous and 2.98 to 4.29 for Others. The analysis of students' data using ANOVA analysis on the seven scales for the four race groups revealed that all the average scale item mean values were statistically significantly different except for teacher authority (see p-values for overall). These results indicated that at least one of the race based comparisons should be statistically significantly different for six factors other than teacher authority. The post-hoc analysis revealed one comparison each on gender equity scale involving Malays and Chinese (ES= 0.36), and deference scale involving Others and Chinese (ES=0.26) were statistically significantly different. Since the differences in these two comparisons were at a low level as indicated by effect size data, these differences are considered to be of little educational importance. Hence, it was concluded that students from the four race groups perceived the extent of gender equity, modelling and deference to equal extent in their science classes.

Table VIII also shows that the average scale item mean values on collaboration scale for Chinese (4.08) students was statistically significantly lower than for Malay (4.23) and Indigenous (4.35) students. Similarly the scale item mean value for students categorized as Others (4.02) was also statistically significantly lower than for Malay (4.23) and Indigenous (4.35) students. The effect size values for these comparisons (0.23 to 0.51) ranged from low to moderate level. These results suggest that the perceptions of students from different races on collaborative learning in their classes were different. Post-hoc analysis suggested that the perceptions of Chinese and students classified as Others were comparable. Similarly the perceptions of Malays and Indigenous students were also comparable. A similar trend was observed for modelling data. The perceptions of Chinese (3.42) students as well as of students categorized as Others (3.27) were statistically significantly lower than for Malay (3.71) and Indigenous (3.78) students. The effect size values for these comparisons were (0.46 – 0.69) of moderate level. The Chinese (3.46) students also perceived learning in their classes to be statistically significantly and moderately less modelled as compared to the perceptions of Malay (Mean 4.01; ES=0.66), Indigenous (Mean 3.89; ES=0.48) and Others (Mean 3.79; ES=0.36). Based on these results it was concluded that there were valuable differences in perceptions of students from different races on the competitiveness of teaching and the learning process in their classes. The perceptions of Malay students were comparable to those of indigenous students and of Chinese to Other students.

The post-hoc analysis of the congruence scale data revealed that the Chinese (3.41) group perceived congruence in their class to be moderately statistically significantly lower than for the other groups: Malay (Mean 3.67; ES=0.36), Indigenous (Mean 3.71; ES=0.40) and Others (Mean 3.74; ES=0.45). These results suggested that the students grouped as Malay, Indigenous and Others perceived that learning in their classes, to some extent, was associated with the environment at home and helped in their daily life to resolve day to day problems, whereas the Chinese students perceived a relatively low level of congruence between learning at school and its use at home. The overall analysis of race based data on congruence scale revealed three out of six comparisons to be statistically significantly different. These results guided the conclusion that students grouped in four race groups perceived congruence in their classes to be at a different level.

Table VIII shows 16 of the 42 possible comparisons to be statistically significantly different. Chinese students were involved in 12 of these 16 comparisons and perceived significantly lower values for all these comparisons than their counterparts. For the remaining 4 comparisons, students categorised as Others perceived significantly lower mean values on collaboration and modelling scales than their Malay and Indigenous counterparts. Malaysian society is classified as a collectivist society that values more collaboration than individualism (Thomas, 2000). Brunei Malay cultural values overlap with the Malaysian culture to a great extent. This is reflected in results where Malay and Indigenous students perceived their classes to be more collaborative than others. Moreover, in the Kingdom of Brunei, the society is very hierarchical and directive. These effects are reflected in the Malay and Indigenous students' data for Modelling where their mean values are significantly higher than that of Others.

Chinese students in the country follow Confucian ethics. According to Thomas (2000), the diligence and positive attitudes of these students towards education coupled with a high level of achievement motivation, are consonant with the fundamental Confucian concept of learning. These conceptions include a striving for perfection and education for all, and the application of effort to fuel a high level of achievement. This philosophy seems to explain the Chinese students' data in Brunei. These students are generally high achievers and are less satisfied in their classes as they expect more in their classes. They also seem to enjoy more cultural freedom than their Malay counterparts. Moreover, being a minority in the country, Chinese parents are highly concerned about the education of their children and they are heavily involved in helping children with homework and paying for tutors to improve their children's achievement. Chinese parents' pressure on the children to achieve high grades is also associated with their cultural values. The students in the Other category are mostly from India and Pakistan. These students are also high achieving students and experience high parental pressure for high achievement. These cultural variations in the backgrounds of the students seem to be associated with significant differences in the perceptions of these four groups of students.

Table VIII

Scale Item Mean Values, Standard Deviation data and Significance Levels for Malay, Chinese, Indigenous and Others on Students' Races on CLEQ-S Seven Factors

Scale	M	C	I	O	p-values	p-values *(ES)*					
	N=443	N=695	N=65	N=131	for overall	M vs. C	M vs. I	M vs. O	C vs. I	C vs. O	I vs. O
Gender equity	4.12# (0.59)	4.08 (0.65)	4.08 (0.48)	4.29 (0.54)	0.005	0.757	0.976	0.057	1.000	0.005 (0.33)	0.184
Collaboration	4.23 (0.60)	4.08 (0.69)	4.35 (0.47)	4.02 (0.71)	0.000	0.003 (0.23)	0.590	0.012 (0.34)	0.017 (0.40)	0.775	0.010 (0.51)
Deference	3.57 (0.62)	3.40 (0.66)	3.59 (0.55)	3.41 (0.76)	0.000	0.000 *(0.26)*	0.998	0.090	0.170	1.000	0.333
Competition	4.01 (0.66)	3.46 (0.92)	3.89 (0.61)	3.79 (0.84)	0.000	0.000 *(0.66)*	0.759	0.062	0.001 *(0.48)*	0.001 *(0.36)*	0.877
Teacheraut	3.05 (0.77)	2.96 (0.84)	3.03 (0.66)	2.98 (0.90)	0.306	0.328	0.999	0.833	0.916	0.990	0.984
Modelling	3.71 (0.63)	3.42 (0.71)	3.78 (0.68)	3.27 (0.76)	0.000	0.000 *(0.43)*	0.873	0.000 *(0.66)*	0.001 *(0.51)*	0.163	0.000 *(0.69)*
Congruence	3.67 (0.67)	3.41 (0.75)	3.71 (0.72)	3.74 (0.73)	0.000	0.000 *(0.36)*	0.984	0.806	0.018 *(0.40)*	0.000 *(0.45)*	0.993

M, C, I and O are codes given for students from Malay, Chinese, Indigenous and Others races respectively.* Significance levels (p-values and effect size (ES) values in italicizes). Teacheraut=Teacher authority. #Mean and (SD); N = number of respondents. Ninety three students didn't disclose their race.

Conclusions

Under this section responses to research question are summarized.

How suitable was the CLEQ instrument in collecting the data on cultural factors of learning environment of students in non-government schools?

The determinant value of 1.275E-04, Bartlett's test: p =0.000 and KMO value of 0.813 suggested that data were suitable for factor analysis. The excellent grouping of 35 items into 7 factors during factor analysis and low values (0.06 – 0.17) for discriminate validity justify the conceptual distinctions among the scales. The high internal consistency (Cronbach alpha reliability coefficient) values for all the scales (0.58 – 0.82) suggested that each scale has an acceptable reliability. The reliability coefficient of 0.81 for the overall instrument also supports the reliability of the instrument. Moreover, the values are comparable with the data on these coefficients reported in literature (Dhindsa, 2005; Fisher & Waldrip, 1997). Based on these results it was concluded that the instrument was internally consistent, valid, and reliable for collecting quality data on cultural factors pertaining to the learning environment of students in non-government schools. However, the readers should take note that the reliability coefficient for deference scale was low (0.58), and this scale appears to need some revisions.

What are the magnitudes of the cultural learning environment factors, covered in the instrument, in the science students' classes in non-government schools?

The scale item mean values for gender equity (4.11) and collaboration (4.13) are high and for teacher authority (3.01) is low. The mean values for competition (3.69), congruence (3.55), modelling (3.51) and deference (3.46) are at moderate level. The high values for gender equity and collaboration scales in science classes are good indicators of effective science teaching especially using constructivist philosophy. These indicators get relatively less support from teacher authority, competition, congruence, modelling, and deference factors for effective classroom practices. The mean values in the positive range for five scales and teacher authority values at median indicate no serious conflict between these cultural factors in the Bruneian school classroom. Hence these factors are supportive for classroom learning however, the teacher authority, deference and modelling needs attention. Moreover, there is scope for all these factors to be optimized for effective learning.

Were the teachers able to predict their students' perception of these factors?

Statistically non-significantly different mean values for teachers and students for gender equity, collaboration and competition scales suggest that the teachers were able to predict the students' mean response data for these scales. However, low to medium (Effect size range 0.32 – 0.48) level significant differences in prediction of mean data on deference, modelling, congruence and teacher authority suggest that the teachers were unable to predict students' mean perceived data for these scales. These results suggest that teachers were partly able to predict their students' perceptions of cultural factors in their classroom learning environment.

How did the researcher's observation data compare with students' perception and teachers' prediction data?

ANOVA analysis of the three sets of data revealed the mean observed values for gender equity, collaboration, competition, deference and congruence scales were non-significantly different than students' perceived and teachers' predicted values for these scales. However, for teacher authority and modelling scales the differences were statistically highly significant. These results suggest that observation data were comparable with students' perception and teachers' prediction data for all the scales except for teacher authority and modelling. For these two scales as suggested by high effect size data, the researcher observed a statistically significantly higher level of deference and teacher authority than what the students perceived and the teachers predicted. These results suggest that the researcher's observation data partly matched with the other two forms of data.

How are the cultural factors influenced by the subcultures (based on the gender, region, grade level, and race) of this population?

While comparing data for gender, it was observed that mean values for all the scales were statistically non-significantly different except for deference (p= 0.015, ES= 0.14) and competition (p= 0.001, ES= 0.19) scales. Similarly for regional variations, mean differences for gender equity (p= 0.004, ES= 0.07) and competition (p= 0.024, ES= 0.13) were statistically significantly different. However for grade level differences mean values for all the scales except for Modelling (p= 0.49) were statistically significantly different with a range of p-values from 0.000 to 0.013 and effect size values from 0.13 to 0.28. A low level effect size data suggests these differences to be of little educational importance. Based on the effect size data it was concluded that the cultural factors of non-government school students' learning environment were not influenced by their gender, region and grade level.

However, when race based comparisons were considered, it was found that 16 out of 42 possible comparisons were statistically significantly different with low to moderate effect size values. Further analysis revealed that all the mean values on teacher authority scale for four race groups were statistically non-significantly different. The means values on deference scale for the four groups of students were comparable except that Malay students perceived significantly (p= 0.003) but marginally (ES = 0.26) higher deference in their classes than the Chinese students. Similarly for gender equity scale only one comparison where students classified as Others perceived a significantly (p = 0.005) but marginally (ES = 0.33) higher mean value than Chinese students. Based on effect size data representing low level statistically significant differences, which are of little educational importance, it was concluded that the perceptions of students from the four race groups on gender equity and deference were similar in their science classes. However for collaboration, competition, modelling and congruence scales, statistically significant differences for 14 (3 to 4 per scale) out of 24 possible race based comparisons with low to moderate level effect size were obtained. These data guided the authors to conclude that the students from four race groups perceived collaboration, competition, congruence and modelling in their classes differently. The overall results show that the perceptions of cultural factors of the four race based groups of students were comparable on gender equity, deference and teacher authority, but different on collaboration, competition, modelling and congruence scales.

Implications and suggestions

The results of this study supported the suitability of using the Cultural Learning Environment Questionnaire (CLEQ-S) for the evaluation of socio-cultural factors of the learning environment of Form 3 and From 4 science students in non-government schools. Dhindsa (2005) reported that the CLEQ-S was valid and reliable for assessing these factors in a similar setting at government schools. These studies also supported the validity and reliability of the instrument for evaluating the cultural learning environment of science students at various stages of the curriculum in Brunei educational institutions. However, its suitability for other subjects needs to be evaluated. Teachers should modify the items of the instrument to improve its suitability in other contexts.

This instrument includes seven dimensions of culture that influence the learning environment. However, there are more cultural dimensions that influence classroom practices and need attention. Hence there is a need either to extend this instrument to include additional scales or to develop new instruments to cover additional scales. Salwana (2006) developed an instrument to evaluate cultural communication in science classes and the instrument has been reported to be valid and reliable. However, researchers can think on these lines to develop similar instruments that teachers can use to understand better the cultural dynamics in a classroom.

The results of this study revealed that the magnitude of these cultural factors supports the learning process. However, the scale item mean values for the scales are less than 5, the optimum value. There is scope for improvement in these factors. An improvement in scale item mean values and also minimization of differences in scale item mean values for various groups based on gender, race, region and educational standard can be achieved through modifications to the curriculum. A fair representation of examples from various subcultures in the curriculum can help improve the magnitude of these scales. For example an unfair gender representation in favour of males in lower secondary science books used in Brunei has been reported (Elgar, 2001). The mean values for deference (3.46) and teacher authority (3.01) scales as perceived by students suggest that they were willing to air their views only to some extent in the presence of their authoritarian teachers. The curriculum should allow opportunities for students from all subcultures to express their views about scientific knowledge based on their cultural backgrounds. Teachers should use these differences in students' cultural perceptions to develop their lessons. It is important that teachers use cultural values of students to adopt an inclusive teaching approach in their classes. Since, teachers' cultures also influence the teaching and learning process, they should also express their personal views during the development of their lessons, rather than teaching the views of the authors of the book. The curriculum should also encourage teachers' role as a guide than authoritarian. Teacher communication behaviour has been reported to influence the cultural learning environment in science classes. It is important for teachers to be careful while communicating in the class. The Bruneian being a collectivist majority culture and high mean value for collaboration (4.13) can provide support for constructivist teaching. Constructivist teaching encourages group work. Group work encourages students to air and defend their views. Teachers can help the optimization of the cultural learning environment in their classes by grouping students from majority and minority cultures together. This will encourage interactions between students from various cultural backgrounds. Certain actions such as adjusting the curriculum content, changing the methodology of teaching or even bringing up some examples from different cultures in teaching might help to improve the cultural learning environment in science classes.

The results of the present and previous studies have shown a high level of gender equity in science classes. In recent years the dynamics of the classes at institutions of higher education have changed in terms of gender enrolment. At the university level there are about 40 males for every 100 females (Dhindsa, 2008). Similar data has been reported for enrolment at other tertiary institutions and even at the elite schools of the country. This difference has emerged because at school level the number of high achieving girls is higher than that of boys. It is highly desirable for the Brunei Ministry of Education to be vigilant on the effects of this shift in enrolment balance on the various dimensions of the teaching and learning processes in the national education system.

This research is focused on non-government schools where most of the teachers are expatriates and some of them are even untrained. There is a need for these teachers to improve their qualifications as well as to be up to date with the latest developments in the educational field. Teacher training institutions and these schools should concentrate on staff development programmes to improve these teachers' classroom practices especially for teaching multicultural classes. The Brunei government is trying to replace the expatriate teachers with locally trained teachers. Keeping in view how the future teachers should teach the multicultural classes, the teacher training institutes can benefit from this research to train teachers to be culturally sensitive. This can be achieved by designing a culturally sensitive curriculum. Moreover, the teacher trainers should also concentrate on training science teachers on how to teach effectively in culturally diverse classes. Furthermore teacher training should focus on how to use cultural diversity for enhancing the effectiveness of teaching and learning process. According to Thomas (2000), multicultural classrooms help to concentrate the minds of teachers on how to manage their teaching and learning strategies in class. The teachers could be given workshops to get them exposed to activities which concern the cultural learning environment. The need for the development of culture sensitive teacher education and training programmes is highly desirable so that in the long run it is likely to provide a teaching force which would be better prepared for meeting the challenges of the cultural diversity in the multicultural classroom. Thomas (2000) reported that the case for culture-sensitive teacher education is not only viable and clear but it is also long overdue. The local pre-service teachers complete their teaching practice in one semester at one school only. By doing so, they get only limited experience of teaching students from different cultural backgrounds. The distribution of ethnic populations is distinct and specific in four districts of Brunei. The teacher trainees can improve their ability to teach in multicultural classes if they are given an opportunity to teach in more than one school located in culturally diverse districts of Brunei.

In this study, it was found that the teachers were able to partly predict culturally sensitive factors of their students' learning environment. However, improvements are desirable to minimize teachers' reliance on the use of instruments because it requires time and money. Teacher training programmes often put little emphasis on association between cultures and science teaching. It is therefore, important that the teacher training curriculum should include topics on predicting human behaviour with special reference to cultural variables associated with science teaching. Moreover, there is a need to further research the differences between data reported by the students, teachers and observer.

Some significant differences in perceptions of different race groups on certain cultural factors of the learning environments have been reported in this study. It poses a challenge for teachers in non-government schools to optimize their teaching practices to minimse these differences and also to use the cultural diversity in their classes to create a more conducive learning environment for all the students.

In this study, some of the statistically significant differences were treated as of little importance because the effect size values for these differences were low. However, the readers, more specifically teachers, should consider the importance of these small differences. These differences could be of some importance, because teaching and learning are complex processes involving a large number of variables. A complex interaction between large variables involving small significant differences could give rise to useful gains. Therefore, teachers when considering the applications of this research should keep in mind the existence of these differences. Rennie (1998) reported that the small non-significant differences in p-values and low effect size may be of some importance especially when these differences are repeated.

In summary, a major implication of this research is that if we can identify the culturally sensitive factors of the learning environment of multicultural classes, then we can make use of the multicultural make up of science classes to (a) optimize the teaching and learning processes, (b) optimize the curriculum to train culturally sensitive teachers and to develop curriculum materials that should cater to the needs of the multicultural classroom, (c) organize workshops for teachers to get them exposed to activities which concern the cultural learning environment, (d) to improve the culturally sensitive factors of the learning environment in multicultural classes, (e) make use of the multicultural make up of science classes for the optimization of the teaching and learning processes and (f) prepare teachers to meet the challenges posed by students from diverse cultural backgrounds. Teachers could make use of this information to prepare them to meet the challenges of teaching students from culturally diverse backgrounds. Research on how to train teachers so that they are able to predict students' perceptions on these factors is also desirable.

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How does a curriculum intervention that anchors instruction to the study of urban coyote behavior affect student learning?

Jonathan G. Way
Boston College

Abstract

One component of the science education reform process must be a sustained effort toward making the study of science more interesting and meaningful to students, especially in urban areas. Creating authentic learning opportunities where a scientist instructs the curriculum intervention is one way to make science lessons more relevant. This project involved assessing student cognitive gains on a locally relevant science topic: eastern coyotes (*Canis latrans*). This study used a mixed methodological (qualitative – quantitative) framework for students from two urban environmentally-based high school science courses in the Boston area. Both classroom interventions tended to show meaningful learning gains when assessed before and after the short (two to three week) curriculum unit. Furthermore, students retained much of this knowledge during a post-delayed survey ten weeks after the curriculum unit finished. Coyotes and other common wild animals could potentially be used as flagship or charismatic species to trigger increased interest and a knowledge base of the environment in which students live.

Correspondence should be addressed to Jonathan Way, Eastern Coyote Research,
89 Ebenezer Road, Osterville, Massachusetts 02655; E-mail: jw9802@yahoo.com.

Introduction and Purpose

There is mounting evidence that one component of the science education reform process must be a sustained effort toward making the study of science accessible to more students (Jones, 1997). For example, it was found that only 7 percent of all positions in science and engineering were held by minorities, despite the fact that minorities constitute 24 percent of the current United States population (National Science Foundation, 2002). Furthermore, reports indicate that United States students rank very low in science scores, with 18 out of 20 nations outperforming them in international tests (Glenn Commission, 2000). When race is considered, the difference is even more pronounced, While scores of white students in the U.S. were exceeded by only three other nations, black children were outscored by every single nation (Berliner, 2001). But despite this disparity, documents (e.g., National Research Council, 2002) clearly put forward the idea that all students, regardless of culture, gender, and/or race, are capable of understanding and learning science. Because 53 percent of African Americans live inside cities and 88 percent reside in metropolitan areas (United States Census Bureau, 2001), it is critical to engage and motivate urban students to learn science in order to achieve many of the goals of the National Science Foundation (2002), such as diversifying the workforce.

It is increasingly recognized that authentic learning opportunities are one way to make science more relevant to all students (Bouillion & Gomez, 2001; Fusco, 2001; Rahm, 2002), such as involving students in scientific activities similar to those engaged in by scientists (Barab & Hay, 2001). While 'authentic' means different things to different authors (Chinn & Hmelo-Silver, 2002; Hay & Barab, 2001), I view authentic science activities as opportunities for students to learn how scientists conduct their research; this could be by directly participating with scientists or in simulations (see Barab & Hay, 2001), such as videos of research activities (indirect participation) that are brought into the schools.

One way to involve students in an authentic project is to choose a topic of interest because of its local relevance (Rickinson, 2001). For example, coyotes (*Canis latrans*) are often in the news (e.g., Nejame, 2005) across the country due to their nationwide range (Parker, 1995), and some students who normally wouldn't be interested in a standard science issue might be attracted to coyotes because of their notoriety and the fact that they are a wild, relatively large, and potentially dangerous predator. By giving urban students the opportunity to experience a curriculum unit on eastern coyotes, an animal found where they live, they and their teachers will be exposed to many of the goals and objectives of education, such as providing educating to all citizens with the technology to increase the understanding of scientific topics (see American Education Research Association, 1998; Goodlad, 1993; Pine, 2002).

This paper will examine how choosing a locally relevant topic, eastern coyotes, affects student learning. Therefore this paper will attempt to fill in gaps in the education literature by addressing:

What happens to students' knowledge of eastern coyotes after participating in a curriculum unit on them?

The objectives of the coyote unit were:

1. To improve student knowledge and understanding of coyotes.
2. To have students gain an appreciation of the local wildlife around them.
3. To have students understand key terms associated with coyotes.

Background

Urban Science Education

There has been a relative dearth of studies with a primary focus on the needs of urban students and their science teachers, even though 75-80% of the U.S. population resides in urban centers (Barton, 2001; Barton & Tobin, 2001). The literature indicates that providing resources (Spillane, Diamond, Walker, Halverson, & Jita, 2001) and valuing relevant active learning environments are important for students to be able to engage in the practicing culture of science learning in urban settings (Fusco, 2001). Active learning environments are often inquiry-based or hands-on in nature and involve students becoming engaged either in classroom activities, such as labs, or in informal (e.g., zoos), out of the classroom experiences (Hofstein, Bybee, & Legro, 1997). To be successful, science learning and experimentation must take place both in urban schools (Bouillion & Gomez, 2001) and in less structured formats to give students a range of hands-on experiences.

People of color have typically underachieved in education (Norman, Ault, Bentz, & Meskimen, 2001; Seiler, 2001) and are subsequently woefully underrepresented in many professions, particularly those related to the sciences and technical fields (Haury, 1995). There is no single explanation for the gap, but (Haury, 1995) lists two factors that have to do with the disparity: first, African Americans experience more obstacles along the path to careers in science; and second, they have fewer opportunities to see people like themselves in the sciences. Inner city African-American students, especially males, often struggle between representing their own cultural norms or conforming to mainstream standards (Teel, Debruin-Parecki, & Covington, 1998). Teel et al. noted that inappropriate teaching strategies often cause poor performance. Thus, unsurprisingly, black students receive proportionally fewer degrees than their white counterparts with only 73.8% versus 83% receiving high school diplomas, and 13.2% compared to 24% earning college degrees (Teel et al., 1998). A way to reverse the trend is to involve more students directly in real world, place-based science projects (Fusco, 2001; Rahm, 2002; Woodhouse & Knapp, 2000) such as the eastern coyote curriculum unit that is the focus of this paper.

Student Learning of Animal Behavior/Science Concepts

While it is important to involve students from all backgrounds and living environments (e.g., cities and rural areas) in science projects, it is just as important to document the effectiveness of these collaborations and/or the subsequent student learning (or lack thereof) that results from these partnerships. For example, there are 6,314 sources in The Bibliography of Students' and Teachers' Conceptions and Science Education by Reinders Duit (2003). None of these studies addressed the topic of student and teacher learning of animal behavior. However, a few conference proceedings have addressed student learning of animal behavior (Golan, Kyza, Reiser, & Edelson, 2002; Hay, Crozier, & Barnett, 2000; Margulis et al., 2001). Hay et al. (2000) found that students could participate in science by designing virtual reality models of gorillas; these authors noted that students became aware of basic rudiments of gorilla behavior, but more effort was needed for the students to understand gorilla social behavior such as body postures and dominance interactions. The use of technology, such as classroom videos, was found to scaffold student learning, or provide support to enable learners to succeed in more complex tasks, thereby extending the range of experiences from which they could learn (Barab & Hay, 2001; Golan et al., 2002). Margulis et al. (2001) found that a zoo field trip was a very good way to supplement student learning initiated in the classroom. All these studies suggest that combining simulation (e.g., videos) and real-world authentic experiences are important to engage students in learning about animal behavior. Finally, Way and Eatough (2008) found that students could effectively learn about wildlife in the classroom, but it was difficult to involve them and their teachers in an authentic wildlife study without having additional funding to provide for a full-time scientist to implement and design adequate scientific research protocols that incorporate teachers and their students.

Surveys of young people in several countries report low levels of factual knowledge relating to environmental issues, often coupled with poor understanding of such matters (Rickinson, 2001). But studies reveal that participating even in week-long outdoor residential field courses with a local environmental focus, effected positive changes in students' environmental knowledge, attitudes, conflict resolution skills, cooperation, and environmental behaviors (American Institutes for Research, 2005; Rickinson, 2001).

As exemplified by these studies, providing students with experiences and examples from the real world is important toward their understanding of science. Numerous studies that have focused on student participation in outdoor scientific activities show the importance of the local environment in a child's life (Barnett et al., 2004; Bouillion & Gomez, 2001; Fusco, 2001; Rahm, 2002; Sobel, 2004). Odom (2001) also noted that outdoor-based activities are not the exclusive domain of exotic wilderness settings. Rather, worthwhile field projects can be performed in any setting, including cities. The important thing is that inquiry-based authentic activities allow one to experience, not just imagine, reality (Thomson & Diem, 1994).

Study Context

This study focused on two teachers' classrooms and their students from two schools in the Boston area during fall 2004. The participants in this study were the students of the two high school environmental science classes taught by teachers who worked with the Urban Ecology Institute (UEI) at Boston College. The north Boston school (Coyote High School, pseudonym) was urban, while the south Boston school (Wolf High School, pseudonym) was inner-city based. I focused on studying one class from Coyote High School (14 students) and two classes from Wolf High School (totaling 40 students). These classes ranged from low to intermediate level (i.e., at Wolf High) to advanced placement (Coyote High) classes.

Team Members

Doug (pseudonym). Doug, from Coyote High School, was directly involved in the field research component of the coyote study. He was a full-time science teacher and collaborated with the researcher during the capture, collaring, and monitoring of our radio-collared subjects (see Way & Eatough, 2008). Doug also had worked in partnership with the UEI for the past five years in various inquiry-based learning projects, including the coyote study. The curriculum intervention was implemented in Doug's 14-student advanced placement Environmental Studies course for two weeks from October 19 – 22 and 25 – 29, 2004. On 25 October we met at the Stone Zoo's coyote exhibit and gave a presentation to the class in the coyote exhibit with the three resident eastern coyotes.

Tanya (pseudonym). Tanya, of Wolf High, had worked closely with UEI since its inception in the late-1990s. She taught science at Wolf High but did not directly participate in the ecological study of coyotes with Doug and the researcher. However, she allowed the curriculum unit to be taught to her class. The curriculum unit was given to two of Tanya's classes (which occurred back to back at the end of the academic day) in

Tanya's Urban Ecology courses from November 29 – December 3 and December 13 – 17, 2004. Both courses were basic level courses designed to help students gain a science credit to graduate high school. According to Tanya, most students taking this class were trying to obtain the three credits in order to graduate; in other words, as Tanya told me, "they weren't there by choice." Tanya's two classes greatly fluctuated in size with people routinely coming and going, almost like the course was optional (which it was not). Combining the two class periods, on average 20 people were regularly in class on a consistent basis, even though about 40 were signed up. I did not take daily attendance records because of our focus on the curriculum and assessments (classroom observations), and also because students frequently left early or entered the class tardily which made it difficult to keep track of who was present or absent.

The Researcher's Role

The researcher worked on a hybrid doctorate at Boston College which involved scientific (Way, 2007; Way, Ortega, & Auger, 2002; Way, Ortega, & Strauss, 2004) and education (e.g., Way, 2005; Way & Eatough, 2008) components with the goal of conducting an authentic field study of coyotes in urban Boston. Thus, the author acted as lead scientist and educator (who designed the curriculum unit and the assessments) of the coyote study. Other staff at UEI assisted with logistic issues.

I was an active participant in the study, teaching the curriculum unit in a teacher/researcher role. As teacher/researcher, I sought to understand an emic (insider) view of the classroom in order to uncover the perspectives and viewpoints of participants (Pine, Under review for publication; Rossman & Rallis, 1998). This insider perspective allowed the researcher to immerse into the classroom's culture and work directly with my human study subjects. Despite the aforementioned insider point of view, I also could be viewed as an outsider to the schools since I was a scientist/educator coming from outside of both settings and therefore never fully experienced the classroom cultures. Therefore, through interviews and field notes on classroom observations I acted as an outsider (etic perspective) examining the efficacy of the coyote curriculum (Barnett, 2003; Rossman & Rallis, 1998). As an outsider in this sense, I was in the position to relate the participants' experiences to a larger audience (Barnett, 2003).

Settings

Coyote High School. The town, with 44,000 residents, is a multi-cultural city located on the north edge of a large northeast city. Ninety-one percent of its residents are Caucasian, 3.8% are Hispanic, 3.5% are Asian, 1.3% are African American, 0.2% are Native American, and 0.2% are listed as other races. There are 6,984 people per square mile in the city. Coyote High School consists of 1,338 students, 43 percent of which are from families with incomes at or below the poverty level. There are over 140 teachers at Coyote High. In spring 2000, Massachusetts Comprehensive Assessment System (MCAS) scores at Coyote High was 228 for English Language Arts, 224 for Mathematics, and 222 for Science/Technology compared to similar statewide averages of 229, 228, and 226, respectively.

Wolf High School. Wolf High occupies the third floor of a school building that formerly housed an entire high school. The building has been split up into three separate schools that stay largely separated, creating a small school community of about 350 students in each school. The school is a small learning community school in Boston with 390 enrolled students that is theme-based on environmental science. At Wolf High, at least 14% of the students are single parents with young children of their own. Over 85% of the students are from racial/ethnic minority backgrounds (50% black, 30% Latino, 10% white, and the remaining 10% is a mixture of Pacific Islander, Native American, Cape Verdean, and other racial classifications); 13% speak English as a second language; 20% of the students have disabilities; and, all students are from low-income families and 28% live in Boston's federally designated empowerment zone neighborhoods, areas considered to be the most impoverished with the highest rate of unemployed adults and the lowest rate of Boston residents with high school diplomas. In spring 2007, MCAS scores at Wolf High indicated that 0% were advanced, 21% proficient, 69% needed improvement, and 10% failed the English Language Arts test compared to state averages of 22%, 49%, 24%, and 6%, respectively. For Mathematics, 12% were advanced, 17% proficient, 35% needed improvement, and 37% failed compared to state averages of 42%, 27%, 22%, and 9%, respectively. For Science/Biology, 0% were advanced, 2% proficient, 43% needed improvement, and 55% failed compared to state averages of 8%, 34%, 34%, and 24%, respectively.

Curriculum Unit: The Study in a Nutshell

Development

During summer 2004, I developed and implemented a two to three week technology-enhanced curriculum intervention that was designed to support students in learning and caring about coyote behavior. The unit was co-developed and co-taught with participating teachers. The curriculum used PowerPoint presentations (Microsoft corporation, www.microsoft.com) and Windows Media Player videos (Microsoft corporation, www.microsoft.com) of coyotes as multimedia tools (Way, 2005). The unit covered aspects of our research such as capture techniques, handling and radio-collaring procedures, ecology in the wild, behavior in captivity, and coyote behavior around people. The curriculum was designed to get the students involved by having them ask questions related to the material discussed and to have them answer questions based on these activities. The students read relevant literature pertaining to each of the daily activities and also participated in two in-class activities where they were virtual coyote biologists for the day. Finally, the students were provided the opportunity to visit the Stone Zoo and directly observe live coyotes that I hand-reared (Way, 2005).

Piloting

Prior to collecting data, I used two of Peter Auger's (no pseudonym) Ecology classes and his students at Barnstable High School on suburban Cape Cod, as a pilot for this study. I was in his classes for 3 full weeks from 20 September to 8 October 2004. I covered all 10 of the daily lesson plans that I created during the three week unit (see Way, 2005). The three week experience taught me to be flexible in time spent on issues and the order of topics covered based on student and teacher interest in particular topics. The differing length of classes (from 60 – 86 minutes), both in terms of true length (i.e., from bell to bell) and usable time (i.e., when the teacher was not handling other things like attendance), as well as frequent student questions, altered the structure of the class, which made it imperative to be adaptable by answering questions to maintain interest and to satisfy students' curiosity. Nonetheless, I focused primarily on relevant student comments related to the daily activities.

The varied structure of the class (for example, lecture, activity, and field trip to the Stone Zoo) was desirable for the students. Individual students liked different parts (e.g., more lectures versus hands-on related learning) of the curriculum unit making it important to give them multiple learning opportunities. Most importantly, the students seemed to like the curriculum unit. They asked lots of questions, loved the videos, and told me that they thought the videos (in Windows Media Player .mpeg format) illustrated what we talked about very well during the PowerPoint presentations. Because of these comments, I concluded that the curriculum was authentic to the students. Students were especially interested in the videos because it provided a sense of reality and being physically present. Because of the students' interest in the videos I made sure to add more questions to the pre- and post- interviews for the two high schools to better understand why and how the videos helped them learn.

Methods

The methodological framework for this project attempted to engage in an ongoing, evolving design or teaching experiment (Barnett, 2005; Cobb, 2000; Collins, 1992; Dede, 2004; Kelly, 2004; Lesh & Kelly, 2000; Shavelson, Phillips, Towne, & Feuer, 2003). This study relied on mixed methods with a naturalistic, qualitative component (Lincoln & Guba, 1985; Rossman & Rallis, 1998; Schram, 2003) along with some quantitative measures (Scriven, 2000). I triangulated data to gain insight into the effectiveness of the curriculum intervention.

Design Experiments

Design experiments are intended to transform classrooms from academic work factories into learning environments that encourage reflective practice amongst students, teachers, and researchers (Brown, 1992). From this perspective, theory is seen to emerge from practice, and to feedback and guide it (Cobb, 2000). Research is best conceived of as a dialectical process through which both teachers and researchers work together to try new teaching strategies in the classroom and to evaluate the outcomes (Barnett, 2003). In this sense, collaboration between participants (e.g., student, teacher, and researcher) is important in order for teaching experiments to be implemented and conducted successfully. This was put into practice by the researcher presenting the curriculum unit and, taking into account student/teacher comments and suggestions, revising it accordingly for subsequent class periods or curriculum interventions.

Data Sources

Student evaluation was assessed with pre- and post-interview data and pre-, post- and post-delayed survey data. Additionally, teachers came up with their own evaluation related to their course. Standard tests (multiple choice/short answers) and quizzes were given on the material. Homework/class work grades were recorded for participating in the curriculum unit. Lastly, students at Wolf High individually made a mini-book or journal of a compilation of the notes given during the unit (Tanya didn't give them traditional tests).

Qualitative Data Collection. Interviews and my journal/field notes (i.e., classroom observations) were used to obtain qualitative data. By studying two high school science teachers' classes, a description of their students' perceptions and knowledge of coyotes was obtained. The researcher also used tenets of ethnographic research such as observation and participation where the researcher studied and contributed to the culture of the classroom involved in the assessment of the coyote curriculum (Rossman & Rallis, 1998; Schram, 2003). .

I informally interviewed participants, including the teachers, throughout the project to assess the intellectual development during the different stages of implementing the curriculum into the classrooms. Informal interviews were on-going (on average one or two a day, usually after a class period ended) as I formatively documented the observations and experiences that the teachers and their students had during the course of the coyote unit. I also conducted semi-structured interviews (Merriam, 1998) with 10 students from each class before and after the curriculum unit was implemented. For consistency, I attempted to use the same 10 students per class for both interviews; in reality, this did not always occur (Table I). Interviews were digitally taped and audio-data backed up in a personal computer. An interview sheet was used, which consisted of questions in three major sections: one, general science interest; two, general coyote knowledge; and three, specific coyote knowledge (Way, 2005). In addition to taping the interview the researcher occasionally jotted down important notes, such as critical parts of the interviews. I used Escribe software (Express Scribe, 2004) to transcribe the entire interviews onto a laptop computer.

Table Ia.

*Students (pseudonyms) interviewed from Coyote High School, in urban north Boston during October 2004. Note: only students that were interviewed (12 of the 14 students in class) are included herein. * denotes students interviewed both Pre and Post.*

Pre-Interviews		Post-Interviews	
Girls:	Boys:	Girls:	Boys:
Katie	Matt*	Samantha*	Matt*
Nicole*	Tim*	Michelle*	John
Samantha*	Rick*	Nicole*	Rick*
Rachel*	Brad	Robin*	Tim*
Michelle*		Jen*	
Jen*		Rachel*	
Robin*			

Table Ib.

Students (pseudonyms) interviewed from Wolf High School, in urban south Boston during November and December 2004. Note: only students that were interviewed (n = 16) are included herein.

Pre-Interviews		Post-Interviews	
Girls:	Boys:	Girls:	Boys:
Melissa*	Jermaine	Melissa*	Jack*
Marcy*	Chad	Marcy*	Dave
Nadia	Jack*	Lisa	Jamal
Evelyn	Derek	Keisha*	
Keisha*	Bob	Eve	
		Beyonce	
		Carol	

*Interviewed both Pre and Post

For each daily classroom summary I focused on providing a synopsis of each class, describing important things or interactions that occurred, and making any interpretations or emerging hypotheses. I analyzed classroom notes (usually just short phrases written down) made into a curriculum binder and added those thoughts to the summary of each class. Each journal entry was dated for ease of locating specific entries in a file. Included in this summary was the students' involvement as well as my interactions with the participating teacher on a given day.

Quantitative Data Collection. I gave pre-, post-, and post-delayed content surveys and assigned rubric values to two of the interview questions (Appendices 1 and 2) to test students' knowledge of coyotes before and after the curriculum intervention. A follow-up post-delayed survey was given 10 weeks after each intervention to assess student retention of the curriculum. This survey was a modified form of a previously validated one given to students by the Urban Ecology Institute (Barnett et al., 2004) that was originally administered by Moore and Foy (1997). It used a five-point Likert scale of five possible multiple-choice answers (strongly disagree – mildly disagree – no opinion – mildly agree – strongly agree) and consisted of three sections with 35 questions total, two of which were developed and used by UEI. The 20 UEI questions are presented elsewhere (Way, 2005). For purposes of this paper, I only discuss the knowledge related questions (n = 9) on the coyote scale. This scale, specifically designed for this study, intended to uncover students' understanding of coyotes (Way 2005). It ranged from general questions like coyote distribution and range to specific questions on their sociobiology (Tables II and III). Results from this quantitative section should be taken conservatively due to small sample sizes, and should be viewed as trends to support the more in-depth qualitative component of this research.

Triangulation. I triangulated information from multiple sources (Yin, 2000) of evidence by bringing together information from the researcher's field notes/reflexive journals, interview data, documents/data recovered during the project, and pre, post, and delayed surveys. This was done to holistically gain insight into the efficacy of the curriculum unit on student learning of animal behavior.

Data Analysis

Interview and reflexive journal/classroom observation data were coded as described by Strauss and Corbin (1998). Open coding enabled relationships to be identified and similarities among the codes to be recognized. Accordingly, the researcher looked for similarities in the data when coding and grouped similar responses by codes. Subcategories were used where codes were similar yet slightly different. For instance, responses might have been similar because of behaviorally-related responses to an answer. Thus, all coyote behavior answers were coded for in a similar manner (like using a "B"). However, some answers might have been more related to social ecology, or communication (e.g., howling), or how the captive coyotes behave around me. These subsets of behavior would be marked B.1, B.2, B.3, with the 1 meaning things related to social ecology or a 2 related to communication (see Way 2005).

For two of the interview questions related to knowledge of coyotes, the researcher initially created a rubric from 1-5 and scored those questions based on appropriateness of response (Appendices 1 and 2). For each score (i.e., 1, 2, 3, 4, or 5) the researcher wrote a sample answer to aid in the scoring process. The rubric is based upon Barnett and Morran's (2002) categorization scheme except that I used 1 – 5 instead of 0 – 4 for simplicity in converting the data to SPSS. In order to obtain a reliability index of the rubrics that were created, a graduate student in the Urban Sciences Research and Learning Group (USRLG) at Boston College then scored the same answer. Poor correlation (e.g., 40 % at Wolf High) on the first reliability index between the researcher and the USRLG scorer resulted in a modification of the rubric into four categories (Way, 2005). I used correlation analysis to examine consistency in response between the two scorers, and the second iteration of the rubrics produced better correlations with an average of 77% (81% and 73% for the two rubric questions) agreement. I used the scores that the researcher obtained (i.e., not the USRLG scorer), then used a paired t-test (SPSS Inc., Chicago, IL) to compare rubric scores from pre and post interviews.

Additionally, I entered the raw scores of all pre-, post-, and post-delayed survey scores into an excel spreadsheet. The five possible answers were converted from a – e to 1 – 5 depending on desired answer (i.e., either strongly agree or strongly disagree) for each question. These data were then converted into an SPSS file. I used analysis of variation (ANOVA) for comparing the pre-, post-, and post-delayed surveys and Tukey's post-hoc test when ANOVA revealed significant differences in order to examine differences among the three testing periods. I considered $P < 0.05$ to be significant for all of the tests described herein and $P = 0.05\text{-}0.10$ as marginally significant. Again, results from this quantitative section should be taken conservatively due to small sample sizes.

Cross-case analysis

The purpose of examining multiple cases is to increase generalizability (Schofield, 1990), reassuring one that the events and processes in one well-described setting are not wholly idiosyncratic, and to deepen understanding and explanation of the research under study (Miles & Huberman, 1994). Therefore, I examined data from the two schools and searched for themes that cut across cases by:

- Listing important or main themes from each dataset and looking for similar groupings of themes between the two cases and using the established codes to help the researcher in this process.
- Summarizing and grouping the important concepts into a partially ordered meta-matrix.
- Comparing the rubric scores from each school using a paired t-test.

Results

Table II.
Average scores and statistical differences between pre-, post-, and post-delayed surveys at Coyote High School for each coyote-related question. For all comparisons degrees of freedom (df) between groups (i.e., the different surveys) = 2, while within groups the df = 39. For all questions, a score of 1 = strongly disagree, 2 = mildly disagree, 3 = no opinion, 4 = mildly agree, and 5 = strongly agree.

	Pre		Post		Delayed			
Question	M	SD	M	SD	M	SD	F =	P =
Wild coyotes exist on Cape Cod	4.0	0.9	4.9	0.3	4.9	0.3	13.24	0.000
Wild coyotes exist in metro. Boston	4.1	1.1	4.6	0.9	4.7	0.6	2.13	0.133
Coyotes live most of their adult life alone	1.9	0.8	1.8	0.9	1.4	0.8	1.46	0.244
Coyotes often move long distances	3.4	1.0	4.1	0.9	4.3	0.8	3.60	0.037
Coyotes are mostly active at night	4.1	1.0	3.9	1.0	3.9	1.0	0.30	0.743
Coyotes howl to scare people away	2.1	1.0	1.2	0.4	1.0	0.0	11.48	0.000
Coyotes are more like foxes than wolves	2.9	1.1	2.5	1.0	2.0	1.2	2.54	0.092
Coyotes in the eastern U.S. are different than coyotes in western U.S.	4.1	0.7	4.6	0.9	4.7	0.6	2.41	0.103
Coyotes are very difficult to trap	3.2	0.9	3.4	0.9	3.1	0.9	0.21	0.813

Table III.

Average scores and statistical differences between pre-, post-, and post-delayed surveys at Wolf High School for each coyote-related question. For all comparisons degrees of freedom (df) between groups (i.e., the different surveys) = 2, while within groups the df = 64-67 (different values reflected different sample sizes among individual questions). For all questions a score of 1 = strongly disagree, 2 = mildly disagree, 3 = no opinion, 4 = mildly agree, and 5 = strongly agree.

	Pre		Post		Delayed			
Question	M	SD	M	SD	M	SD	F =	P =
Wild coyotes exist on Cape Cod	3.8	1.0	4.5	0.7	4.2	1.0	3.50	0.036
Wild coyotes exist in metro. Boston	3.5	1.2	3.7	1.0	3.3	1.3	0.73	0.485
Coyotes live most of their adult life alone	3.0	1.1	2.7	1.5	2.9	1.3	0.36	0.699
Coyotes often move long distances	3.7	1.0	4.3	1.0	4.1	0.9	2.83	0.066
Coyotes are mostly active at night	3.9	1.0	4.6	0.9	4.4	1.0	3.81	0.027
Coyotes howl to scare people away	2.7	1.2	1.7	1.1	1.8	1.0	6.37	0.003
Coyotes are more like foxes than wolves	3.3	1.0	3.1	1.2	2.4	1.1	4.43	0.016
Coyotes in the eastern U.S. are different than coyotes in western U.S.	3.1	0.9	3.8	1.3	3.7	1.4	2.13	0.127
Coyotes are very difficult to trap	3.1	0.9	3.6	1.2	3.2	1.5	1.20	0.308

Survey questions related to coyote knowledge

Of the nine survey questions related to knowledge of coyotes, three (33%) and four (44%), respectively, at Coyote (Table II) and Wolf High Schools (Table III) produced statistically significant results, with another two (22%) at Coyote High and one (11%) at Wolf High being marginally significant. There were differences in five questions from pre- to post-surveys: (1) Coyotes exist on Cape Cod; (2) Coyotes often move long distances; (3) Coyotes howl to scare people away; and (4) Coyotes are more like foxes than wolves; and (5) Coyotes are mostly active at night. There was a trend for students to score better after students were exposed to the curriculum unit, and students retained much of that knowledge well after the unit finished (i.e., during the post-delayed surveys).

Wild Coyotes exist on Cape Cod. Differences were strong between pre and post surveys ($p < 0.001$) and between pre- and post-delayed surveys ($p < 0.001$). Thus students retained knowledge for an extended period of time related to this question. At Wolf High, Bob believed that the Cape was wooded (compared to Boston) and that is why coyotes live there:

Bob: If you live in the city, then no (coyotes aren't around you), but if you live where there is woods like Cape Cod, then… I don't think they live near me.

Tanya, teacher of Wolf High, noted that the students certainly knew that coyotes were found on Cape Cod. Her comment highlights this point:

Tanya: Well, Jon. It is certainly clear that students know about coyotes on the Cape. A couple of students have asked me when they might be able to go to the Cape and see some coyotes. I tell them that we will look into funding for a school bus to take a trip down there.

Coyote Howling. Large differences existed at Coyote High between pre- and post-surveys ($p = 0.002$) and pre- and post-delayed surveys ($p < 0.001$), yet no difference existed between post- and post-delayed surveys ($p = 0.640$) meaning that students remembered the information after the curriculum unit finished (Tables II and III). Interestingly, the curiosity to this question began during the first class at Wolf High:

Student: Mister, mister, why do coyotes make them noises?

Coyote High's teacher, Doug, also commented about the frequency with which howling was mentioned in class. He made the following comment to me at the end of the first week of the curriculum unit:

Doug: You know, Jon, it is pretty amazing how many questions the students have asked you in this first week of you being here, especially regarding coyote communication. I tried to tell them how cool this research was but it seemed to go in one ear and out the other. Now students are mentioning that they can't wait for you to come back and answer their questions. I am amazed how howling interests them. They know what it sounds like but have no idea why coyotes do it.

Wild Coyotes in Boston. Despite seeing videos of coyotes from urban areas around Boston, students did not believe that they inhabited Boston. I believe this was the case because the students have never observed coyotes near where they live before, and even though I showed video from nearby areas (i.e., towns surrounding Boston-proper), they didn't associate that with coyote presence in their immediate area (i.e., the town/district where they live). For example, during the interview question, "Do coyotes occur near your backyard?," Beyonce's answer was typical of student responses:

Beyonce: No, because I live in the South Boston projects and I don't really think there is many coyotes around.

Interviewer: So, too developed?

Beyonce: Yeah, its like, all buildings, there is really no trees and stuff in South Boston, so…

Doug's comment illustrates the students' confusion with this question:

Doug: A few of the students live by the cemetery where we track some of the radio-collared coyotes. They know that coyotes go in and out of their yards because they live in cul-de-sacs. However, a few of the students live within a short walk of the cemetery but on the other side of the road dividing the cemetery with houses. Over there, there is high density housing and the coyotes rarely, if ever, seem to go over there. Those students, despite their proximity to the cemeteries, don't feel like coyotes occur in their immediate area because they don't see them in their backyard even though they only have to take a five minute stroll to where coyotes are regularly observed.

Following the comments made by Doug I made a note in my journal to reformat the question.

Journal: To be clearer to students, in the future the question should be revised to say something like, "Wild coyotes exist in the Greater Boston area." This may affect results as it seems that many people think of their yard (often in the middle of the city) as their physical backyard and not a nearby park where coyotes may actually live.

Capturing Coyotes. There was no difference at both schools to the survey answer to, "Coyotes are difficult to trap." Students gave the most neutral pre- (3.21), post- (3.36) and post-delayed (3.14) responses of any question at Coyote High (Table II). Students watched videos of the coyotes, saw them being collared, and just assumed because we have done it that they are not that difficult to catch. I was very curious how Doug felt about this question since he worked with me on the wild coyote component of the study.

Researcher: Doug, I don't know how to go about grasping this question. We spend so many exhausting days tending traps before and after school, you would think that the students realize how much effort and hence how difficult it is to trap these critters.

Doug: I agree with you, but you have to remember that you are showing so much video of coyotes captured in traps, then getting collared and measured, and then finally released, that even as I sat in the back of the classroom, it looked like a routine activity, which of course it isn't. The fact that we capture them only about one percent of the time is meaningless to them, and I don't blame them.

Rubrics related to coyote knowledge

In addition to the surveys, two of the questions during the interviews were quantitatively scored based on a rubric (Appendices 1 and 2). Both questions produced significantly different responses at both schools (Tables IV and V).

Table IV.
Rubric scores (1-4) and statistical values from the pre and post content related interview questions at Coyote High School.

	Pre Interview		Post Interview			
Question	M	SD	M	SD	T value	P =
Why do or don't coyotes all act the same?	2.6	0.52	3.5	0.53	-3.857	0.004
Why do or don't you think that coyotes can be eliminated from an area?	1.9	0.32	3.4	0.70	-6.708	0.000

Table V.
Rubric scores (1-4) and statistical values from pre and post content related interview questions at Wolf High School.

	Pre Interview		Post Interview			
Question	M	SD	M	SD	T value	P =
Why do or don't coyotes all act the same?	2.2	0.79	2.9	0.32	-3.280	0.010
Why do or don't you think that coyotes can be eliminated from an area?	1.7	0.48	2.5	0.97	-3.207	0.011

Do All Coyotes Act the Same? Students provided better and richer examples during post-interviews to this question, hence the significant difference observed. The following excerpt from Marcy at Wolf High is representative of students' reasoning during pre-interviews:

Marcy: No they don't act the same, just 'cause coyotes in Boston act differently from the ones in the Midwest; it depends where they are in the country.

Marcy's answer was not technically correct because not all coyotes act the same locally. In fact, individuals in a given locality could be quite different yet particular individuals could potentially be very similar to some coyotes in disparate regions. Coyotes are social, group living carnivores (e.g., Way et al. 2002), but they still are individuals just like any animal is. After the curriculum intervention, students clearly gained a better understanding of the question, as noted in my journal:

Journal: Students approached me before and after classes at both schools. They were giving examples of coyotes and could this or that scenario occur with wild coyotes. The nature of the questions varied, but I repeatedly responded with a similar comment noting that just like you and I are different, so are wild animals.

Beyonce, in the post interview at Wolf High, provided a detailed answer where she gave good examples, explained individual distinctiveness, and compared their (coyote) behavior with humans:

Beyonce: I think some are like, more aggressive. It depends on how, like, they live. Like what they've been through. Just like humans, kind of in a way. Like if coyotes have been through fights, or injuries, they might be more aggressive.

Tanya noted how her students improved their knowledge of this question at the end of the unit:

Tanya: You know Jon, you are really instilling in them the knowledge that coyotes, or any animal for that matter, are individuals just like you and I are. By showing video of the captive coyotes and you interacting with them, you clearly noted how different each individual was. Like how you said that [captive coyote] Cane will fight for possession of your lap, yet is the best hunter in the group... That is really neat that they got to see video of that and hear your experiences first hand.

Can Coyotes be Eliminated? Most students inaccurately answered this question during the pre-interviews but seemed to comprehend the question better and hence scored significantly higher during post-interviews (Tables IV and V). Because of the short length of the curriculum intervention the researcher and teachers could not have possibly expected them to understand coyote terminology completely accurately (like discussing dispersal or territoriality). Pre-intervention answers commonly included the belief that coyotes could be easily removed from an area. In addition, inappropriate terminology was often used. For example, Matt's inappropriate use of the word terminate instead of extirpate is a case in point:

Matt: Yeah if we really want to target and terminate them, yeah, we could do it. It would take a lot of power, a lot of resources to do it.

In addition to not using appropriate terminology in wildlife ecology jargon, it is unclear as to what kind of power Matt is referring to (and no follow-up question attempted to clarify this). I suspect he meant man-power and a lot of effort to eradicate coyotes. Other students thought that coyotes could be eliminated from a general area, they just did not agree with that occurring, as indicated with Jack's statement:

Jack: Very easily (they can be eliminated). It has happened so many times in the past; like grizzly bears, they are almost gone.

Students initially do not realize the difference between coyotes and other predators and how coyotes can quickly colonize new areas, have high reproductive potentials, and don't need as much space as larger species do. However, student understanding of coyote ecology increased after the curriculum unit. Some students had a complete understanding of coyote ecology by the end of the unit and thus explained their results in an accurate and complete way during the post interviews. Rachel's response at Coyote High was notable among the interviewees:

Rachel: No, because of what you told us in class. If you eliminate a certain pack then other packs are going to come in. So, no I don't think that you can eliminate them. You can get rid of individuals but not coyotes in general.

The researcher noticed that some students were grasping the important concepts of the course and the futility of killing coyotes. For example, on 22 October 2004, Samantha asked an important question when we were talking about coyote home range and territoriality. My response was somewhat similar to many of their answers from the interview question:

Samantha: If coyotes are killed won't others just move in?

Researcher: Yes, that is precisely why control efforts are useless unless specific animals are causing unacceptable damage or are a threat to people. It is amazing how basic of an ecological concept that is, but how little people understand that simple concept.

Melissa, during the post-interview at Wolf High, also understood the concept by noting:

Melissa: No, they can't be eliminated. I think people could try but I don't think it would work. Because you said that they reproduce fast and I don't think that you would get all of them if you tried to kill them or move them.

Cross-case Findings

Both classes showed increases in student knowledge during the curriculum unit and that knowledge was retained during post-delayed surveys 10 weeks after the curriculum unit ended in each classroom. Despite similar improvements in the unit's survey and rubric questions (Tables II–V), Wolf High School generally had lower survey scores such that all but one rubric showed significant differences between the two schools (Table VI). This performance difference might be expected since Coyote High School was an advanced course (with more prepared students) while inner-city Wolf High's were lower-level classes with many students on the verge of not graduating. Tanya's comment is illustrative of this:

Tanya: You know Jon, the students really liked the time that you spent with them. They really learned new stuff in a fairly short amount of time. It might be frustrating for you to come into an inner city setting like this and not have students always paying attention, but 20 of the students completed their field journal based on your notes and activities. That is an accomplishment for them.

Doug's comments summarize his students' experiences with the curriculum unit at Coyote High:

Doug: I am really impressed with my students' performance while you were here. They learned and comprehended the material that you gave them and made many positive comments to me, such as asking when are you coming back and wishing the curriculum unit was longer. My gut reaction was that the students really learned something while you were here, and the excellent test scores are now proving that!

The curriculum unit was suitable for multi-level learners, as experienced during the two interventions. My journal notes from Wolf High reflect my continued desire to disseminate this unit to more classrooms:

Journal: I am very happy with both classes at Wolf High and Coyote High. It is clear that this curriculum unit is transferable in a multitude of settings. While Coyote High had higher level learners due to the AP class, students at Wolf High still managed to learn a good amount from the intervention. I hope I can find funding and implement this in other, more diverse areas.

Table VI.
Rubric scores (1-4) and statistic values comparing pre and post interviews at Coyote and Wolf High Schools.

	Coyote High		Wolf High			
Question	M	SD	M	SD	T value	P =
Why do or don't coyotes all act the same?						
Pre-interview	2.60	0.52	2.2	0.79	2.449	0.010
Post-interview	3.50	0.53	2.90	0.32	3.674	0.011
Why do or don't you think that coyotes can be eliminated from an area?						
Pre-interview	1.90	0.32	1.70	0.48	1.500	0.168
Post-interview	3.40	0.70	2.50	0.97	3.857	0.004

Discussion

The curriculum unit improved students' knowledge of coyotes and helped change some of the students' preconceived notions about coyotes and coyote behavior. The advantage for the students was for them to get the opportunity to learn from an expert (i.e., the researcher/scientist) in his respective discipline while participating in legitimate scholarly, school-based activities. While it was beyond the scope of the study to determine if the researcher/scientist was more effective in delivering content than, say, the students' own teacher, the literature indicates that these type of school – university/scientist partnerships are important (National Research Council, 1996; Richmond, 1996). In order to address improving student learning, a number of partnerships have emerged recently in science related issues (e.g., Clark, 1996; Fradd et al., 1997; Hay et al., 2000; Lasley, Matczynski, & Williams, 1992; Sterling & Olkin, 1997; Tallman & Taylor, 1997), and providing students with authentic experiences (e.g., showing video of local coyotes) has been a common theme and a critical component for these partnerships to succeed. Student and teacher interview comments from this paper indicated that students were able to learn and grasp important components of coyote behavior in a fairly short period of time, likely a product of involving students in real science that was authentic and meaningful to them (Barab & Hay, 2001; Barnett et al., 2004; Bouillion & Gomez, 2001; Fusco, 2001; Rahm, 2002). Place-based studies, ranging from urban gardening (Fusco, 2001; Rahm, 2002) to coyotes (this study), overwhelmingly show that students can effectively learn about and/or be empowered to care for their surroundings when they are interested and encouraged to do so.

Importantly, local and national learning standards were addressed during this curriculum intervention. Specifically, this unit addressed Ecology Concepts 6.1, 6.2, & 6.3 and Evolution 5.2 for the Massachusetts frameworks. It also addressed multi-discipline issues in Mathematics by using extrapolation, rate pairs, and by calculating home range, territory sizes, and population sizes. English standards were addressed by reading scientific papers and other literary sources. Finally, scientific inquiry skills standards were met by students designing and conducting scientific investigations and observing the world (i.e., the wild) around them. Students also learned how to graph results from a simple experiment done in class (Massachusetts Department of Education, 2001, revised 2006).

The positive learning gains achieved by the students in this study in a short time period were noteworthy. More effort is needed to teach students and community members alike that it is perfectly natural for coyotes (and other wildlife) to inhabit urban areas. Urban areas (just like any other ecological habitat) can give individual coyotes a chance to raise a family of their own, since coyotes might already live in nearby, more rural environs. Teacher comments and my journal indicated that students better grasped why coyotes live around them at the end the curriculum unit.

Given that students learn well with multiple performance opportunities (Teel et al., 1998), such as participating actively in the intervention's varied activities (Fusco, 2001; Rahm, 2002), it is not surprising to see good learning outcomes from these two schools. A major advantage of this study is that video-clips of coyotes were taken from the field by a scientist and brought into the classroom, thereby giving students the opportunity to learn about the science being taught without having to spend the time directly participating in the research. This strategy can greatly facilitate the content being delivered to students. Similarly, Kahle et al. (2000) found students in inner city areas could learn science effectively if their teachers are well prepared and use standards-based teaching practices. The coyote curriculum unit described here was successful because it was designed from a local, place-based study, it used a diverse array of teaching tools to maintain student interest and to encourage their learning and beliefs about coyotes, and it involved a trained scientist teaching the unit. Future studies, using scientists specialized in different subjects (e.g., other animals besides canids) to teach students about animal behavior, should be evaluated to elucidate the differences in student knowledge in varied curriculum units related to animal behavior. This would enable one to detect differences in the success of certain curriculum pieces that have specific subjects (e.g., coyotes), different instructors, and different materials such as videos.

Implications

Much of the rhetoric in support of student-scientist projects assumes that participants will increase their understanding and/or knowledge of a science topic (Means, 1998; Trumbull, Bonney, Bascom, & Cabral, 2000), yet, very little research on the educational impact of such projects has been carried out. Designing curriculum to engage student interest in science and animal behavior is important (Margulis et al., 2001) and potentially one way to increase student understanding of science concepts. It is important to test students' conceptions of scientific processes and reasoning in order to understand how they learn (Tytler & Peterson, 2004). The use of technology, such as the videos in this study, can be used to provide support to enable learners to succeed in more complex tasks, and thereby extend the range of experiences from which they can learn (Golan et al., 2002). This scaffolding is needed since students often do not possess some of the tacit knowledge required to plan and conduct scientific investigations. Observing animals, whether in the wild or on video, is an activity most students have had some experience with. Thus, animal behavior affords an easier entry into the world of scientific inquiry since students are already familiar with some of the key elements of the domain, such as common animals (e.g., dogs, squirrels) and behaviors (e.g., playing, running) (Golan et al., 2002).

The public often views large carnivores (e.g., wolves and tigers) as flagship or charismatic species that generate much interest because they are familiar to many people (Caro, Engilis Jr., Fitzherbert, & Gardner, 2004; Golan et al., 2002; Walpole & Leader-Williams, 2002). The fact that coyotes are a relatively large, furry mammal that is closely related to dogs and wolves, suggests that they may naturally arouse interest in students. As noted by Caro et al. (2004), flagship species are often used in a strategic role to raise public awareness and have been variously defined as: (1) a popular charismatic species that serves as a symbol and rallying point to stimulate conservation awareness and action; (2) a species that draws financial support more easily; (3) a species that has become a symbol and leading element of an entire ecosystem campaign; and (4) normally a charismatic large vertebrate that can be used to anchor a conservation campaign because it arouses public interest and sympathy. Due to their predatory habits and presence in urban areas, the public is very aware of coyotes which make them an ideal subject for science education. Because of the coyote's continent-wide range (Parker, 1995), they could potentially be used by science educators in quite diverse settings. I argue that coyotes could serve as an excellent flagship species for engaging students in science education and ecology-related issues. Future studies should examine these types of curriculum units and assess the ability to empower students to learn and care about their local environment and wild inhabitants, especially in urbanized settings. For example, environmental education programs on bats in the Indian Ocean region empowered residents to protect native forests and bats in those places (Trewhella et al., 2005). It is logical then that this could also happen with common species in diverse areas ranging from rural to urban locales.

It is critical to ensure that there is adequate funding for curriculum units on the natural history of different species, as natural science studies are gradually being replaced by molecular research (Louv, 2006). It is also important to promote scientists working with teachers and their students in more numerous and varied settings to give students the opportunity to capture an interest and/or better learn about science topics near where they live.

Limitations of the study

There were some obvious limitations with this study. First, I only studied two high school teachers' classes. Despite the potential usability and generalization that this curriculum might provide, this particular study cannot demonstrate conclusive and widespread results with such a small sample size; successive, future studies will have to do that. Second, I was only in each of the classes for a few (2-3) weeks each. Thus, I had a very focused and narrow window for assessing student learning. While it is potentially beneficial to limit this curriculum unit to about a week (e.g., so more schools/classrooms can fit it in with existing curricular units), this shortened time frame would likely make it difficult to notice any long-term learning gains. Third, I taught the unit to different audiences, ranging from inner-city to suburban-like city-based students. These students clearly had different levels of experience with nature. Fourth, the researcher's presence may affect the future usability of this material. Being a content specialist on coyotes I will most likely be able to respond to any potential problems or questions that arise. Though this material is in effect a pilot for future aspirations of implementing this curriculum to more venues, my absence might make implementing this unit difficult in other classrooms where I am not the teacher.

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Appendix 1.
Rubric for the question "Explain why coyotes do or don't all act the same."

1) No conception, confused, or short response: Students are unable to articulate a response to the question or students lack knowledge of basic concepts. They give short answers without any supportive statements. For example, students say yes/no without any reasoning.

2) Incomplete/Inaccurate Understanding: Students do not have a good understanding of the question. They use poor terminology to explain their answer such as saying that coyotes are communal animals, coyotes are a breed, or that one population has similar individuals but as a whole they differ from other areas. Students often conflict their statements saying that coyotes are different (do not act the same) in one statement, then they say that coyotes are the same at another point.

3) Partial Understanding: Students know the basic concept that coyotes do not all act the same. They either give examples by saying they are dominance-related, behaviorally- related, etc. or they explain that coyotes are individuals (many say like people are). However, they do not give a complete answer, both giving accurate examples and explaining that coyotes are individuals; i.e., they display variation.

4) Complete Understanding: Students understand that all coyotes do not act the same. They explain that coyotes are individuals and provide examples relating to other animals (such as humans) in their response. They give examples of individual variation such as dominant and submissive coyotes, variation in communication, and/or different roles that they play. Statements can be short and to the point as long as they include both examples and individual variation.

Appendix 2.
Rubric for the question "Why do or don't you think that coyotes can be eliminated from an area?"

1) No conception, confused or short response: Students are unable to articulate a response to the question or they give brief responses without providing any details. Students lack knowledge of basic concepts.

2) Incomplete/Inaccurate Understanding: Students do not have a good understanding of the question. For example, they explain why coyotes can be eliminated from a given area when in actuality it is very difficult. Students may also note that if we kill them, then they can be eliminated. They may state that we have done that with many other animals in the past. Or students correctly answer that coyotes cannot be eliminated but do not describe how this can happen. Some students use a questionable rationale that has nothing to do with recolonizing a territory, such as that it is difficult to kill each and every coyote.

3) Partial Understanding: Students know the basic concept that coyotes cannot be eliminated from a given/general area, but do not explain how coyotes can quickly reach new areas or that although individuals can be killed, it is difficult to get all coyotes. Their answer is missing key terms and lacks a full, detailed and completely accurate understanding.

4) Complete Understanding: Students understand that coyotes cannot be eliminated. They mention that they are difficult to kill and if one is killed another coyote will quickly move (disperse) into that territory. Thus, people can kill individual coyotes but it is very difficult to eliminate (or extirpate) an entire population in a given area.

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Looking Inside a Student's Mind: Can An Analysis of Student Concept Maps Measure Changes in Environmental Literacy?

Thomas Meagher
University of Minnesota

Abstract

This study examined hand drawn concept maps from 34 students, ages 17 – 55, enrolled in a community college environmental biology class. Maps were collected three times during the semester-long course, and analyzed using graphical representation and structural analysis to determine the level of complexity at which students organized and learned the content of environmental science. Graphical changes within concept maps showed a significant increase in the number of complex network-style concept maps generated with a Chi-square analysis calculated a $x^2_{.05}(2) = 7.52$, which exceeds the critical value of 5.99. Structural components within concept maps measured linear increases in the number of nodes, links, and link terms or propositions used. Map components increased by 29% and 35% for nodes and links respectively, and by the end of the semester, measured a 70% increase in proposition usage. In conclusion, significant increases in map propositions and graphical complexity support how students develop skills in articulation of knowledge and demonstrate a more literate understanding of environmental science content.

Correspondence should be addressed to Thomas Meagher, University of Minnesota, meagh014@umn.edu

Rationale

Understanding the synergistic effects of the interactions of biological, chemical, and geologic factors impacting ecological systems requires students to understand complex relationships among many scientific concepts. Environmental science is a complex discipline that pushes students to see connections among multiple disciplines of learning. In today's world, students who choose to study environmental science examine how local, regional, and global events have interconnected and multifaceted components. Environmental science teachers should use assessment tools that can measure how students understand the conceptual complexity and interrelatedness among systems.

Teachers generally use multiple assessment tools such as exams, quizzes, research papers, inquiry projects, and portfolios to gauge the learning and understanding of concepts studied. One rarely used form of paper and pencil assessment is student-generated concept maps (McClure, Sonak, & Suen, 1999). Concept maps have been used extensively as assessment tools by researchers to determine how students develop a relative knowledge base and interrelation understanding of concepts within science content (Iuli & Helleden, 2004; Van Zele, Lenaerts, & Wieme, 2004). Teachers have also used concept maps as assessment tools to gauge student perceptions of science concepts (Kinchin, 2001; McClure, Sonak, & Suen, 1999; Odom & Kelly, 2000).

In this study, concept maps were used as an assessment tool to examine how students enrolled in an introductory environmental biology course developed more complex understandings of scientific content. Students creating hand-drawn concept maps can graphically demonstrate their interpretations of how the concepts studied in environmental science are interrelated on a single page, while an in-depth essay may take many pages for a student to accurately explain how they envision these same cognitive relationships. By using concept maps, a researcher, or teacher, has a rapid assessment tool for measurement of student interpretation of concepts being studied. The goal for this study was to determine how students' understanding of environmental concepts developed over an entire semester of study, and if students developed a complex integrated understanding of the environmental concepts. To observe how student knowledge construction changed over the course of the semester long class, there were several questions this study investigated. First, does a student's knowledge construction of environmental issues become more complex over the course of the semester? How does the composition of student concept maps, the number of nodes, link, and link terms change from the beginning to the end of a course? And lastly, is there an increase in the graphical complexity displayed in the student's concept maps?

Literature Review

Environmental literacy can have several meanings (Stables, 1998). The most widely accepted foundations for environmental literacy were put forth by the National Environmental Education Act of 1990, stating that literacy can be identified by students displaying knowledge and skills in ecological concepts, conceptual awareness about how behavior effects the environment, knowledge in investigation and environmental action skills (United States Environmental Protection Agency, 1996). In the past, measuring successful acquisition of knowledge in environmental studies has been assessed through pre-post test analysis (Morrone, Manacle, & Carr, 2001), self-reporting surveys (Cullen & Money, 1999), or student interviews (Gayford, 2002). Since environmental science consists of the integration of several scientific disciplines, students are expected to study and learn how concepts in geology, biology, chemistry, or ecology are related and interdependent (Roth, 1992). Restricting assessment to standard tests or survey responses presents a limitation to measuring how a student successfully integrates concepts from several domains of science. This also limits a researcher to verbal responses, which attempt to demonstrate knowledge, but may show a partial picture of how a student understands the complex interrelationships among environmental concepts. Researchers utilizing concept maps may gain additional information to determine how students organize complex, and integrated science concepts.

Researchers utilizing concepts maps as research tools have explored student's knowledge construction in several science disciplines. For example, in biology education researchers examined student concepts maps in order to identify how they categorized information and organized integrated science concepts (Odom & Kelley, 2000). Concept maps have also been used to measure how students demonstrate hierarchical relationships in their understanding of what they have learned (Rice, Ryan, & Samson, 1998). To determine where students demonstrate misconceptions, researchers have analyzed student concept maps to gauge how students may represent their misunderstanding of scientific concepts (Iuli, 2004). In this study, the researcher utilized concept maps to determine how students can demonstrate the complexity of the interrelationships among unique scientific concepts as they relate within environmental science.

A wide variety of techniques have been employed in scoring the complexity of concept maps. Novak and Musonda (1991) emphasize a hierarchical approach to examine the levels of knowledge, the number of nodes (single concepts), links between nodes, and cross-links among nodes. Yin, Ruiz-Primo. Ayala, and Shavelson (2005) used a graphical approach, categorizing maps into groups based on overall shape such as linear, circular, hub & spoke, or network. Yin et al. (2005) proposed several categories of maps considered simple in form and therefore representative of a simple understanding of a particular subject (Yin et al., 2005). Simple categories included maps shaped into *linear*, *tree*, *circular*, and *hub & spoke* (see Appendix A). Maps considered complex were shaped in a *network* (see Appendix A) format in which there were more interconnections than nodes within a concept map. Kinchin and Hay (2000) discussed a methodology of interpreting maps using a more qualitative approach for categorizing maps but classifying maps into three categories: spoke, chain, or net. They argue for using both a qualitative and graphical analysis of concept maps for several reasons, suggesting this method is less cumbersome than numerical scoring and provides more structural interpretation of concept maps. However, having only three categories can be too limiting when attempting to catalog maps into groups based on structure, because the compositions of some maps cannot be fully classified simply as a chain or a spoke. Neither method, as described by Yin et al. (2005) and Kinchin and Hay (2000), had full or complete explanations of how each of these categories of concept maps could be classified. Both authors agreed, however, on how simple structured maps correlated with simple or naïve understanding of scientific concepts while complex or network style maps demonstrated more advanced or mature understanding of the interrelationships among multiple scientific concepts (Kinchin & Hay, 2000; Yin et al., 2005). In this study, these techniques were used in initial analysis of the concept maps, however, results proved to be too subjective in determining the precise placement of various concept maps based on their graphical structure. Student concept maps collected within this study, exhibited variance in both graphical and structural composition and demonstrated significant measurable differences in concept map construction.

In a study conducted by McClure, Sonak, and Suen (1999), the researchers utilized six different methods to score 63 maps collected from undergraduate education students. The scoring techniques ranged from a holistic method, to a subjective technique where raters could award a map with a score from 1-10 based on criteria from complexity, to a structural method quantifying each of the components within a map such as links, nodes, cross links etc. Interestingly, the data the team collected showed a balance in inter-rater reliability when examining composite scores. However, individual analysis methods demonstrated greater variance in subjective graphical scoring methods than in the more time-consuming structural analysis of concept maps (McClure et al., 1999). Kinchin's (2000) qualitative approaches to categorizing maps provide a rapid assessment method for analyzing how students develop mature understanding of biology concepts. Kinchin (2000) further argued, “the construction of a concept map is to reveal the perceptions of the map’s author, rather than a reproduction of memorized facts” (p.44). Following the foundations provided by these researchers, this study examines how student concept maps evolved over the period of one semester of study.

Method

Participants

The participants in this study were 34 students enrolled in an introductory environmental biology course offered through a community college in southern Minnesota in conjunction with two local corporations. The course had an environmental science-focused curriculum that integrated several domains of scientific studies, including biology, chemistry, and geology. Students participating in this course were adults enrolled in the college and employed at either local corporation. This course was offered at the worksite and after work hours for employees to further their education. Students ranged from 17 years old to 55 years old, and it was their first science course after enrolling in community college.

Measures

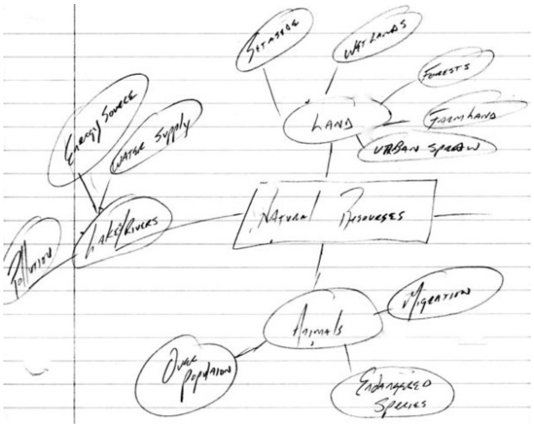
To examine how students organize and display their conceptual framework of environmental science concepts, students were asked to generate hand-drawn concept maps during class time and collected three times during the semester. Students were instructed on how to create concept maps using two approaches. First, students were asked to read a short section of their textbook that described how to create concept maps and showed a simple concept map diagram. The instructor then led a large group class discussion to generate a concept map on the white board using topics and link descriptions forwarded by students during the course of the class discussion. After the large group had completed the concept map on the whiteboard, students were asked to create individual concept maps and encouraged to use examples presented in class to assist them in created their own hand-drawn concept maps. To provide for some randomization of data, students were encouraged to pick any topic for their maps from a list of concepts studied during the course of the semester and written into their syllabus at each point of data collection during the study. Since the students were allowed to randomly pick topics for their individual maps, analysis focused on the structural components of maps from the entire participants in the study group, rather than on changes observed in specific individual’s maps during the semester. The scientific content of any one specific participants’ map could vary during the course of the study; for example an individual could create their first concept map about water pollution, their second map about urban impacts on water, and their final concept map may have been focused on Minnesota lakes and streams.

Concept maps were collected three times during the semester, on the first day of class, with the midterm exam, and with the final exam on the last day of class. This provided a chronology to be used for examining how students progressed in the complexity of their content understanding. These maps were collected, with traditional exams, to be analyzed to observe how content knowledge related to new information learned during the semester.

This study utilized a combination of graphical organization and quantitative data analysis of concept map components. First, maps were scored by tabulating the number of structural components for each map which included counting the number of nodes, links, and link terms (Figure I). Mean scores were then determined for each component of the concept maps, at each collection point during the semester. Ratios of each component were also calculated to see how the composition of student maps changed during the semester. For example, a ratio of the mean number of links to nodes was examined to quantify increases in the number of links used as the number of key concepts increased in student concept maps. Link terms also play a critical role in concept map formation, as these terms describe the relationship between two node concepts (Novak, 1991). Therefore, analysis of the ratio of link terms (propositions) to links generated was also quantified and compared to other components of the concept maps. The percent increase in link term usage was determined over the course of the semester, for the study group.

Scoring of individual maps was statistically analyzed to determine mean values of individual components within maps for each point of collection during the semester. Quantification of the interrelationship of components was also determined through calculation of ratios between the usage of various parts within maps and the percent of total usage of the nodes, link, branches and link terms within class concept map samples. Percent totals for both simple and complex form maps were calculated and differences in percentage were analyzed using chi-square analysis to determine significance. Since concept maps are composed of three major interdependent components chi square analysis provides the most accurate analysis of the goodness of fit between the observed data and the expected theoretical results.

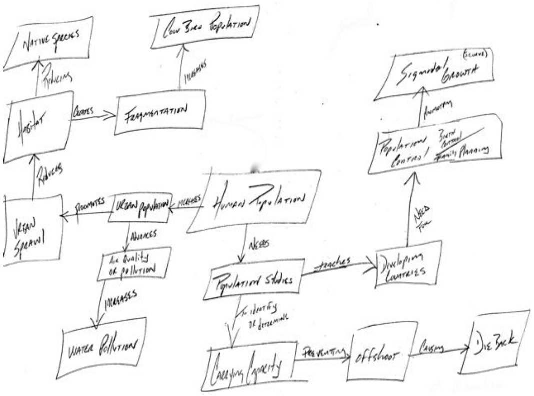
In addition to analysis of propositional complexity, concept maps were analyzed for graphical sophistication (Figure I). Concept maps were grouped, at each collection point, based on the structural categorizations put forth by Kinchin & Hay (2000) and Yin et al. (2005). This included grouping student concept maps into structural categories such as linear, circular, tree, hub & spoke, network or wheel shaped maps based on the qualitative visual comparison of student maps to example templates (see Appendix A). Totals were calculated for each graphical category and statistical analysis to determine percent of total for each category was tabulated (see Table I).



Student 1 concept map from the 1st day
Graphical categorization: Branched Tree

Quantitative analysis:
\# nodes = 15
\# links = 15
\# link terms = 0
Ratio of link terms to links = 0 (propositions)

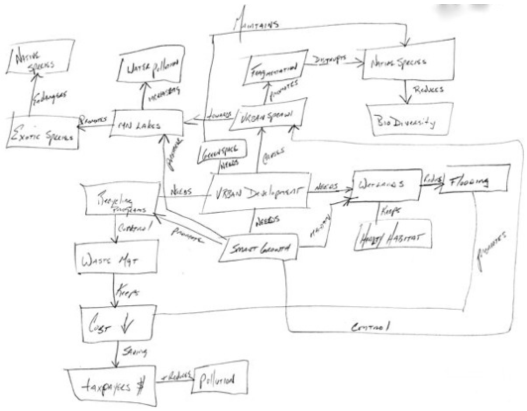
See Appendix B for larger image



Student 1 concept map from midterm
Graphical categorization: Branched Tree

Quantitative analysis:
\# nodes = 16
\# links = 15
\# link terms = 15
Ratio of link terms to links = 1.0 (propositions)

See Appendix B for larger image



Student 1 concept map from final day
Graphical representation: Network

Quantitative analysis:
\# nodes = 19
\# links = 23
\# link terms = 23
Ratio of link terms to links = 1.0 (propositions)

See Appendix B for larger image

Figure I. Exemplars identifying graphical representation and quantitative scoring of one student's concept maps collected three times during the study.

Reliability Measures

In this study the all maps are scored and categorized within a three-month period of the completion of the course. The quantifying of structural components of maps was conducted when all maps form the entire semester had been collected. Each component of the concept maps were gauged for scientific accuracy based on the criteria of science content relevant to the course of study, the textbook used in the course, and any lecture or lab materials available for the students. Data recorded from student concept maps within this study reflects accurate representation of information with reference to environmental science as judged by the researcher and solely responsible for tabulating all structural components of nodes, links and link terms.

Categorization of maps structures were assessed within three months of the completion of the course and collection of all concept maps. Also, the investigator was responsible for all categorization of concept maps based on graphic representation and utilized the same graphic categories for each set of maps collected during the semester. Since the investigator conducted all quantification of data, bias due to inter-rater reliability has been minimized. Also, measurements were conducted within the same time frame to minimize bias in categorization of samples.

Results

An analysis of student maps shows several significant changes over the course of a semester. Since maps were analyzed using several basic methods, the results from each technique will be discussed separately.

Graphical Categorization of Concept Maps

A gradual shift in graphical complexity was observed of the simplest maps, such as the linear and tree formats, to the more complex circular and hub & spoke formats. Percentages of each of the other simple concept map types remained relatively stable through out the semester. Concept maps created in a tree formation had the most stable measurements throughout the semester varying by only 3.5% (see Table I).

Table I

Percentage of student map complexity by type of structure and group for each occasion of sample collection.

Structure	Map Type	1st Day (n=22)	% of total	Midterm (n=34)	% of total	Final (n=29)	% of total
	Linear	2	9.1	3	8.8	0	0.0
Simple	Tree	5	22.7	8	23.5	6	20.7
	Circle	3	13.7	3	8.8	5	17.3
	Hub & Spoke	9	40.9	9	26.5	11	37.9
Complex	Network/Wheel	3	13.6	11	32.4	7	24.1

(Each type of map is hyperlinked to an exemplar to 1st day concept map samples, see Appendix C.)

The study found 9% of students using the simplest linear form of map on the first day, dropping to no students using the linear concept map on their final class. Interestingly, only one student who used the linear concept map format in the early part of the course completed the entire course and received a grade.

Analysis of concept map scoring based on graphical shape and representation, students showed a significant increase in generating complex maps, going from a percentage of the class using complex designs of 13.65% at the start of the course to over twice as many students, 32.35%, using the network style design at midterm. However, only 24.14% of students utilized the complex design on their final exam, a decrease from the previous high value but still demonstrating twice as many students were displaying more complex maps compared to the beginning of the course. The drop from 32.35% to 24.14% is unexpected, but possibly demonstrating that students improve greatly by midterm and then maintain an elevated level of performance for the rest of the course (see Figure II). Statistical analysis of these results using chi-square analysis demonstrates significant differences in the percentage of students generating complex concept maps. Calculating a $x^2_{.05}(2) = 7.52$ x^2 exceeds the critical value of 5.99, and therefore results demonstrate a significant increase in observed complex concept map generation by the end of the semester (see Appendix D for final class network/wheel exemplars).

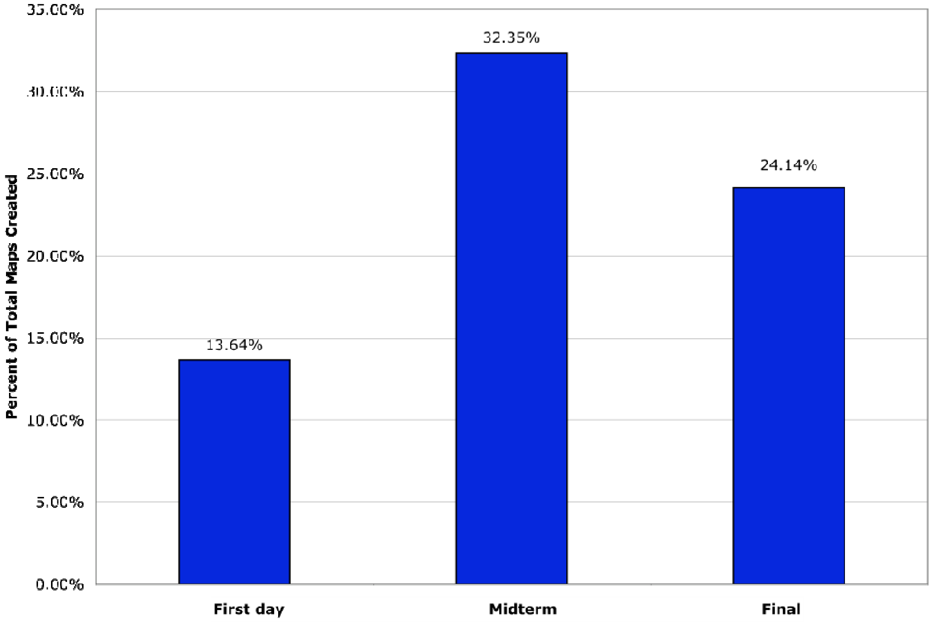


Figure II. Comparison of complex concept map development.

Concept Map Component Usage

In node acquisition and usage there is an almost linear increase observed in student concept maps over the course of the semester. For example, mean increase in node usage increased from 11.64 nodes per map to 16.38 nodes per map, a linear increase of 2.37 nodes per sample. Also, the mean use of links has a similar rate of increase from the beginning of the semester until the final exam, from 12.27 links per map to 18.93 links per map. This translated to a linear rate increase of 3.37 links per sample. Lastly, link term (proposition) usage increased over twice the rate of node acquisition with a rate of 4.88 terms per sample (see Figure III).

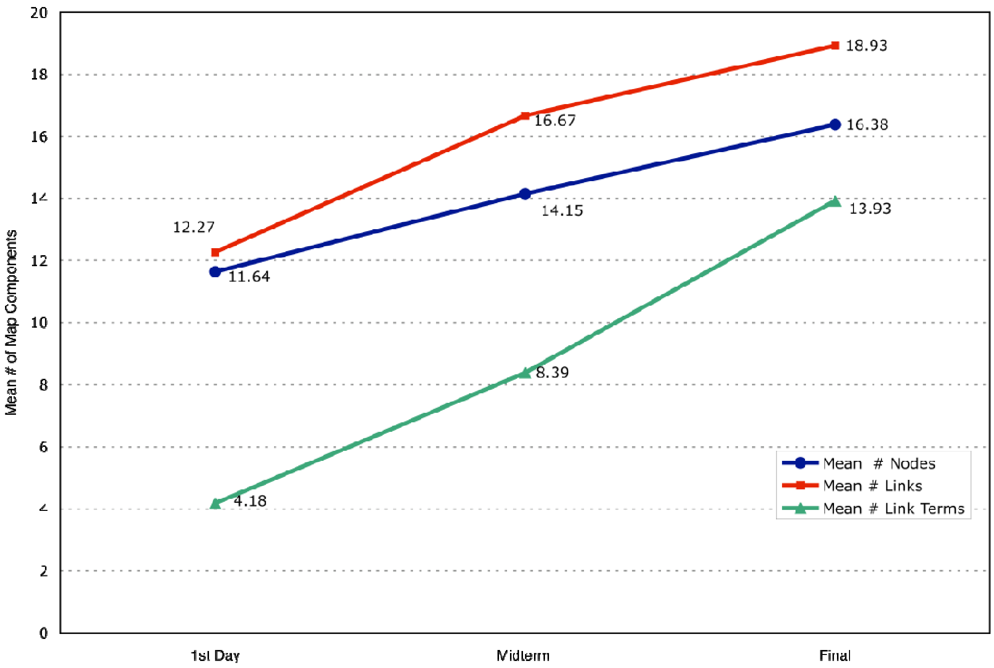


Figure III. Comparison of changes in map component usage.

The most dramatic and significant change in component usage is the mean number of link terms per map changing from 4.18 to 13.93 from first day to final day. Link term usage changes from only one third of links being identified with appropriate terms to an almost 1:1 ratio of number of links to link term usage (see Figure IV). This is a 70% increase in term usage over the course of a semester compared to increases of 29% and 35% for node and links usage during the semester respectively, and is twice the increase in component usage compared to the other two components within maps. A $x^2_{.05}(2) = 21.92$ exceeds the critical value equal to 5.99, and we can therefore reject the null hypothesis that all concept map components have the same percent, which suggests that students demonstrated a significant increase in link term use on their concept maps over the course of the semester.

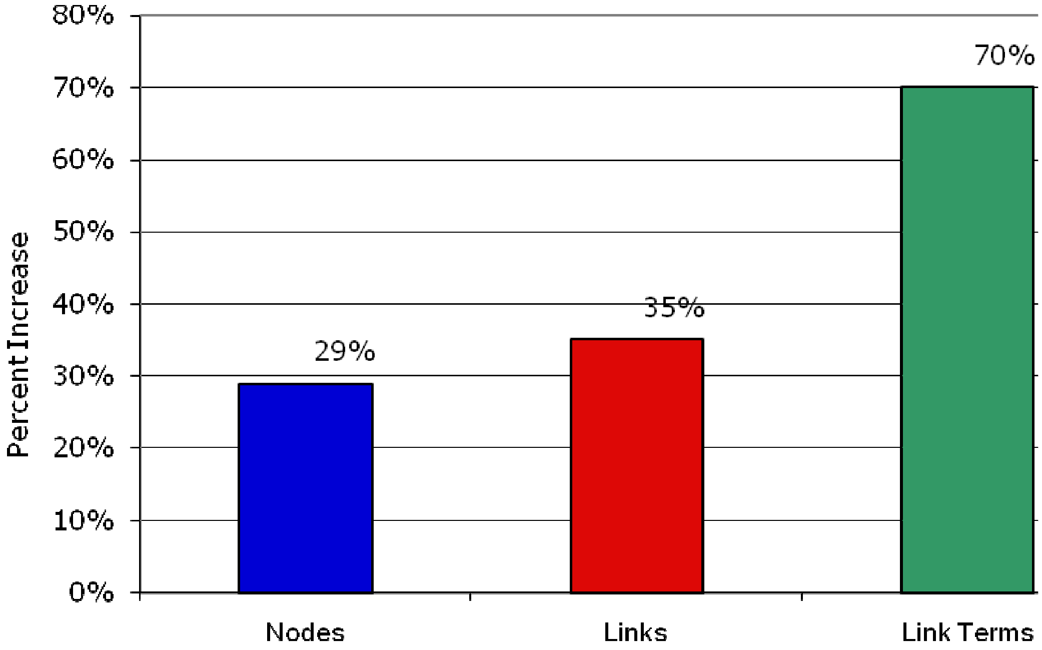


Figure IV. Percent increase of concept map component usage over the semester.

Ratios Comparing Concept Map Components

On the first day of class, students had a ratio of 2.93:1 links to link terms respectively, while by the final exam this ratio dropped to 1.36:1. Novak describes a concept map as a diagram where encircled concept nodes are connected by drawn links with terms to describe the relationship between concepts, which would give an expected ratio of drawn links with appropriate link terms to be 1:1 (2005). This definition suggests that students would properly label all links within their maps, to create an accurate scientific proposition, if they possess the appropriate level of literacy to articulate perceived relationships among scientific concepts. Data within this study shows distinct differences in student ability to accurately label links (see Figure V).

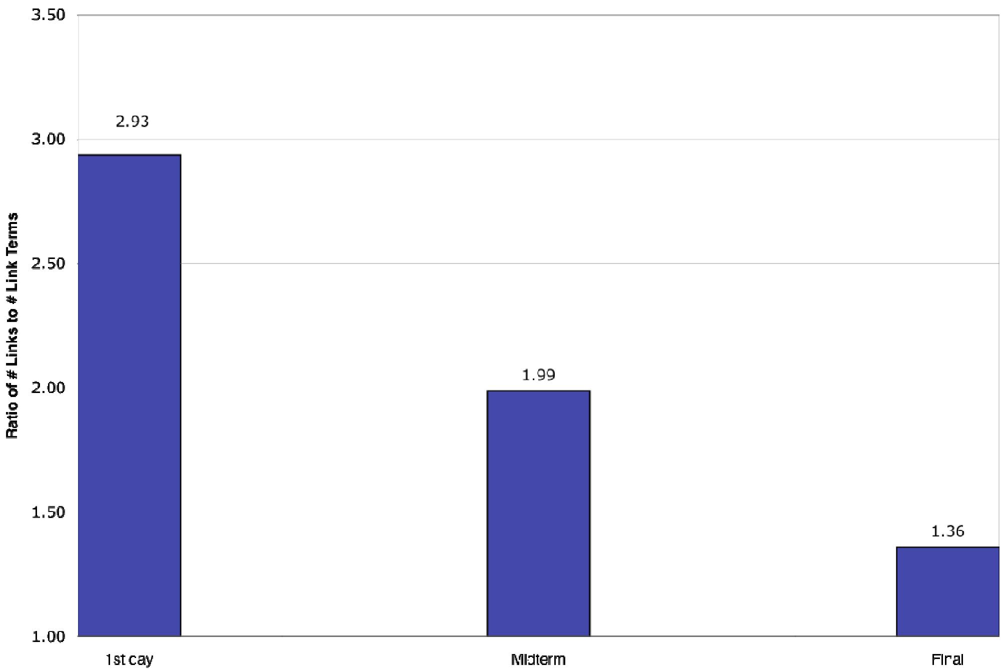


Figure V. Ratio of link term usage to links present in concept maps.

As students demonstrated gains in the mean number of both links and nodes within their concept maps, there is little difference in the ratio of the number of links used to the number of nodes used. Students maintained a ratio of 1.05 links per node at the beginning of the course compared to 1.16 links per node at the end of the course. Therefore, the number of links students utilized remained virtually unchanged during the semester, and it is how the links were used that showed measurable differences. As students changed how they used links within their concept map, they created different shapes of maps, observations of which were discussed earlier in regards to concept map graphical representation (see Table II).

Table II

Analysis of the ratio of student map component usage over one semester.

Map Component	1st Day (n=22)	Midterm (n=34)	Final (n=29)
Link	12.27	16.67	18.93
Link Term	4.18	8.39	13.93
Ratio	2.94	1.99	1.36
Link	12.27	16.67	18.93
Node	11.64	14.15	16.38
Ratio	1.05	1.18	1.16

Discussion

In examining the results from these samples, there appear to be significant changes in student concept map complexity in the first half the undergraduate science course, with students maintaining a consistent level of performance until the end of the term. As demonstrated by an increase in map shape complexity, from 13% to 35% by the midterm exam, students demonstrated more sophisticated interrelatedness of environmental concepts among concepts being studied in class. A drop in 7% of students producing complex maps during the final exam may be attributed to several reasons. Most obviously, students may have been making a less vigorous effort at the final day compared to the midterm point. Another possible explanation may be that students were changing the structure of their map from a network format to a hub & spoke format. There were more students, 37.9%, creating hub & spoke type maps on the final exam compared to 26.5 on the midterm (see Table I).

The most dramatic change observed in student-generated concept maps is in the increased usage of link terms with their maps. Link terms are integral for creating scientifically accurate propositions within concept maps and for displaying how a student articulates complex information about the topics being studied within class. These link terms identify the interrelationships necessary for linking two or more concepts together (Novak, 1991). If these link terms demonstrate an accurate relationship between the two topics the relationship is considered a *proposition* (Yin et al., 2005). As students generate greater understanding of the material studied within a particular class, their ability to generate propositions should increase (Novak, 1991; Yin et al., 2005). In this study, students on the first day of class, after having initial instruction on how to generate concept maps, had means of 4.13 link terms and 12.17 links per map. This demonstrates that students created propositions for roughly one third of links they could perceive between topics. This ratio of proposition formation, or the ratio of links to link terms, was 2.93:1 at the beginning and dropping to a ratio of 1.36:1 (see Table II), reaching close to a one to one ratio, and thereby increasing accurate propositions. Incorporating accurate proposition usage in concepts maps can be a means by which students demonstrate how they have created meaningful learning of what they have studied. Ormrod (2004) discusses how development of appropriate proposition usage provides students a mental model that helps in understanding relationships among concepts and storing knowledge in terms of the underlying meaning. Strike & Posner (1985) argue that the key for students to develop understanding of concepts studied in class lies in their interpretation of the essential meaning of new concepts within their own cognitive framework, and that ideas must function, psychologically, within some representation of a network of propositions. Following this line of argument, students within this study demonstrated their interpretation of the interdependent concepts within environmental science by creating more complex, networked concept maps, with an increase in scientifically accurate propositions, demonstrating a sophisticated and literate meaning of science content.

Conclusions

This study examined several questions concerning how students learn complex environmental concepts that emphasize the interrelationships among various scientific fields. Changes in the complexity of student generated, maps are significant, based on the measurements used within this study, from the beginning of the semester with little change at a midterm peak to the end of the semester. A linear increase in the mean number of nodes, links and link terms used within maps shows students are quantitatively increasing their knowledge, however, using structural methods of scoring may be limited in determining the true development of concept map complexity (Kinchin & Hay, 2001; Yin et al., 2005). A significant increase in proposition creation does demonstrate that students can better articulate their understanding of how nodes, key concepts, are interrelated.

Being able to articulate interrelationships is an important skill in demonstrating more sophisticated understanding of complex concepts. Rye and Rubba (2002) demonstrated this in their study examining how concept map scores correlated with student aptitude tests in California. Students who had high structural concept maps scores also had high California Achievement Test (CAT) scores and verbal scores. By increasing their usage of link terms to form propositions, students were more successful at articulation of the interrelationships among concepts they were trying to demonstrate through their concept maps. This points to two prongs of knowledge acquisition, one in the form of sophisticated understanding of interrelationships among environmental concepts, and the second in the ability of students to articulate these relationships. Therefore, the most prominent development in this study was observed in proposition creation and articulation of interrelationships of concepts. If assessment is a teacher's, or researcher's, attempt to examine how a student understands what they have studied, then using techniques such as rapid assessment categorization plus component usage of concept maps can be an effective teaching and assessment tool in science courses for all age levels.

Ormrod (2004), summarizes many learning theorists when she explains how students integrate new knowledge into long-term memory through meaningful learning by storing new propositions with related propositions in a network of concepts. If knowledge acquisition and retention is an important end goal of education, then students generating complex concept maps, with accurate propositions are demonstrating literate, meaningful learning.

Limitations & Further Study

There are several limitations within this study that can be observed. A primary limitation is the use of concept maps as a graphical measure of literacy and knowledge acquisition. A previous method of measuring what a student knows or has learned is the traditional paper and pencil assessment, which provides for ease of quantitative analysis. However, this study attempts to bring another method of quantifying student's knowledge acquisition through examination of their hand-drawn concept maps. Since a comparison of standard assessment data or student grade achievement and their individual concept maps is outside the purview of this paper, there is room for debate on how complex maps demonstrate increased student literacy or earning.

Another limitation within this study is in the subjective nature of classifying each of the student's concept maps into graphical categories, described by Yin et al. (2005). It is difficult to classify the graphical concept maps without clear explanation as to how each of the different categories is defined. For example, the investigator had to decide if a map was a hub and spoke, circular, or complex format when the shape of the map would be a central idea with many outside nodes connected to the central topic but outermost nodes were connected by unidirectional links, in essence forming a true wheel with hub, spokes and rim (see Appendix C). Or would this particular map be better categorized as complex, since there are cross-links but the map itself does not form a true network? This ambiguity caused several of the maps to have the possibility of being categorized into different groups, and thereby influencing results. There also needs to be further research in quantification of concepts to clearly define the parameters by which maps are accurately assigned a graphical categorization.

Another limitation was precision when measuring the number of links and link terms. As concept maps become more complex and the number of nodes, links, and link terms increased, reading the hand drawn maps becomes more difficult, a result of the immense differences in handwriting quality and length of link lines separating node topics. If students have large, irregular handwriting and short link lines between node topics, the appearance of the map can become quite crowded and the lines of distinction become blurred. This can cause differences in measuring each of these components, since some propositions may be missed or misidentified as nodes. This is where computer generated concept maps would greatly assist an instructor or investigator measuring various components within maps. However, as Royer and Royer (2004) determined in their study comparing hand drawn and computer generated maps, students created far more complex maps while working by hand than they did when using computer software.

In analysis of concept maps, the investigator considered different methods of quantifying the relationships among various components found within student concept maps. There are many methods of scoring and identifying the complexity of concepts maps left unstudied. Developing expert-based maps for each of the topics students used to construct their maps would be an important analysis on the development of student knowledge towards expert-level comprehension. There is a need for studies into the accuracy of the relationships identified by students within their maps and if students increase the accuracy of their links between nodes. This information may shed light on the development of knowledge by students as they generate more complex concept maps.

Lastly, construction of these maps had very open parameters under which the students had to work. The students were not directed to have a specific number of nodes, links or link terms. Also, the students were not directed to construct their maps in any prescribed form either hierarchical or non-hierarchical. The only directions given to the students included that they choose subjects from a list of topics studied, create as complex a map as they could, given their knowledge of their subject choice, and be sure to label their links with appropriate link terms. How students chose to follow these directions was up to them, and there is evidence that some students chose not to hand in their maps, which influenced sample sizes during the semester. Students are individuals who are free to think and act independently, this study focused on observing a glimpse at how their minds work.

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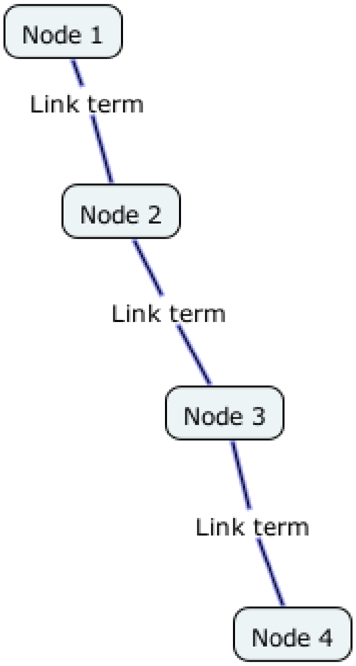
Appendix A

Concept Map Shape Exemplars Using Florida Institute for Human and Machine Cognition (IHMC) CMapTools® computer software

Linear Concept Map



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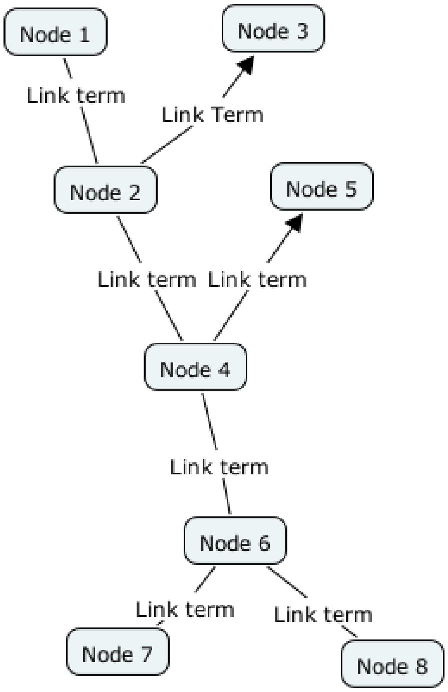
Tree Concept Map



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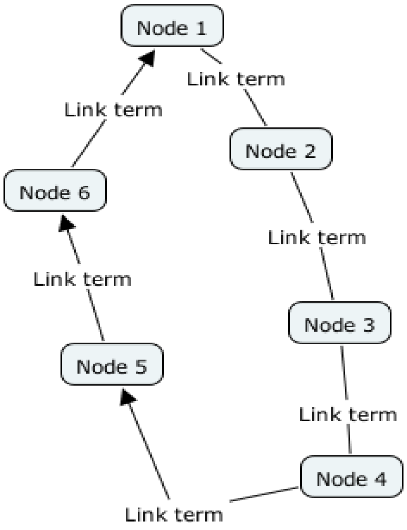
Circular Concept Map



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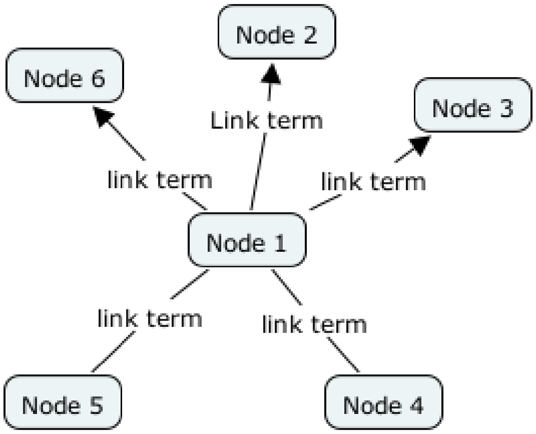
Hub & Spoke Concept Map



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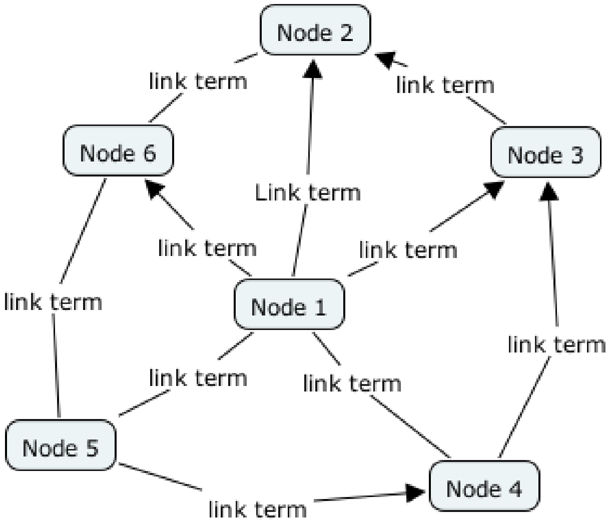
Complex Style Concept Maps Drawn with Florida Institute for Human and Machine Cognition (IHMC) CMapTools® computer software.

Wheel Concept Map



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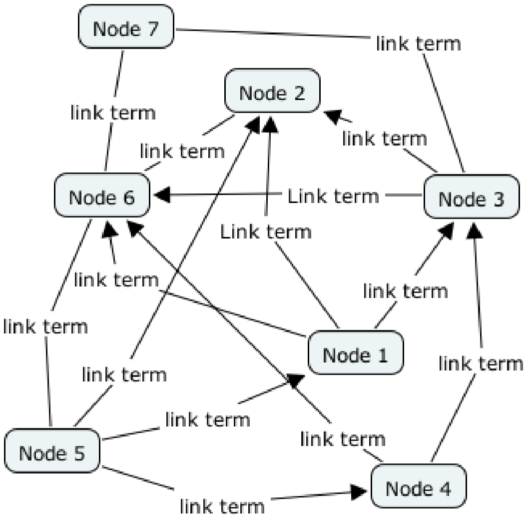
Network Concept Map



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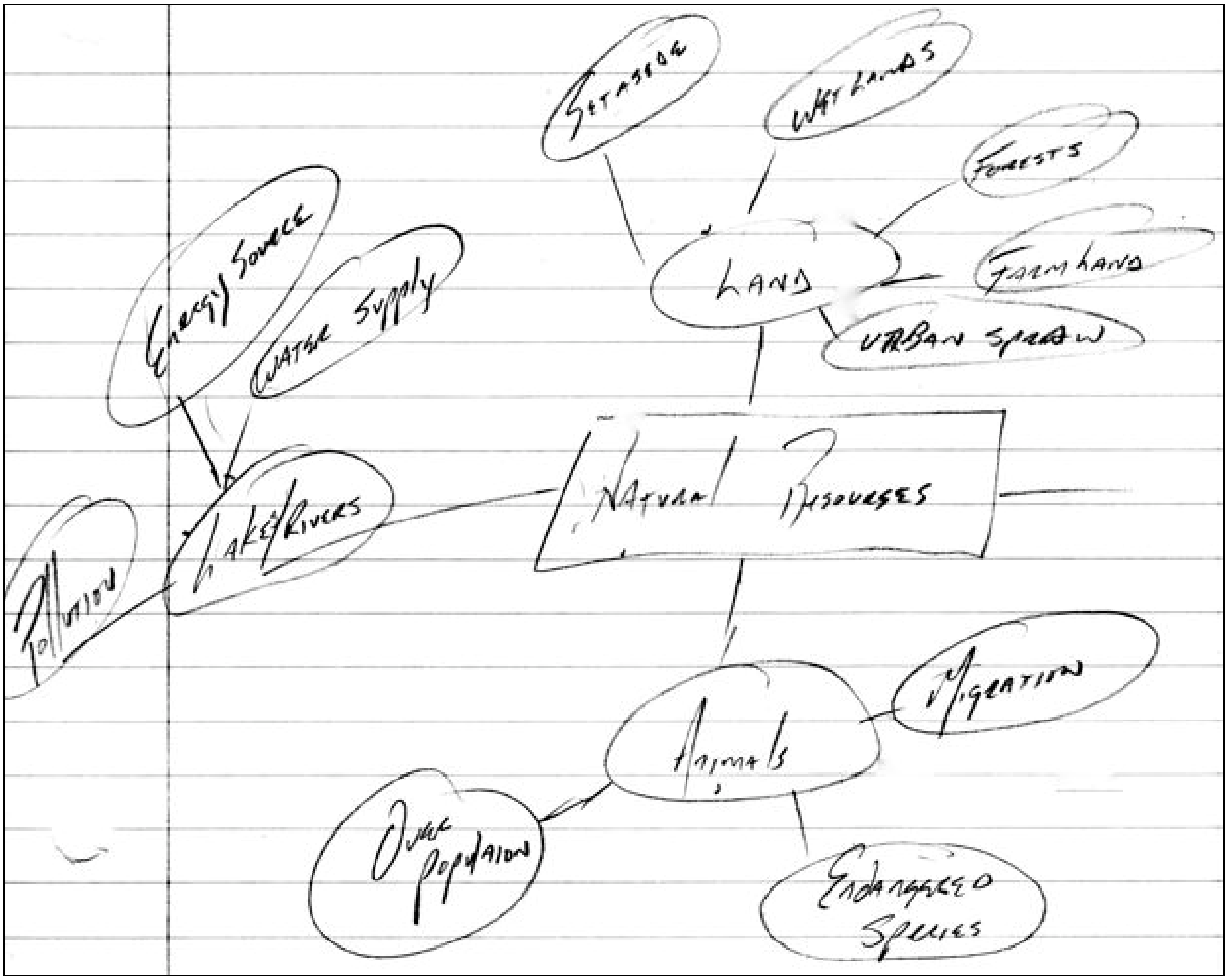
Appendix B

Student 1 on 1st day of class



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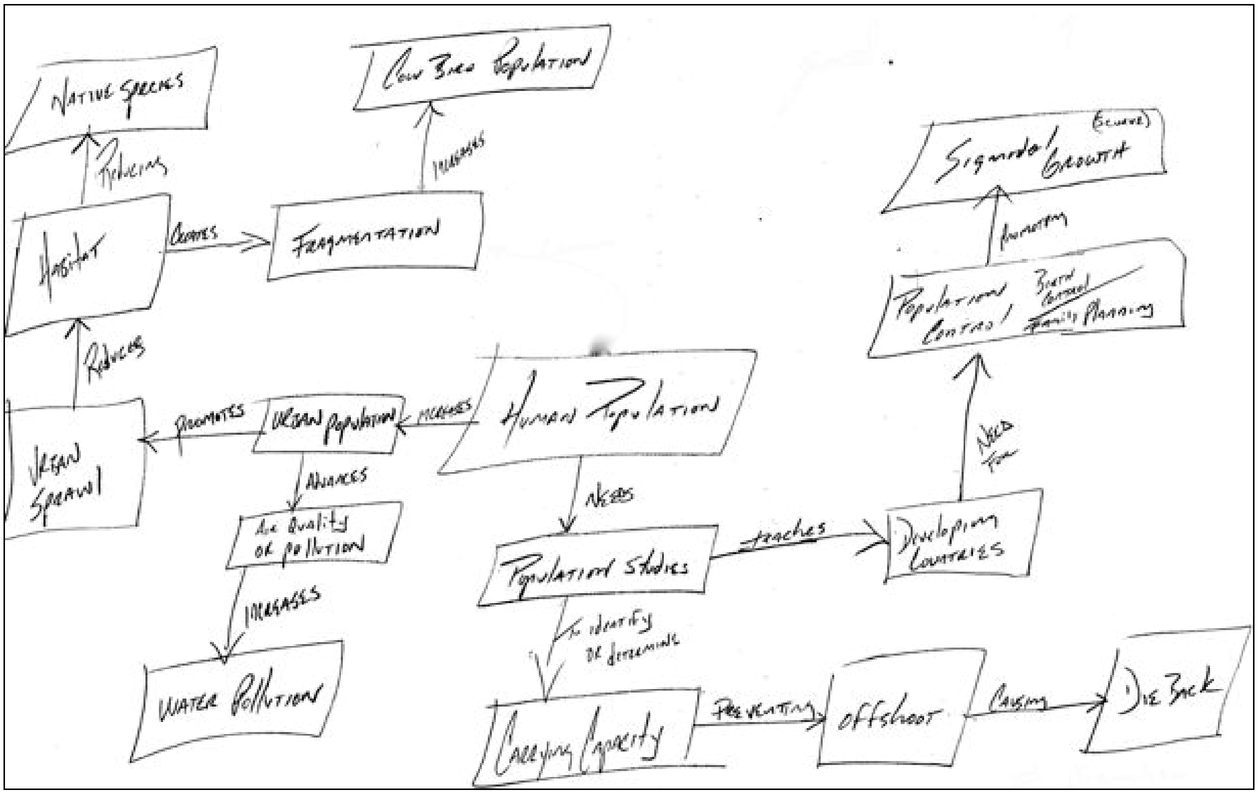
Student 1 at midterm



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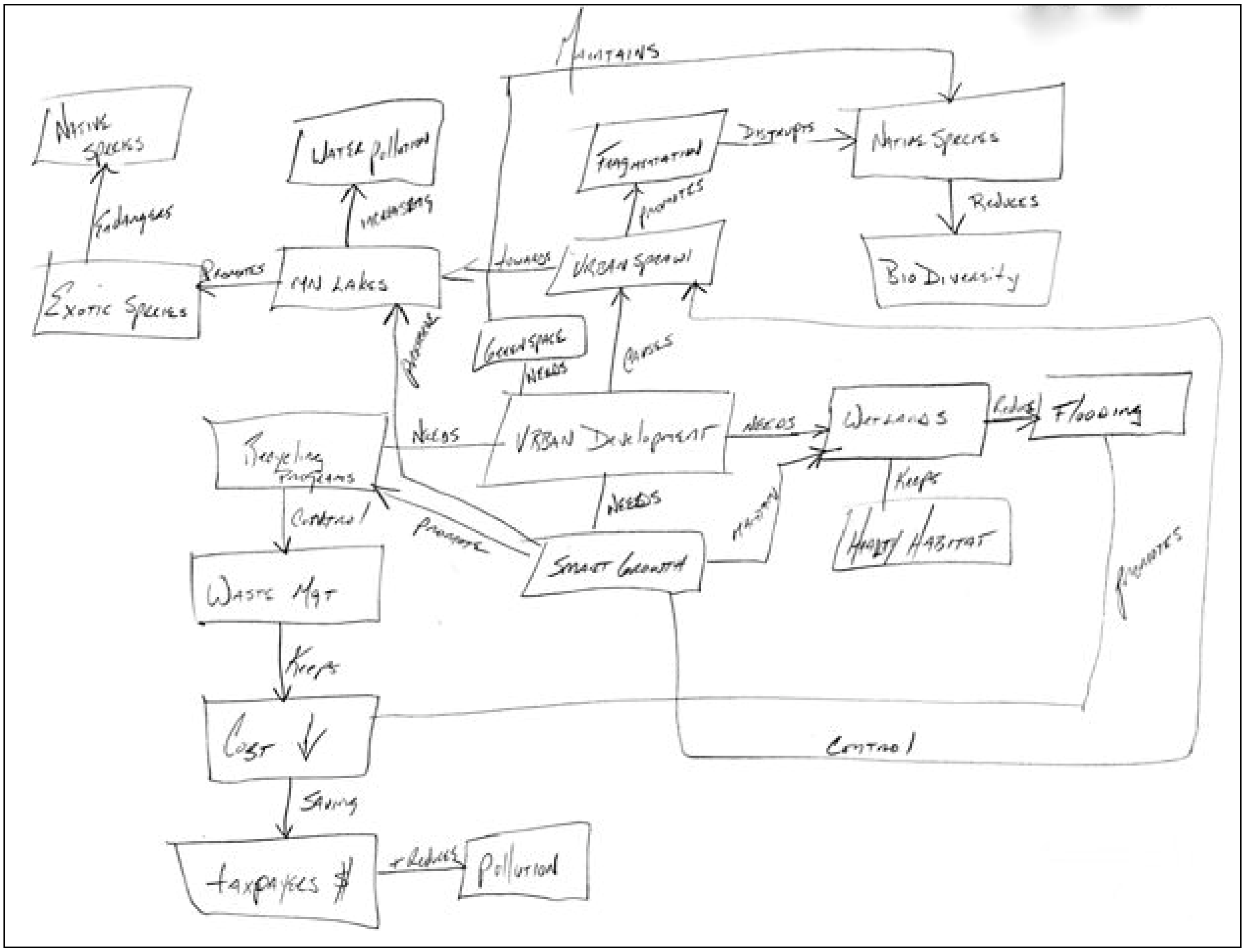
Student 1 on final day of class



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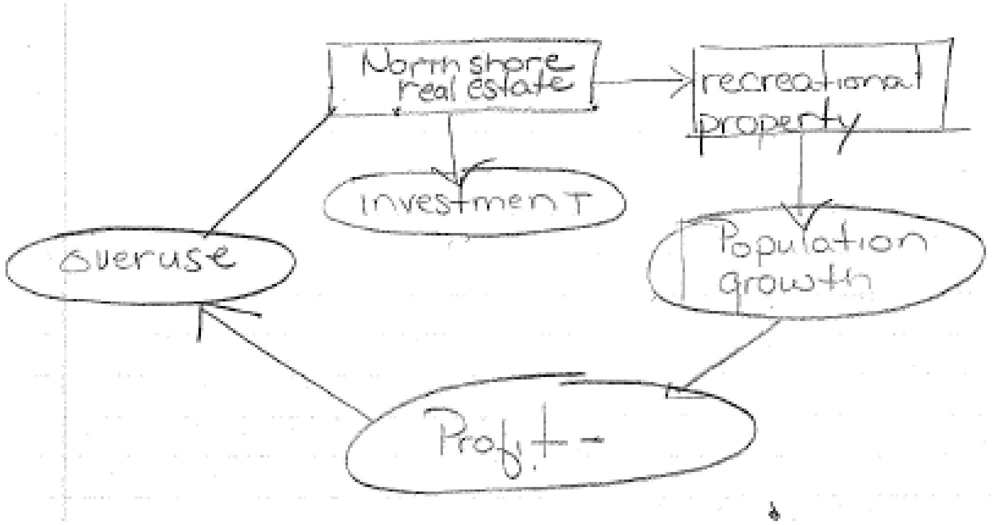
Appendix C

Simple Concept Map Exemplars From 1st Day of Class

Linear

back

Circular



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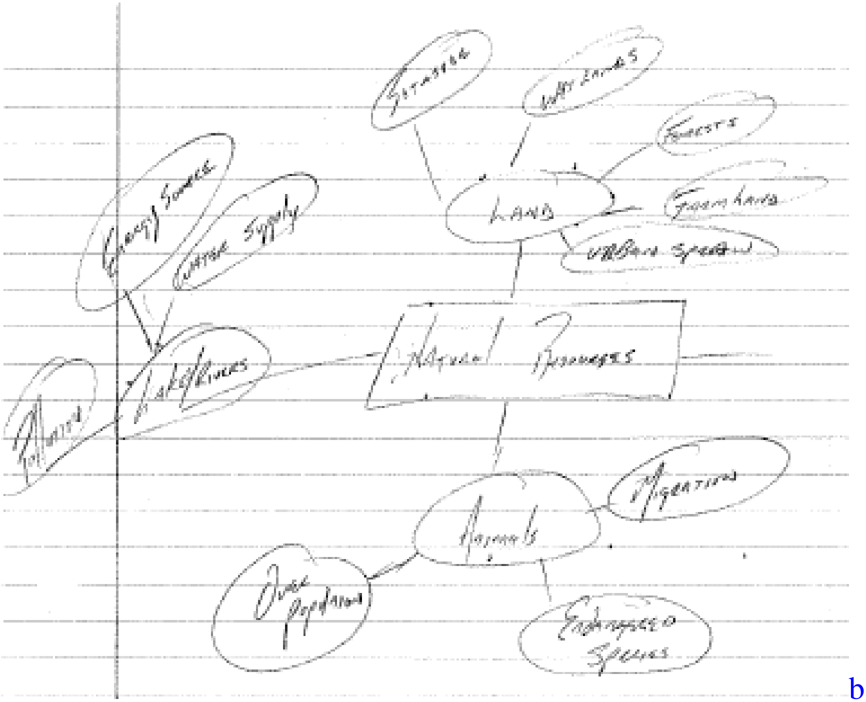
Tree



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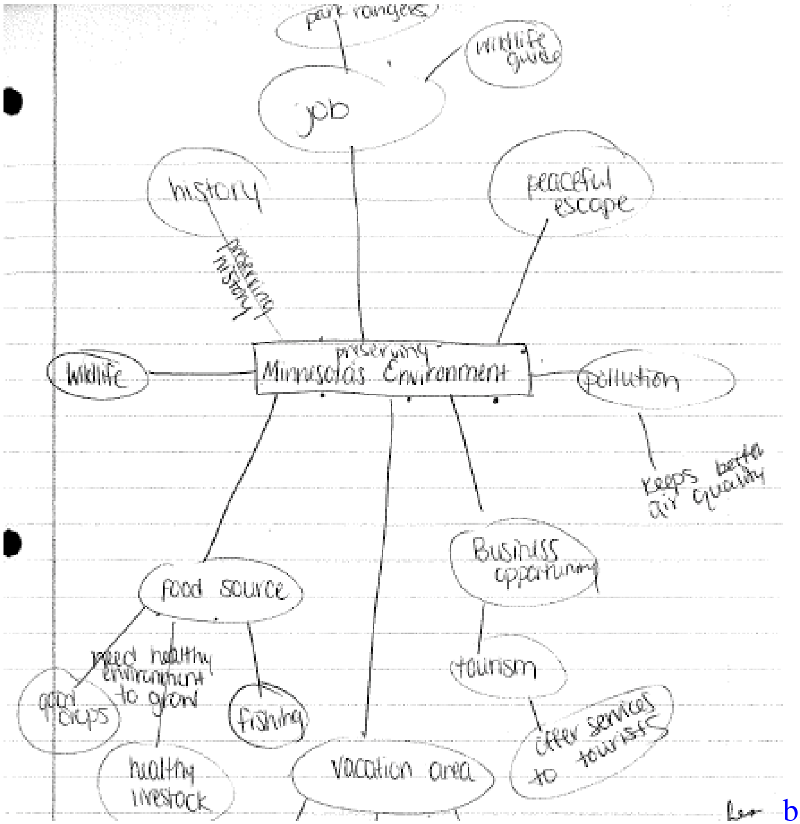
Hub & Spoke



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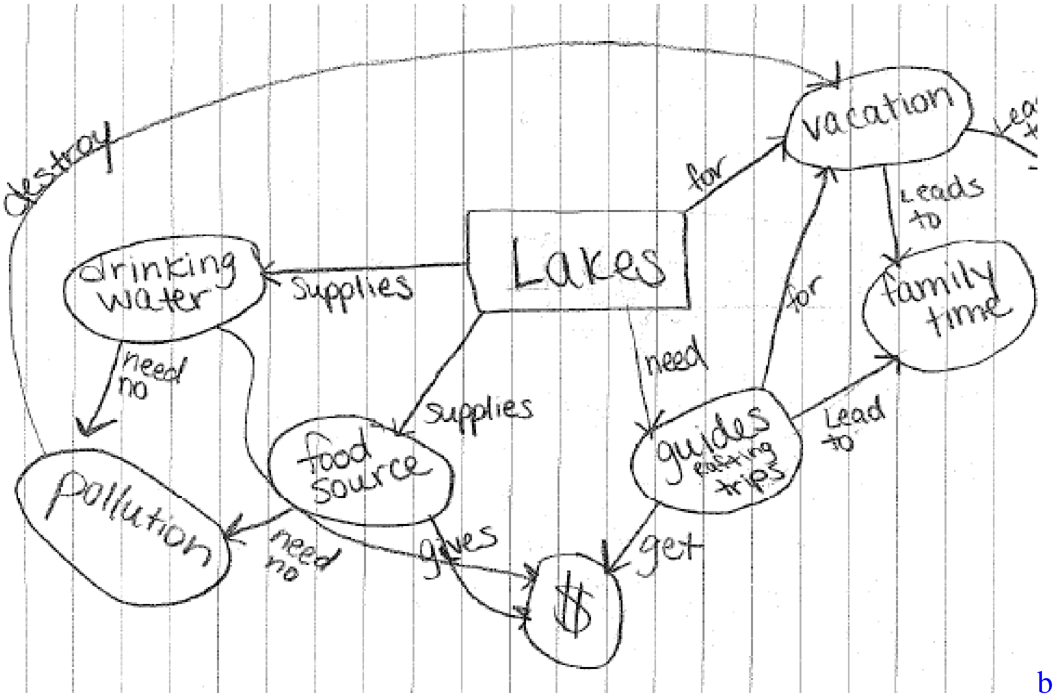
Complex Concept Map Exemplars From 1st Day of Class

Wheel



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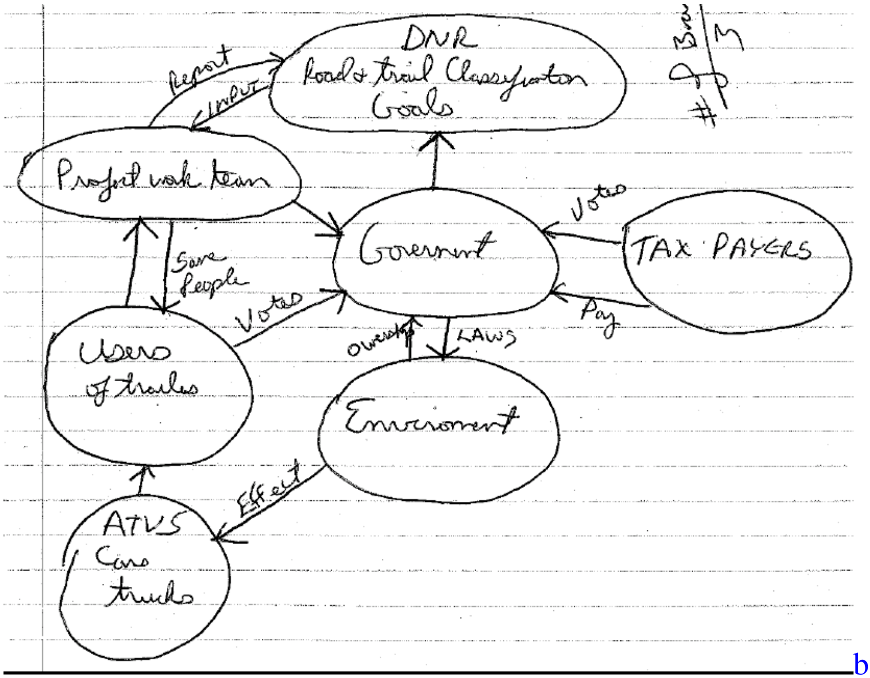
Network



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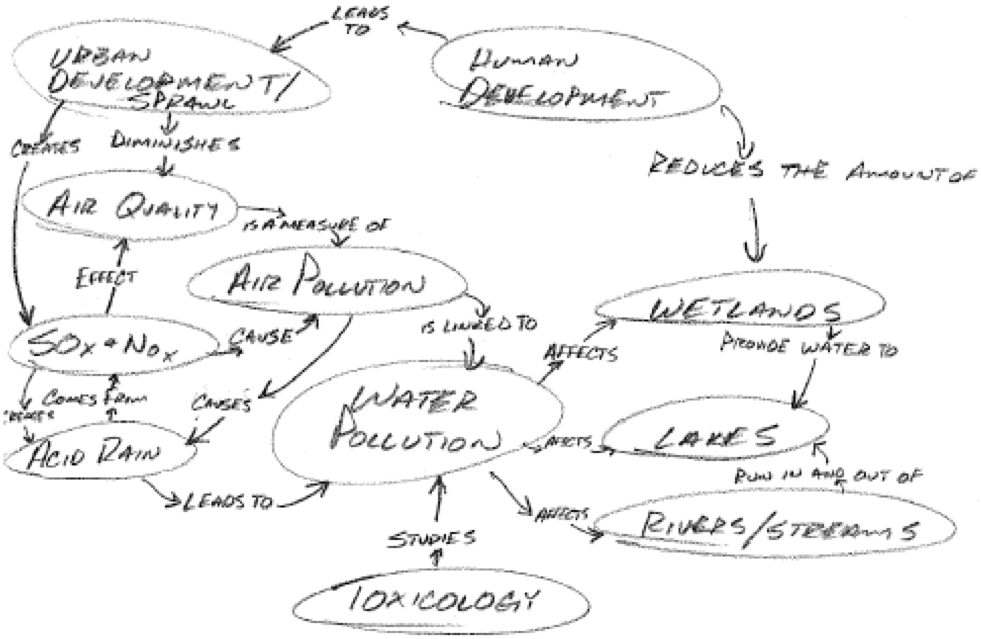
Appendix D

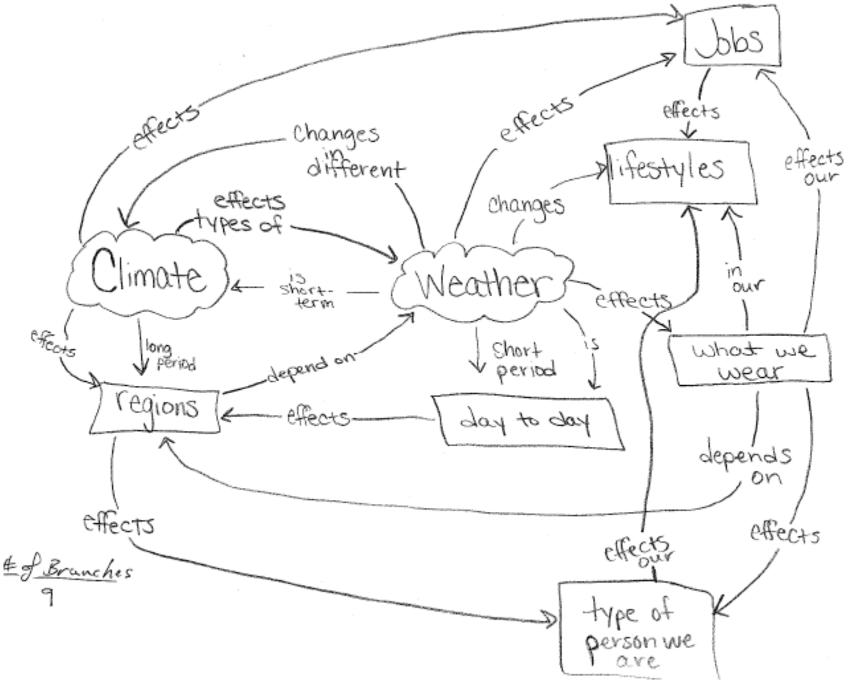
Complex Concept Map Exemplars From Final Day of Class

Network



back

Wheel



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Technology-Integrated Project-Based Approach in Science Education: A Qualitative Study of In-Service Teachers' Learning Experiences

Sumita Bhattacharyya, Ph.D.
Nicholls State University

Kakali Bhattacharya, Ph.D.
Texas A & M University Corpus Christi

Abstract

This qualitative study examines the impact of a technology-integrated project-based approach (PBA) on the learning experiences and subsequent decision-making of in-service teachers pursuing their master's degree who are enrolled in a science methods class. The authors employed in-depth interviews, journal reflections, observations, performance in class projects, and content of class projects as data sources. Through inductive data analysis the authors found that banter is a key factor in collaborative learning, that technology-integrated PBA fostered interdisciplinary connections in the science methods class, and that in-service elementary education teachers intended to integrate technology and PBA in their science classes as a result of their learning experiences in the science methods class.

Correspondence should be addressed to Sumita Bhattacharyya, Ph.D. (Email: sumita.bhattacharyya@nicholls.edu), Nicholls State University, Department of Teacher Education, 249 Polk Hall, Thibodeaux, LA 70310 or Kakali Bhattacharya, Ph.D. (Email: kakali.bhattacharya@tamucc.edu), Texas A & M University Corpus Christi, Educational Administration & Research, FC 224, 6300 Ocean Drive, Unit 5818, Corpus Christi, TX 78412-5818.

The underperformance of students in science (National Center for Education Statistics [NCES], 2006) has put science education in the United States in a state of crisis (Cognition and Technology Group at Vanderbilt, 1992). Comparing eighth to twelfth grade students against international performance paints an unflattering picture of science education in the U.S. (NCES, 2006). Investigating the reasons for this poor performance, educational researchers have identified multiple barriers to improving students' performances. These barriers include, but are not limited to, the quality of U.S. teacher education programs, the lack of science content knowledge among teachers, and the lack of professional development opportunities for teachers after completing their teacher education programs (Albion & Ertmer, 2002; Ertmer, 1999; Trowbridge, Bybee, & Powell, 2000).

Despite recent reports showing that over 90% of schools provide student access to computers with broadband connections to the Internet (Parsad & Jones, 2005; Wells & Lewis, 2006), both teachers' and students' use of technology is limited largely to low-level productivity tasks such as word processing, email, basic Internet searches, and electronic presentations (Lanahan, 2002). While the use of technology in a science classroom can exist on a continuum where minimal use might include basic Internet search and maximum use might include a fully integrated learning environment where students use application and synthesis skills, unfortunately, the examples of the fully integrated learning environment are limited. Moreover, the understanding of the term "technology-integrated" varies from teacher to teacher, school to school, and administrator to administrator. Thus, it is critical to investigate both situation- and policy-based implications of barriers and facilitators of technology-based science education curriculum in order to identify context specific challenges and solutions.

Of specific interest to the authors is the lack of utilization of technology in science classrooms in elementary school where students often form their first impressions about science. There is evidence that suggest that teachers often lack the confidence in using technology in ways that construct knowledge beyond the level of recall and that they have had poor modeling of methods classes in their training programs demonstrating how learning science can be enhanced using technology while following standardized curricular mandates (Laffey, 2004; McCannon, 2000). When teachers do receive training in technology integration in their teacher education programs, they report increased knowledge of and confidence in using technology (Overbaugh & Lu, 2008; Snider, 2003).

In-service or pre-service teachers who report increased confidence in their ability to use technology identify the value of hands-on, project-based, constructivist learning environments (Bhattacharya & Han, 2001; Halpin, 1999; Vannatta & Beyerbach, 2000; Wright & Wilson, 2007). Additionally, in-service teachers respond favorably to both teacher education programs and other professional development programs offering opportunities for collaborative, project-based approaches to integrating technology in science classrooms (Hall, Fisher, Musanti, & Halquist, 2006).

The project-based approach (PBA) is born out of the broader epistemological framework of constructivism (Piaget, 1985) which has a longstanding history in education (Airasian & Walsh, 1997; Bhattacharya & Han, 2001). PBA relies on the notion that if learners are given opportunities to construct their own meaning based out of their experiences of participating in a project with their peers, then multiple opportunities of meaningful learning occur.

By directly engaging the learner with the science (or content-related) problem, a PBA can create authentic learning experiences through which learners discover a fact, concept, or principle on their own. A systematic inquiry into the role of PBA in science instruction has revealed its value in developing scientific investigative skills among students (Krajcik, Blumenfield, Marx, & Soloway, 2001). There is also evidence that PBA, when integrated with technology, can enhance students' performance by helping them internalize various concepts and their applications in science (Ryser, Beeler, & McKenzie, 1995; Cognition and Technology Group at Vanderbilt, 1992).

Educational researchers have provided models and strategies and explored both the pitfalls and potential of creating a technology-integrated project-based learning environment in science classes (Blumenfield, Fishman, Krajcik, Marx, & Soloway, 2000). Nevertheless, such strategies are not widely read by teachers or commonly practiced in science education classes (Wenglinsky & Silverstein, 2006). It is difficult for teachers to stay current with educational research literature, given their daily workload and performance expectations. Consequently, the responsibility lies with teacher education and subsequent professional development programs to provide teachers with the knowledge and skills to implement new initiatives and research findings, in order to prepare qualified teachers who can facilitate students' successful performance in science.

Efforts to include systemic and sustainable integration of technology in teacher education, or to offer professional development opportunities to teacher education faculty and in-service teachers, have been found to increase educators' confidence in using pedagogically grounded technology in their classrooms (Hall et al., 2006; Overbaugh & Lu, 2008; Snider, 2003; Wright & Wilson, 2007). However, few teacher education programs currently model systemic and sustainable technology integration in science classrooms, and as a result both pre-service and in-service teachers often hesitate to use such approaches in their instruction (Ertmer, 2003; Rosaen, Hobson, & Khan, 2003). To encourage teachers to implement such approaches, it is critical to understand how learning occurs when science teachers are introduced to technology-integrated learning environments and how such environments strengthen teachers' conceptualization of their subject matter, as well as their teaching skills and openness to integrating technology.

The purpose of this exploratory study is to identify the role(s) of a technology-integrated, project-based approach in a science methods course as perceived by in-service elementary school teachers. Two research questions guide this exploratory study:

1. How do in-service teachers describe new insights learned as a result of participating in technology-integrated, project-based activities?
2. In what ways does a technology-integrated, project-based approach contribute to the in-service teachers' intentions of teaching science with technology in their future practices?

A third research question the authors wish to explore investigates the long-term effects of technology-integrated PBA on in-service teachers' classroom approaches, by examining the ways in which they use technology in their science classrooms. However, that question is beyond the scope of the current investigation.

Theoretical Framework

Grounded in PBA, this study investigates the value of PBA in a learner-centered, constructivist classroom environment in increasing in-service teachers' comfort with technology integration. PBA is reported (Bransford & Stein, 1993) to yield a product or performance that demonstrates learners' ability to apply new concepts in complex, meaningful ways. PBA offers learners an experimental, interactive, investigative, and cooperative form of learning (Schwab, 1964; Willis & Mehlinger, 1996). By incorporating personal experiences and social interaction with peers in the learning process, PBA allows learners to connect, reflect on, interrogate, and integrate new information into their pre-existing knowledge. The instructor's role is mainly that of a facilitator who fosters a learner-centered environment to create autonomous learners (Marx, Blumenfield, Krajcik, & Soloway, 1997). Thus, learners become skilled at developing evidence-based arguments by discovering facts, concepts, and principles in their informal interactions with each other, such that learners can act as mentors to one another.

An integral part of PBA involves collaborative learning, in which peers work together and serve as mentors for one another through formal and informal conversations. Informal conversations leading to the internalization of concepts in PBA reveal the importance of providing a non-threatening learning environment in which peers provide models of training for each other. Several studies support the value of such training in enhancing teaching and learning (Glazer, 2004; Snyder, Farrell, & Baker, 2000).

The informal academic training aspect of PBA supports the idea that students who have mastered instructional skills can act as mentors and teach those who are struggling by using modeling, coaching, and scaffolding until the mentee demonstrate an understanding similar to that of the mentors. When peers demonstrate expertise for each other, they model successful engagement and confidence in subject matter for those who are underperforming. The mentors can model the target skill or task, then ask the mentees to emulate the task or the skill with the their guidance, coaching, and scaffolding. The more comfortable the mentees become with the task or skill, the less the mentor provides guidance or scaffolding.

PBA can be divided into three phases: planning, creating, and processing (Katz & Chard, 2000). Each phase requires collaborative learning and cognitive apprenticeship. However, although the three phases may be described separately, it is important to understand that the experience of project-based learning is an iterative one. Learners do not move in a unidirectional, linear progression from the planning, creating to processing phase. Instead, they may move back and forth from one phase to another based on the ways they construct knowledge.

In the planning phase, learners collaboratively choose a project, set goals and identify necessary resources. The second phase, creating, involves collecting data and other relevant information for the project. During this phase, learners might choose to revise their topic based on feasibility, access to resources, etc. In processing, the third phase of project-based learning, learners reflect on their own projects, assess how well they have accomplished the goals set during the planning phase, and revise any goals if they need to.

Additionally, during the final phase, learners share their product and/or performance with other members of the class and reflect on the learning process and the product through dialogue and feedback. Because PBA has the potential to improve students' knowledge and performance, it can also reinforce the in-service teacher of her/his teaching strategies and ability to create successful learning environments (Trowbridge et al., 2000).

While strong evidence-based arguments support the value of project-based methods in all areas of instruction, such methods may not be appropriate in cases where learners lack the requisite intellectual ability, social skills, or attitudes to participate effectively in such projects. However, these learners may be inducted into the method after they have developed the necessary skills. Moreover, the method may be less effective if introduced at the beginning of a term, when learners are less likely to know one another and the teacher may not have sufficient knowledge of each student's predispositions, strengths, and weaknesses.

Research Methodology

This study sought to identify the role of a technology-integrated, project-based approach in a science methods course as perceived by in-service elementary school teachers. Because this study was exploratory, an open-ended systematic inquiry was used to identify participants' perceptions of their learning experiences and how those experiences will inform their future instructional practices. The data sources included observations of participants' activities in the science methods course, participants' reflections about their learning experiences throughout the semester the science methods course, and analysis of documents such as journals, assignments, lesson plans, and in-depth open-ended interviews with participants about insights learned as a result of their participation in a science methods course which was driven by technology-integrated PBA. Hence, qualitative methods were most suited to this study. Qualitative research provides an in-depth understanding of people's experiences in a specific environment. This method of inquiry allows stories to be told in context and compiles evidence drawn from several methods of data collection (Patton, 2002a).

Qualitative research methods may be used to describe processes, relationships, settings and situations, and people's actions (Peshkin, 1993). Thus, in order to develop an in-depth understanding of the in-service teachers' learning experiences, the research design was informed by interpretivism. Interpretivism is a theoretical framework used in qualitative inquiry that focuses on the ways in which participants make meaning of their experiences, actions, and performances by interpreting their interactions with people and the world around them (Crotty, 1998).

According to Max Weber (cited in Crotty, 1998, p. 67), an early theorist of this framework, interpretivism does not seek causality. Instead, interpretivism seeks to understand how people make meaning. Another tenet of interpretivism is that as humans create meaning, they also re-interpret meaning based on their interactions with others. In other words, the interpretivist approach "looks for culturally derived and historically situated interpretations of the social life-world" (Crotty, 1998, p. 67).

Underlying this approach is the belief that we as individuals do not simply drift through life as passive objects of socialization. Instead, we actively engage in constructing our social world, thus creating our own social reality (Crotty, 1998, p. 74). Since interpretivism is aligned with the constructivist theory of learning, we chose this framework for our research design. Interpretivism relies on inductive approaches to data collection and analysis. Qualitative studies informed by inductive approaches rely on working "up" from the data (Patton, 2002a) to identify patterns and themes within and across all data sources. Therefore, this study utilizes a multi-method approach to data collection in order to systematically analyze data for codes, categories, and themes that represent the participants' experiences, activities, and perceptions.

Context and Study Design

The University of Chalksville[1] is a teaching university in the southeastern U.S. with a college of education that offers both undergraduate and graduate teaching degrees. Both pre-service and in-service teachers attend the University of Chalksville for teaching certification and to enhance their professional qualifications. The participants in this study were volunteers chosen through purposeful selection (Patton, 2002b). The criteria for selecting participants were twofold. Volunteers had to be in-service teachers in Chalksville; and complete a science methods course at the University of Chalksville as part of their master's degree prior to participating in the study[2]. While all the participants had taken methods classes as part of their undergraduate training, their training varied in terms of its focus on mastery of content, teaching strategies, and technology literacy. The master's program at the University of Chalksville offers in-service teachers a required science methods course to help them gain mastery of content and increase their confidence in using technology in their science classes.

The authors selected 70 participants over the course of four semesters who taught between grades one to six. Twenty-three teachers participated during summer 2004, 17 in fall 2004, 22 in summer 2005, and eight in fall 2005. The participants provided demographic data as well as information about their experience with technology, knowledge of project-based approaches, and previous participation in professional development experiences. Table 1 represents the demographic distribution of the participants across all semesters.

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[1] A pseudonym

[2] To avoid putting pressure on the students to participate in this study, the study was not introduced to the students until they had completed the science methods class.

Table 1
Demographic survey of participants

N=70	Total # of students	Experience with PBA	No experience with PBA
Highest degree held by students			
a. B.S.	52	4	48
b. M.S.	13	2	11
c. Post-Graduate Diploma	5	0	5
Students' years of teaching experience			
a. 1-3 years	41	4	37
b. 4-6 years	26	2	24
c. More than 6 years	3	0	3
Number of technology-integrated science lessons taught by students			
a. Internet surfing only	37	0	37
b. Use of Word, Excel, Graph, and Internet	30	5	25
c. Use of Image Probe, MS Office, and Internet	3	1	2
Attendance at science workshops for professional development			
a. Once a year	47	5	42
b. Once in two years	9	1	8
c. Once in three or more years	14	0	14

At the beginning of each semester, as part of their course requirements students were asked to write reflective essays about their experiences in teaching science, their familiarity with a project-based approach, and the teaching practices they intended to implement as a result of the class. During the semester, students were expected to document their learning experiences through reflective journaling. The students were introduced to various technologies to help them design mini-research projects investigating the effects of pollution on a local bayou and their implications for local culture. The mini-research project included developing a research purpose and questions, conducting data collection and analysis using the technologies introduced in class, and presenting their findings as a group to the entire class using appropriate technologies.

The technologies the students used included Image Probe software to test properties of bayou water samples including salinity; ph; and the levels of nitrate, phosphate, and dissolved oxygen. The students were encouraged to take photos with a digital camera as part of their data collection and to import these into a PowerPoint presentation to be delivered at the end of the semester. To aid the students in conceptualizing the data, they were introduced to Inspiration software that helped them develop concept maps to connect their ideas and make sense of the data they gathered.

Finally, students learned how to enter their data into Excel spreadsheets, perform descriptive statistical functions, and represent information graphically. At the end of the course, students were expected to complete their reflective journaling by documenting how their participation in this science methods class affected their confidence in teaching science with technology grounded in PBA. As part of the research design, we wanted students to feel comfortable using these technologies as we facilitated a constructivist learning environment. Our subsequent inquiry into the students' experiences directly aligned with the purpose of the study.

The second author of this paper, a qualitative researcher, acted as the primary methodologist for this study. She invited 14 students for open-ended, in-depth interviews after the conclusion of the course. These students were selected from among those who volunteered to participate based on a range of representative variables, including the semester in which the student took the science education class (marked 01- 04), initial comfort with technology based on their journal reflections, years of teaching experience, and previous attendance at professional workshops. We used the maximum variation sampling strategy (Patton, 2002) to obtain an in-depth understanding of diverse perspectives. Table 2 demonstrates the maximum variation sampling selection of participants.

Table 2
Demographic survey of in-depth interview study participants

N=14	Semester	Initial comfort with technology	Years of teaching practice	Attendance at professional workshops
Participant 1	01	Uncomfortable	3	Once a year
Participant 2	01	Comfortable	5	Once a year
Participant 3	02	Expert	3	Once a year
Participant 4	02	Uncomfortable	3	Once a year
Participant 5	03	Uncomfortable	3	Once in two years
Participant 6	03	Comfortable	3	Once a year
Participant 7	04	Comfortable	4	Once a year
Participant 8	04	Uncomfortable	3	Once a year
Participant 9	01	Expert	5	Once a year
Participant 10	03	Uncomfortable	4	Once in three years
Participant 11	02	Comfortable	3	Once in two years
Participant 12	04	Uncomfortable	1	Once a year
Participant 13	04	Uncomfortable	5	Once in three years
Participant 14	02	Uncomfortable	3	Once a year

At the end of every interview, both researchers compared the data, identified gaps in understanding the participants' accounts, and formulated follow-up questions for the participants. Finally, the methodologist followed up with the participants after data analysis to verify the accuracy of the findings. The collection of interviews, observations, the researchers' journal data, and the students' pre- and post-reflective essays generated in excess of 200 pages of raw data.

Data Analysis

To effectively manage the volume of data, the researchers used QSR NVivo^{TM}, a qualitative data management software program, to systematically chunk the data into smaller analytical pieces in order to code and categorize the data for thematic analysis. Interpretive data analysis in qualitative methods is always iterative and involves working up from small, manageable sections of data to create codes and categories that lead to identifying generalizable themes across all data sources (LeCompte & Preissle, 1993; Miles & Huberman, 1994). Coding in qualitative studies involves labeling chunks of data by identifying salient ideas contained in that section of the data. The NVivo software also allowed the researchers to write analytical memos, search for and retrieve large volumes of data almost instantaneously, and interrogate the patterns in all data sources using various combinations of Boolean searches (e.g., and/or searches, proximity searches).

We employed an open coding technique, which is “the analytic process through which concepts are identified and their properties and dimensions are discovered in data” (Strauss & Corbin, 1990, p. 101). This process involves naming concepts, developing categories, and attributing appropriate contexts in which such labeling is given meaning. Once all data sources were coded, we took like codes and grouped them together. We then looked at the like codes and began to identify broader labels to encompass them by asking, “What is going on here?” These broader labels are called “categories” in qualitative research. The researchers recorded their analysis, thoughts, interpretations, questions, and directions for further data collection through memo writing in order to gain an in-depth understanding of the data.

Once categories were developed, the researchers began to look across all categories and try to answer the research questions by discovering relationships between key patterns in the data. Table 3 represents the connections made between codes and categories in order to determine one of the overall themes in this study.

Table 3
Example of development of a theme

Codes	Frequency of codes	Categories identified	Development of theme
Impacts on water quality using Image Probe	61	Topical research with technology	Technology-integrated learning environment fostered interdisciplinary connections.
Home to animals, people, trees, fish	60	Identify impact on ecosystem	
Connect science and social science with technology	59	Connect multiple subjects and integrate technology	
People's lives affected, bayou culture	49	Impact on local culture	
Sustainability of environmental resource	37	Wildlife preservation	
Maintain ecosystem	31	Identify impact on ecosystem	
Impact of littering	27	Impact on local culture	
Wildlife preserve	19	Wildlife preservation	

The researchers further sought to uncover conceptual relationships across various data sources. Figure 1 demonstrates the conceptual process of discovering relationships between patterns in the data.

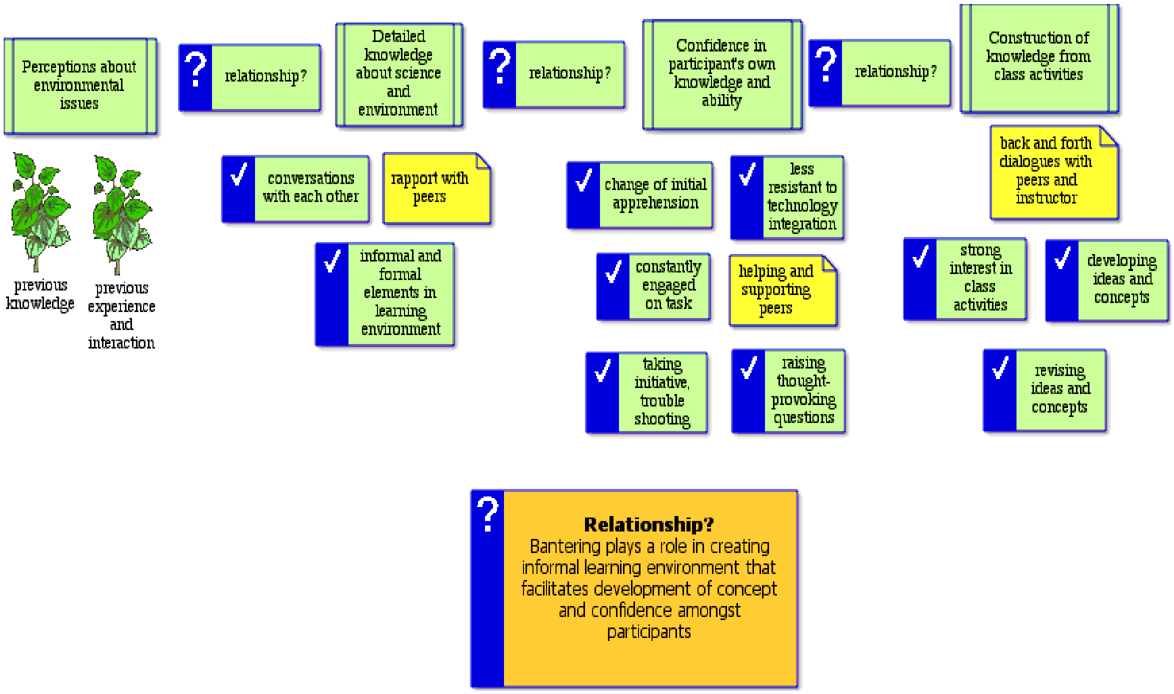

Figure 1. Discovering relationships in data patterns

Through multiple dialogues between the researcher and the participants, and by documenting relationships between the categories developed from all data sources and patterns in the data, the researchers identified three key themes. These themes occurred across all categories in the data and related to the research questions about participants' learning experiences and their intentions for future teaching practices.

For the purposes of consistency between researchers and alignment with the methodological literature (Bogdan & Biklen, 2003; Miles & Huberman, 1994; Strauss & Corbin, 1998), the criteria for a theme had three requirements: First, the theme had to provide an answer to the question, "What is going on here?" Second, the ideas subsumed in the theme had to be repeated by the participants several times in their banter, conversations, and journal reflections. Third, a theme also had to appear in multiple data sources**.** Once the themes were identified, they were further verified with five scholars who are similarly situated in relation to the researchers, both substantively and methodologically. This verification enabled us to establish academic rigor, trustworthiness, and the strength of logical analysis of codes, categories, and their inductive development into themes.

Results and Discussion

Given the qualitative nature of the data analysis, discussion is presented in embedded form within the Results section as part of the thematic description and interpretation of data. This approach aligns with that of other qualitative researchers in many fields, including science education (Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006).

The researchers asked two broad research questions:

1. How do in-service teachers describe new insights learned as a result of participating in technology-integrated, project-based activities?

2. In what ways did the technology-integrated, project-based science methods course influence the in-service teachers' confidence in their ability and intention to integrate technology in their own future practice?

The three themes we identified after conducting inductive data analysis respond to these two questions. The three key themes include: (1) in-service teachers identify banter as a key factor in creating a collaborative, non-threatening learning environment; (2) technology-integrated PBA enables in-service teachers to forge interdisciplinary connections; (3) in-service teachers reported strong intentions to implement hands-on learning in their classrooms as a direct result of the science methods class, the PBA, and their mastery of technology-integrated science projects. In the following section, we elaborate on these themes with excerpts from such data sources as in-depth interviews, observations, and journal reflections.

Banter Created a Collaborative and Non-Threatening Learning Environment

In designing the study, we did not anticipate that banter would play the key role that it did. For the purpose of this study, we situate banter as informal good-humored conversations with a playful, teasing tone between students. We were aware of the value of collaborative learning and identified the relevant literature, as evidenced earlier in the paper. To our surprise, however, one of the key forms of communication between students was banter and friendly competitions set up among themselves to compare mastery of technology and content. Banter became a way for students to teach mastery of technology and content to each other and foster successful collaborative learning in groups.

Since the learning environment demanded that the participants design their own research study focusing on a relevant scientific topic using technology, the participants constructed various inquiry approaches to demonstrate mastery. The process of demonstrating mastery was facilitated with banter among peers. Due to the open-ended nature of the mini-research projects, participants were encouraged to explore, discover, and share their findings with each other. Consequently, the participants were excited and curious to learn about the technology (Image Probes and digital cameras) and to determine how they could use it in their mini-research projects. This excitement resulted in banter as participants explored various functions of the technology and assisted each other in its use. The participants used banter to share anxieties about using technology, joke with each other to create a safe learning environment, and assist each other topically and methodologically at various stages of their mini-research projects.

For example, during the initial stages of participation in class assignments, students used banter as a way to create a safe environment to share their anxieties. Michelle stated, “I am not sure how I am going to handle all the technology that I have to use in this class. I am a technology idiot. Kyla, if I fail it’s all on you girl. You need to get me through this.” This kind of bantering allowed students to feel safe to express their lack of knowledge in one area and seek help from their peers.

Moreover, when the students were successful in using technology to collect research data, they started bantering about how easy it was to learn a new skill as evidenced by Tammy’s remarks, “This is not as hard as you think, Beth. I didn’t know anything about this before but in to time you will be a tech expert.” Such banter created open spaces for mentoring between students where they guided each other and provided encouragement. When discussing the substantive aspect of learning science in a collaborative group setting, Jamie stated, “Hey, I didn’t think I could get excited about this project. But y’all in the group were getting so excited that I thought I would miss out if I didn’t take interest. This was fun!” Banter between group members created a heightened enthusiasm and interest in the subject matter, which facilitated collaboration amongst group members. Additionally, when students became successful in understanding the concepts in the assigned tasks, they used banter amongst each other to provide encouragement and foster a safe collaborative learning environment. Kyla stated, “Nah, don’t worry. It’s not that bad. I didn’t think I could do my own science research project either. Hang with our group. I think we are doing some of the same stuff.” Such supportive banter continued to keep students on task and work collaboratively even though the students might have felt anxious or overwhelmed at the thought of learning new technology as they mastered their subject matter.

As the students began their mini-research projects, they expressed anxiety about the use of technology and uncertainty about the sufficiency of their scientific knowledge to successfully design and implement a research project. The initial demographic data in Table 1 also informed the researchers of most students’ lack of exposure to technology and PBA. Therefore, the learning environment was purposely created to foster multiple social learning opportunities. Since the students did not know each other prior to attending the class, sharing their anxieties became a way for students to interact with and support each other.

For example, many students were anxious about using the Image Probe. The Image Probe technology was integrated in the course to allow students to obtain immediate feedback on subjects like the ph level and salinity of the water in their local environment. The immediate information retrieval prompted students to discuss their previous understanding, formulate a new understanding, and conceptualize how such findings could play a role in the mini-research project they designed. However, because the Image Probe was a new technology to many students, they were reluctant to play with the technology initially. As the semester went on, some students became comfortable using the Image Probe and began to tease and goad their peers to use the technology. These students became experts to those who were apprehensive about the technology. The experts began to playfully tease other students to goad them into trying out the technology as they played the role of a mentor. Once, mentees became familiar with Image Probe, they often expressed excitement with phrases like, “I got it!” or “Is that it?” as they screamed or ran around with the Image Probe. Such actions contributed to further banter and created a safe learning environment.

Due to the informal nature of the banter, students were able to draw on each other as resources when they encountered problems learning the technology or understanding a scientific concept. Through analysis of observation notes, post-course interviews, and post-course reflections, it became clear that banter with peers helped create a collaborative learning environment that contributed to understanding both the subject matter and the use of technology. Banter also provided encouragement and camaraderie, leading the students to take ownership of their learning process through meaningful engagement with content.

The role of banter in shaping students’ learning experiences was especially evident in the post-course reflection essays. These essays were filled with rich descriptions of peer interactions, banter with other students, and informal conversations with the instructor. Beth wrote in her reflection:

> I never realized that using technology could be as fun. Although I was afraid at first, Jenine showed me how to use technology. What a simple way to learn and teach. I am so glad that I remained open to technology because now I can see how I can use it in my classroom. We have a bayou right in front of our school and I didn’t even realize that I can use it as a learning tool and integrate technology. If my students can help each other the same way we did then I can see that this would be a very helpful activity for my students. Going through this class, and watching my classmates use technology so well made me think that I can do it too.

Allowing banter among the students became an instructional strategy that often produced a disorganized and disorderly learning environment. Rather than disrupting the learning process, however, according to the researcher’s observation notes this loosely structured, student-directed learning environment instead enabled meaningful construction of knowledge for students. For example one excerpt from the researcher’s observation journal denotes:

> Kyla and Beth kept snatching the Image Probe out of each other’s hands. Kyla kept running around trying to teach everyone how to use the Image Probe. The other students were joking around and laughing at Kyla’s energy and enthusiasm. Mike said that she was like the Energizer bunny. Every time she went to a group to show them what she learned about the Image Probe, she got them excited. Students would scream out loud for being able to master something with which they were initially struggling. By the middle of the class, people were busy running around, joking with each other, showing each other how to use the Probe,

> and then testing and trying out the Probe, creating what would have looked like a chaos to an outsider. But once students learned how to use the technology, there was no stopping them. They wanted to explore how they could use it to answer their research questions.

Thus banter, while creating a disorderly learning environment, contributed to meaningful educational experiences by allowing students to explore their investigative skills, support each other, and create an environment that was flexible and responsive to the students' learning needs and preferences.

Interdisciplinary Connections Were Facilitated through Technology-Integrated PBA

The learning environment in this science methods class was pedagogically integrated with various technologies including Image Probe, digital cameras, PowerPoint, Inspiration, and Excel spreadsheets. While most students were initially unfamiliar with the technology, they developed a working knowledge of all the technology as they worked collaboratively with their peers. Moreover, some of the technology, like Image Probe, provided immediate feedback, which aided in data collection about the water quality. Such immediate feedback assisted the students in making multiple connections, as they were able to integrate issues of water quality with both science and social science topics.

Immediate feedback on water quality also eased students' initial apprehension about using unfamiliar technology, allowing them to focus on making meaning from the information they collected. Impressed with her own ability to test for information and understanding the implications of her learning experience, Katie stated:

> The research done at the bayou was so helpful. I now have a better understanding of our ecosystem [and] connection[s] between temperature, salinity, ph which made [an] impact on aquatic animals. I went into this project not sure of what to expect and without the science background. I felt lost in left field at first, but then as I became accustomed to the procedures I got into it. The research aspect was very interesting, and I did enjoy going to the bayou and testing for results. The image probes were an excellent idea. I thought, Those equipments are for real scientists; I am an elementary teacher. Why do I need to learn this? Now I am feeling I need a little more time to investigate other areas also. I am not at all intimidated by technology anymore. The research was a very interesting hands-on experiment that I felt students could utilize to learn much about our surrounding environment.

Despite her initial anxiety, Katie was ultimately able to use the technology to collect and test information and make connections to other areas of knowledge. Her initial fears dissipated once she became used to the procedures, and she began to concentrate on what the data meant, not just for the purpose of her mini-research project but also for future projects that could be conducted using a similar approach. Katie's increased comfort and confidence mirrored the experiences of her peers, all of whom were engaged in their tasks and continued to help each other in problem-solving as they learned various applications of technology in research. Thus, a group that began the course with limited exposure to a technology-integrated, pedagogically grounded learning environment became their own agents of change through bantering and social learning opportunities.

Using digital cameras to document the research site and uploading the pictures into PowerPoint allowed students to think critically about both the alignment of the pictures with their research questions and the conclusions they sought at the end of their mini-research projects. Moreover, once students learned to upload pictures into PowerPoint they became more adept at manipulating the pictures in various parts of their presentations. These PowerPoint presentations assisted students in connecting topical issues such ecosystem management, the impact of pollution on local culture, wildlife preservation, and policy implications at local and state levels.

Echoing the experiences of many of his peers, Steve reports:

> First I thought that taking pictures was a really cool aspect of this project. I took the digital camera and took many nice pictures. They were pretty pictures of the bayou and I was really proud of myself when I was able to upload them all to my computer to be used for our PowerPoint presentation later. I also learned how to crop pictures so that I can get exactly what I wanted. But as the course continued, I began to think that the cool pictures weren't the best pictures for the kind of evidence I needed to justify my conclusions. I went back and began to take more topically focused pictures and was very happy at the way the project came together.

The act of taking pictures and uploading them to a computer added another level of comfort in the students' use of technology. Knowing that the pictures required alignment with the content presented, students were able to evaluate the merit of their arguments by focusing their efforts on evidence-based data. Their ability to think critically was particularly sharpened by discriminating between pictures that would count as evidence or support an argument and pictures that were "cool" or "nice" but of less persuasive value.

After using various technologies students delivered a final PowerPoint presentation at the end of the course. The purpose of this assignment was for the students to triangulate multiple data sources and reach evidence-based conclusions. The presentations were rich in information with many visual examples, including pictures, concept maps, graphs, and image probe data that were meaningfully connected to the conclusions. The students reported that watching other people's presentations reinforced their own learning and helped them make further interdisciplinary connections. Jamal reported on the value of the final presentations:

> I do not live near [the] bayou, so I hardly ever think about what is going on there. Well, after our research, other presentations by groups, my interest in the conditions of [the] bayou suddenly changed and I was able to see the bayou as the site of study for multiple subjects.

While Jamal was able to make both personal and topical connections as a result of his own participation and by watching other presentations, Chantal valued the way all the information learned throughout the class was integrated into the final presentations. She observed:

> As for the final presentation, I thought the PowerPoint project was an excellent way to bring everything learned together. Not only did I learn about science, but I felt more confident about working with numbers. I thought even young students (4^{th} grade and up) could benefit from this form of presentation, and they would enjoy the use of technology as well. I also learned how studying water quality in our bayou was more than science. It was about the lives of people who lived by the bayou. This was truly interesting to me, because I could apply (lessons learned here) to my social studies class (in order) to learn about our surroundings and (to learn) so many other topics.

Through final presentations grounded in technology-integrated investigative experiences around a local bayou, Chantal was able to gain an integrated understanding of science, social science, and math as she made connections through her experience in the project-based learning environment.

The technology-integrated, project-based approach allowed students to make meaningful connections between multiple subject areas as they became familiar with applying technology and grew to understand the implications of the information they collected. Students were able to identify the salient issues around the local bayou culture and witness the ways in which various types of data were collected, analyzed, and presented in response to the research questions presented by their mini-research projects. Once their anxieties about using technology were alleviated, students were able to make meaning from the data they collected and improve their investigative skills to support their understanding of the subject. Consequently, students were able not only to respond to their own research questions but also to extend their thinking to multiple disciplines and envision how they might foster those connections in their future teaching practices.

Intentions for Future Practice Involving Technology-Integrated PBA for Science Classes

One purpose of creating a technology-integrated, project-based approach to learning was to create exploratory learning environments that would increase in-service teachers' confidence in using technology. Having participated in such a learning environment themselves, the researchers' expectation was that the teachers' confidence in using technology in their own classrooms would increase. As we analyzed the reflection essays at the conclusion of the course and further probed the in-depth interviews, we found that all 14 of the teachers found the hands-on experiences beneficial and reported being surprised by the ease of using the technology. They identified multiple applications they wished to use in their own classrooms and expressed how engaged they felt their students would be once they experienced meaningful connections to the curriculum.

Sheila, a fourth-grade elementary school teacher, was apprehensive at first about using a technology-integrated learning environment for her students. However, after completing the course she stated, “Even my young students (4th grade and up) could benefit from technology-integrated presentation. I know they are more tech savvy than I am and will think I am a pretty cool teacher to let them play.” Kyla, a social science teacher, stated, “I could apply what I learned here to my social studies class to the learning of our surroundings. This, I definitely can bring into my classroom.” It was encouraging to see that while technology played a role in enhancing the in-service teachers’ learning experiences, their intentions for future teaching were grounded in teaching effectiveness and not in imagining technology as a panacea.

Responding to the value of hands-on learning, in-service teachers expressed their intention to immerse students in the natural environment so they could develop investigative skills. In response to growing concerns about effective classroom management strategies, Katie remarked, “Getting the students immersed in investigation in natural surroundings with technology will make my headaches for classroom management go away.” Not only have these teachers found ways to create meaningful experiences for their students, they have also identified classroom management and teaching strategies as potential advantages of hands-on, technology-based learning.

While all 14 in-service teachers interviewed expressed appreciation for the ease of technology use in hands-on learning, six of them also articulated a need to receive further training to develop better teaching strategies that would allow them to cover the curriculum while integrating investigative learning with technology through project-based experiences. Steve stated, “While I know this will take my teaching to a new level, I am not quite sure about the ways I would develop some of these teaching strategies into my lesson plan and still cover all my material.” Melanie, an elementary school teacher, likewise expressed:

> I have no problem with project-based approach. My class is open to this, but I need to learn how to work it into my ways of teaching. I have always been the leader and let the students follow, however through the knowledge learned in this class I can expand my teaching to new levels but I wish that there were more people in my school who could be role models for me. But I know that I will be able to better my teaching strategies through the use of the lessons learned in this class.

Jamie, a middle-school teacher, discussed the confidence he now feels in using technology, but expressed some skepticism about its practical application in his class due to the amount of material he is expected to cover. He stated:

> I really enjoyed the technology use in this class and thoroughly loved the exploratory aspect of my learning. I would love to use some of these ideas in my classroom but I am not sure how I will be able to cover all the material and continue to remain explorative in my instruction. I will be able to use some of the techniques that I learned in the class but I am afraid that without having someone to talk to at my school about ways to cover the curriculum and still remain current in my teaching strategies I might not be able to accomplish all that I wish to do with my class.

Although in-service teachers discussed various uses of the technology-integrated, project- based approach for their individual classes, they expressed concern about the absence of role models in their schools to guide them in furthering their specific instructional strategies. While the in-service teachers described an increase in their confidence in using technologies, they also feared that without support from colleagues and administrators, and with the pressure of completing all the curriculum mandates, they would be limited in transferring what they had learned in the science methods class to their own classrooms. Nevertheless, the in-service teachers' increased confidence in using technology made them concentrate on designing content to create pedagogically grounded and meaningful instruction that would keep their students engaged and immersed in applied learning experiences.

Conclusion and Implications

This research explored the role(s) a technology-integrated, project-based approach plays in a science education class in shaping the experiences of in-service teachers and their intentions for future instructional practices. We were able to answer our research questions by discovering that in-service teachers gained confidence in using technology-integrated instruction as they became comfortable using several types of technology, and thus were able to concentrate on the content of the class instead of focusing on the nuances of the technology. Using authentic learning experiences through a project-based approach allowed in-service teachers to make connections to a variety of topic areas in science and social science, thereby identifying multiple ways they could use such an approach in their own classrooms. However, while all the in-service teachers identified numerous potential uses of the technology-integrated, project-based approach in their classrooms, many expressed a concern that lack of time, the absence of effective instructional models, and the pressures of standardized testing and curriculum mandates might pose obstacles to implementing innovative, investigative, and exploratory teaching practices.

The implications of this work are multifaceted, highlighting not only the value of a technology-integrated, project-based learning environment but also the need for support at multiple levels, including both K-12 and higher education. Because there is an urgent need to improve teachers' skills in using technology in their classrooms, care must be taken to ensure that the use of technology is pedagogically grounded in authentic experiences in which learners engage meaningfully with the subject of study, instead of becoming mired in the details of using technology. Technology employed in a learning environment should be relatively easy to use, so students can gain confidence in their ability to utilize the technology while focusing their thinking on the material under investigation. The confidence gained through engaging in learning experiences in a technology-rich, socially interactive environment allows learners to identify various possibilities for problem-solving.

Moreover, because students were able to forge interdisciplinary connections between science, social science, and math, they were able to expand their understanding of science beyond textbooks, and results obtained in laboratories, to everyday examples. Through the discovery of these interdisciplinary connections and their increased confidence in using and integrating technology in their classrooms, pre-service and in-service teachers were able to identify multiple possibilities for their future teaching practices.

In light of the progress demonstrated by teachers in this study, more teacher education classes should model technology-integrated, engaged learning environments so pre-service and in-service teachers have a wider range of options from which to choose when developing their own teaching strategies. Furthermore, such technology-infused learning environments would offer in-service teachers multiple possibilities for grounding instruction pedagogically instead of simply adding new technology to the classroom without any connection to learning theories, resulting in isolated and possibly ineffective efforts to incorporate technological literacy into teaching practices. With a range of options and exemplars modeled in teacher education courses, in-service teachers will be able to critically evaluate the appropriateness of instructional strategies in their own teaching environments based on the resources, funding, and support available.

Finally, support for creating and maintaining technology-integrated, project-based learning environments needs to come from all administrative levels. Such support should include, but not be limited to, modeling lesson plans, identifying successful instructional strategies, designing quality instructional aids, and providing funding for necessary resources so that teachers who wish to employ innovative approaches may continue to meet curricular mandates. With teachers' current workload, it is not possible for them to reinvent their teaching unless they are provided with exemplars and necessary resources. To this end, before teachers are asked to adopt a new pedagogy and reinvent their instructional strategies a team approach must be firmly in place. This approach must engage all stakeholders (i.e., administrators, practitioners, university faculty, and students in teacher education programs) in creating and evaluating the effectiveness of innovative learning environments, and identifying all possible resources and support needed for successful implementation.

Because this is an exploratory study, we cannot generalize these findings to other settings. However, our study is situated within the current literature, in which calls for technology-integrated science education are pervasive. Findings from this study might be transferable in part to other similarly positioned teacher education programs. Moreover, this study may provide ideas for creating teacher education programs that are responsive to NCLB initiatives and support teachers in preparing to meet such initiatives. Furthermore, educational researchers, instructional designers, and technologists can work collaboratively with teachers, teacher education programs, and school administrators to identify specific needs and to appropriately address those needs in teacher education programs. Ultimately the investment of time and resources will be well worth the costs, as the performance of students and teachers within a school will only be as strong as the training and support provided.

It is unfair to expect our students and our teachers to be global competitors in science education without adequate training and resources. Because this is a critical issue facing many science educators and teacher education programs across the country, more open-ended conversations and research need to occur to identify possibilities to break through challenges like prior training, lack of exposure to pedagogy-based technology-integrated science education curriculum and instruction, and lack of ongoing support and resources. However, it is undeniable that without developing an in-depth understanding about challenges facing science education, and developing local and national solutions, students in the U.S. will continue to perform poorly in science.

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The "Chemistry Mafia": The Social Structure of Chemistry Majors in Lab

Dawn I. Del Carlo
University of Northern Iowa

George M. Bodner
Purdue University

Abstract

A great deal of attention has been paid to the effects of group work on the performance of students enrolled in chemistry courses. However, relatively little research has been done that addresses possible explanations for the observed improvement in student performance when group work is done. In this study, a combination of field notes based on observations made during classroom laboratory courses taken by chemistry majors, individual interviews with students in the sections that were observed, and focus-group interviews with groups of students who worked together in the lab provided insight into the social interactions that occur when chemistry majors work in groups over a sequence of classroom laboratory courses. The data suggest that these social interactions set the basis for the development of a community of learners, a "Chemistry Mafia", who trust each other well enough to seek help with the content knowledge of their chemistry courses, which they might be loathe to seek from peers with whom they are less familiar. This work suggests that "off-task" interactions (e.g., socializing) in the laboratory are, in fact, valuable in developing this community of learners.

Correspondence should be addressed to Dawn Del Carlo (Email: dawn.delcarlo@uni.edu), Department of Chemistry and Biochemistry, University of Northern IA, 50614-0423

Introduction

Group work in both K-12 and higher education has received an incredible amount of attention in recent years. Most of this work has focused on the benefits of group work, which include better performance in class, better interpersonal skills, higher retention of covered topics, and improved attitudes towards science (Bowen, 2000; Cohen, 1994; Dougherty *et al.*, 1995; Lazarowitz & Hertz-Lazarowitz, 1998; Okebukola & Ogunniyi, 1984; Tlusty *et al.*, 1993). Articles on group work that do not focus on the specific benefits of working in groups, examine the kind of group structure – such as optimal size and ability distribution – that elicits those benefits (Farrell *et al.*, 1999; Lawrenz & Munch, 1984; Lazarowitz *et al.*, 1994). There is abundant evidence that group learning consistently "works" (e.g. Felder, 1996; Gamson, 1994; Springer *et al.*, 1999); what we need to know is how.

Hamby-Towns and co-workers studied what small-group learning activities meant to students involved in an undergraduate thermodynamics class that utilized group work during "Problem-Solving Sessions" (Hamby Towns *et al.*, 2000; Kreke & Hamby Towns, 1997). This study provided useful insights into group work by using a qualitative research approach to determine the students' perspectives on group work. The authors found that group work in this class contributed to positive outcomes such as content learning and assessment performance because it built a feeling of community among the students. This feeling of community in turn fostered the development of "mutual goals centered on learning and achievement" (Hamby Towns et al., 2000, p. 115). The interplay between this feeling of community and mutual goals may ultimately lead to the improvements in learning, achievement and persistence documented in the literature.

Support for building a feeling of community is also found in the literature describing mentor programs established to encourage women and minorities to enter and stay in the fields of science. In a study of women and minority students in science, mathematics and engineering (SME) programs, Seymour (1995) found that participants were unlikely to feel that they "belong" in that field, regardless of how well prepared they were when they entered an SME program. She argued that the lack of belonging leads to shaken confidence and ultimately to a change in major to something outside of SME (Seymour, 1995). Programs across the nation purposefully build resources such as mentoring, tutoring, residential hall programs, cultural centers, and faculty support to encourage a sense of community among their women and minorities majoring in science (Bernstein, 1997; Carmichael & Sevenair, 1991; Hoyte & Collett, 1993; Johnson & Parrott, 1992; Kahveci *et al.*, 2006, 2008). Perhaps it is not surprising that historically black institutions and women's colleges, which actively work to develop a sense of community among their students, have better track records at graduating women and minorities in the sciences than other educational institutions (Carmichael & Sevenair, 1991; Sebrechts, 1992), or that the University of Puerto Rico graduates more Hispanic students who go on for their doctorate than any of its mainland competition (Hoyte & Collett, 1993). In each of these cases, women and minorities are not targeted as isolated groups of people. Instead, they are considered part of the majority and consequently have the support of their surrounding community of peers, which sees them through the difficult times and to the completion of a degree. However, as Kahveci (2006) found, there is evidence to suggest that retention of all students, not just select sub-groups, is becoming critical.

These studies establish that group work and a sense of belonging among science students positively influences their academic achievement and retention in SME. The goal of this paper is to examine the processes involved in the construction of a self-formed community of chemistry majors. Particular attention is paid to both the academic and emotional support systems established among students within their laboratory courses at varying levels in the chemistry curriculum. This is particularly relevant in light of the fact that chemistry is often perceived as one of the more challenging science disciplines (Osborne *et al.*, 2003). The goal is not to assess the productivity of students in the laboratory, their academic accomplishments, or their longitudinal retention in the major as a result of working in groups – relationships which have been studied extensively in the past and were shown to be a positive influence as discussed earlier. Instead, the intent of this study is to focus specifically on how individuals interact both within a group and between groups to develop the sense of community so integral to higher learning and performance, and higher retention in the major. Given that group work has already been established as an effective tool in teaching and retention, the research question guiding this study is:

> What interactions occur between chemistry majors within the context of classroom laboratory group work that contribute to a sense of community between those students?

Theoretical Framework

The theoretical framework chosen to shape this work is symbolic interactionism. Traditionally grounded in elements of social psychology, symbolic interactionism attempts to answer the question: "What common set of symbols and understandings have emerged to give meaning to people's interactions?" (Patton, 1990, p 75). These meanings are of central importance in symbolic interactionism and are governed by three assumptions (Blumer, 1969; Patton, 1990; Schwandt, 1997):

- Humans act toward the objects and people in their environments on the basis of the meanings these objects and people have for them.
- These meanings derive from the social interaction (communication, broadly understood) between and among individuals.
- Meanings are established and modified through an interpretive process undertaken by the individual actor.

These assumptions imply that meaning is only established through social communication and is "objective or behavioral" (Gallant & Kleinman, 1983). In other words, meanings are not held in individuals' minds; they are a social entity and are consequently contextualized in the social environment. Therefore, a particular meaning is not determined by an individual's experiences, but by the social interactions (communications) the individual has with his/her peers. It is these constantly evolving meanings that determine people's actions.

Methodologically speaking, the main goal of an interactionist is to use observable interactions to identify implied symbolic behavior (Denzin, 1969). This goal indicates that certain research practices need to be followed. First, both behavioral analyses and analysis of personally held meanings and definitions must be examined. This means data must consist of both observations of actions – or interactions such as those that occur in a laboratory environment – and in-depth interviews to uncover individual meanings. One without the other would only allow the researcher to gain insight into either the observable or the implied; not both.

Second, both individual and interactional meanings must be examined and analyzed. As the data are examined, the researcher seeks existing associations between the observed behaviors and the meanings that students possess and acquire through the laboratory experience. In the context of this study, behaviors observed in the lab setting were compared to the meanings drawn from interviews in search of connections between the two realms.

Third, the researcher must view things through the perspective of participants involved in the study in order to adequately understand human action. The best way to achieve this is for the researcher to enter the participants' setting or situation. Participant observation becomes a key method here (Patton, 2002); it allows the researcher to contextualize the data being collected and participate in the interactions of the participants. The researcher, in this case a student of science herself – with experience in both the classroom laboratory and research laboratory settings – was allowed a unique insight into the domain under study.

Fourth, meanings are tied to social situations – or contextualized – and therefore the situation or setting itself becomes an element of analysis. Here, one must address the role of the researcher and how his/her presence affects the interaction process. This becomes a particularly important point for participant observation where the researcher's presence in a lab potentially alters the behaviors exhibited by the students and will be discussed in detail later.

Finally, the methodological approach must be pliable, to reflect both the stability and constant change of a social group. This is most commonly handled by triangulation, which involves the use of more than one data collection technique (Patton, 1990, 2002). The multiple methodologies deemed appropriate for this work included a combination of laboratory observations, individual interviews, and group interviews.

Methodology

The methodological design of this study included three parts: individual semi-structured interviews, focus-group interviews, and observations in a chemistry classroom laboratory setting. Each aspect of the study design allowed for a different but complimentary insight into students' ideas about social behavior in a lab setting. One course at each level of a 4-year, chemistry-major curriculum was chosen to study students' perceptions of their experiences as science students. Observations were conducted throughout an entire, 16-week, Fall semester at a large, state funded, Midwestern institution in four courses, three of which were designed for and taken only by chemistry majors — a 100-level general chemistry course taken by first-year students, a 200-level inorganic course taken by second- or third-year students, a 300-level analytical course taken by third-year students, and a 400-level instrumental analysis course taken by fourth- or fifth- year students seeking the ACS certified degree. The only course that included students who were not chemistry majors was the 300-level course, in which 7 of the 18 students were pre-pharmacy majors. Since the courses were spread out over the entire four year sequence leading to a B.S. degree in chemistry, students ranged in age from 18-23 years old. All courses had a mandatory laboratory component and built upon previous courses. The 400-level course, for example, assumed that the students would have had laboratory experiences in all three previous courses. While the same students likely progress through the sequence of courses together, the size of the program – approximately 60-80 chemistry graduates per year – requires several sections of a particular lab course to be offered during any given semester. Therefore, groups of students do not necessarily enroll in the same laboratory sections from year to year, despite the fact that they are in the same lecture and frequently see one another during that time.

These specific courses and their individual sections were selected so that the researcher could fit all four lab sections into her schedule. Each course met once a week and the observer attended every 3-hour laboratory session until all students had left the room (see Table I for additional information).

Table I:
Breakdown of the enrollment of the observed sections, number of lab sessions that met during the Fall 2000 semester, and typical lab group size for each observed course

	100-level	*200-level*	*300-level*	*400-level*
Enrollment	37 (split into 2 adjoining rooms)	16	18	13
Sessions	13	14	9	12
Group Size	2-3	2-4	4-5	2-5

Detailed field notes were taken with pen and paper, then transcribed and elaborated on within 24 hours of the lab meeting. Notes included descriptions of accounts of interactions students had with each other, the equipment used in the lab, the teaching assistant, or the researcher, and even included comments students made to themselves. In line with the theoretical framework and participant observation, the researcher interacted with the students, answering questions about the lab when she could, getting involved in conversations between students, and discussing the details of her research when asked. While it is conceivable that the researcher's presence altered the behavior of the students, the role the researcher attempted to play was that of someone between "student" and "knowledgeable expert". This allowed her to fit in to the laboratory setting with as little intrusion as possible since students were accustomed to the presence of each other and teaching assistants. Observations collected during the labs played a crucial role in determining the content and structure of both the individual and focus group interviews.

Half-way through the semester, volunteers were asked to participate in group and individual interviews. All students who volunteered were scheduled for interviews. Students who could not meet during group times were slotted as individual interview participants. Two focus groups from each class were organized (for a total of eight group interviews) and ranged in size from three to six students. With the exception of one student, no one who participated in the group interviews participated in an individual interview. Groups were also organized such that only students from the same lab sections were involved in a single group, allowing the group to discuss issues specific to their course and section. Unlike the individual interviews, the focus-group interviews supplemented the discussion by adding the social aspect of the classroom laboratory. In line with the symbolic interactionism framework, focus group interviews were able to contextualize the topic of conversation – which was often an event from lab – with the same people involved in the laboratory. This also allowed the researcher to probe for meaning behind the particular event without students being distracted by their lab responsibilities. As with any group setting this may have intimidated some, but it inspired others and usually instigated a lively discourse that allowed for social interaction and was welcomed as part of the discourse.

The key characteristic of focus groups is “the explicit use of the group interaction to produce data and insights that would be less accessible without the interaction found in a group” (Morgan, 1988, p. 12). Focus groups were useful here because they allowed the social aspect of chemistry to emerge and be observed as well as discussed. As Morgan notes, focus groups can reveal attitudes and cognitions in the same way as individual interviews, but they can also reveal social roles and organizations similar to participant observations. Consequently, the focus group interviews served as a connective bridge between the observations and the individual interviews. Although the focus-group interviews did not take place in a laboratory setting, the participants in a given focus group were always from the same laboratory section and therefore had common laboratory experiences to bring to the discussion.

Two individuals from each course volunteered to participate in interviews but could not arrange to meet with the group. These eight individuals instead participated in individual interviews ranging in length from approximately 45-120 minutes. These interviews were conducted within the same time frame as the group interviews but at a time more convenient to the student than the group interview. Individual interviews allowed for a detailed account of what each participant believed and experienced. There were minimal peer-related social constraints and influences on the students in these interviews because only the researcher and the participant were present. The researcher was therefore able to ask probing questions pertaining to issues at hand and uncover the implied meanings that events had for the participants.

All interviews were unstructured and started with the question: “What do you think of [course number] lab?” Where the conversation went from there was determined by the student(s). The researcher asked an occasional question to either get the conversation going, direct the conversation back on track, or probe a particular issue further. Certain topics that became apparent from the observations and were specifically addressed by the interviewer included the social aspect of lab, the time constraints of lab, and students’ attitudes toward lab. Interviews allowed participants to clarify and explain specific observations and validate the researcher’s interpretation of those observations. The interviews were audio-taped and transcribed in full by the researcher for analysis.

Analysis

Inductive analysis was performed with the aid of the “Atlas.ti” software package (Muhr, 1997) and was ongoing throughout data collection. Transcripts and observation notes were read and coded by the researcher based on the predominant themes that emerged from individual text units[3] with the data. The field notes and observations, individual interviews, and group interviews were coded separately with the analysis of the field notes and observations taking place first simply because they were collected before interviews were conducted.

One of the most recurrent themes from the classroom observations was how frequently students entered into social interactions among themselves, with the researcher, and/or with the teaching assistant. During the first phase of the analysis, the codes "social talk" and "social including researcher" were created to identify occurrences of behavior and conversation that were "off-task" — not directly related to the laboratory task at hand. On-task activities were coded separately because group work has already been shown to be effective in improving performance (Lazarowitz & Hertz-Lazarowitz, 1998), and given our research question our focus here is on the social interaction within the laboratory, not the quality of laboratory performance. Therefore, on-task activities will not be discussed this paper, and happened concurrently with – rather than instead of – off-task activities and conversations with the exception of one type of activity titled "killing time." Table II lists the distribution of text units coded for each class in the original categories of "social talk" – social conversations between any number of students – and "social including researcher" – social conversations between students and the researcher.

Table II:
Number of "social talk" and "social including researcher" text units per class over the course of the entire semester. Numbers in parenthesis indicate the average number of text units per session.

Code	*100-level*	*200-level*	*300-level*	*400-level*
social talk	24 (1.85)	51 (3.64)	28 (3.11)	45 (3.75)
social including researcher	20 (1.54)	22 (1.57)	20 (2.22)	27 (2.25)

During the second phase of the analysis of observations, the "social talk" and "social including researcher" categories were divided into a number of sub-codes, listed alphabetically and defined in Table III. The total number of text units in Table III is larger than in Table II because many of the text units fell under multiple sub-codes.

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[3] For the purpose of this analysis, the term "text unit" is defined as a segment of transcribed text which falls under a particular code that can vary in length from a few lines to a paragraph or more.

While qualitative research does not typically involve numerical counts, such as those in Table III, they are informative in this case, especially when averaged over the number of lab sessions, as represented by the values listed in parentheses.

Table III

Breakdown of text units from "social talk" and "social including researcher" categories over the course of the entire semester. Numbers in parenthesis indicate the average number of text units per session.

Code	*100-level*	*200-level*	*300-level*	*400-level*	*Definition*
anti-social	2 (0.15)	1 (0.071)	1 (0.11)	11 (0.92)	Occurrences where students specifically avoided social interaction either by focusing on the experiment or walking away.
background talk	10 (0.77)	6 (0.43)	1 (0.11)	1 (0.083)	Conversation about hometowns, personal hobbies and interests, academic minors (since they are all chemistry majors), and general getting-to-know-you topics.
chem classes	5 (0.38)	12 (0.86)	10 (1.11)	14 (1.17)	Discussion pertaining to chemistry classes; either the lecture component of the observed class or other classes such as organic and p-chem.
Joking / goofing off	8 (0.62)	10 (0.71)	12 (1.33)	3 (0.25)	Cracking of jokes, participating in horseplay, and just plain being silly.
killing time	0	20 (1.43)	13 (1.44)	24 (2.00)	Activity or conversation that occurred during the time between experimental runs, while a reaction was running, or while samples were drying.
non-chem class talk	4 (0.31)	4 (0.29)	3 (0.33)	1 (0.083)	Discussion pertaining to classes other than chemistry including languages, physics, math, computer science, and geo-science.
personal conflicts	3 (0.23)	1 (0.071)	2 (0.22)	0	Miscommunications between lab partners and confrontational discussions.
research/job talk	1 (0.077)	6 (0.43)	4 (0.44)	11 (0.92)	Discussion over internship, research or job opportunities and experiences.
romance	3 (0.23)	3 (0.21)	0	0	Overtly flirtatious behavior between students.
social commentary	13 (1.00)	20 (1.43)	15 (1.67)	25 (2.08)	Conversations of a personal nature about society, men, women, sex, politics, and day- to-day issues of college life.

The amount of social talk per laboratory session, for example, is roughly the same for each of the observed classes. The exception being the 100-level course in which students generally finished early and left, reducing the amount of time for social interaction and consequently the total number of social text units given the larger enrollment. Due to the fact that group composition – and therefore, total number of groups – in all but the 300-level class varied from session to session, an average number of text units per group could not be calculated. Another trend worth noting is the fact that the amount of interaction with the researcher increases slightly in the upper level classes due to the fact that several students had the researcher as a teaching assistant in the past and were already comfortable around her. The rationale behind the frequency of each sub-code can be found in Table IV but only a few of particular interest will be explained further in the results section.

Table IV

Frequency explanation for sub-codes from "social talk" and social including researcher"

Code	*Rationale*
anti-social	Not used very frequently however the unusually large number in the 400-level course reflects one particular student who was very withdrawn from her group throughout the semester.
background talk	Most frequent in lower-level classes where students were less familiar with each other.
chem classes	Smaller number of text units at the 100-level where students only have experience with the course in which they are currently enrolled. However, students in the other courses were either concurrently enrolled or had previously taken several other chemistry classes and so their numbers are higher.
joking/goofing off	Lower number of text units in the 100 and 400 level classes which is reflective of the overall tone of the students in the class. Might be attributed to the fact that these sections met at 7:30 am.
killing time	No occurrences in 100-level class, because experiments in this course were relatively short and students left once they finished.
non-chem class talk	Low number in the 400-level course may be due to the fact that most courses taken by this level are related to chem. This is supported by the slightly larger number in “chem classes”
personal conflicts	Also not used very frequently and simply illustrates some of the natural frustrations that arise from working with other people.
research/job talk	Most frequent in the 400-level class which contained seniors preparing to graduate.

Code	*Rationale*
romance	Text units pertain to two sets of students (one each in the 100- and 200-level courses). One set was in fact dating at the time, however, the other set of students never defined their relationship to the researcher.
social commentary	Overall largest number of text units with an increasing number of text units per lab session as the level of course increases indicating the development of social structure.

Once interview data was collected, the codes generated from the observations were used to begin to analyze the transcripts. This process of triangulation across the three sources (Patton, 1990) is in line with the theoretical framework by allowing the researcher to determine similarities and differences between the data sources (getting at the required pliability of the approach), as well as ascertain the meanings associated with the social situations observed. Text units from codes which existed in multiple sources were examined through the lens of the research question for commonalities to determine what types of interactions contributed to a sense of community among chemistry majors.

Results

Classroom Observations

Interesting results are associated with the sub-code “killing time.” This code was used to indicate activity or conversation that occurred during the time between experimental runs, while a reaction was running, or samples were drying. Examples of observation notes include:

200-level: After students take their spectra and put their samples in the oven several students go out into the hall to play cards since the samples need to dry for an hour.

300-level: There's lot of conversation in Amy's[4] group while the titration is going on…Once they get everything set up all they have to do is switch samples and let the computer do the rest. Each run takes about 15-20 minutes so there's a lot of down time.

400-level: UV/VIS group strikes up a conversation with their TA. Jenna is apparently going to visit upstate New York. Aire is from there and Anna also seems familiar with it. They're all waiting for the reaction to come to equilibrium before doing the run.

There were no recorded occurrences of “killing time” in the 100-level class, which is in accordance with the fact that the experiments in this course were relatively

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[4] Pseudonyms were assigned to all participants.

short and students were allowed to leave once they had finished. The other three courses had about the same amount of social interaction while "killing time" per lab session indicating similar types of experiments and classroom structure.

Closely related to "killing time" is "joking/goofing off", which was used to indicate when students did anything from crack jokes to dismantling the backside of a lab bench to see what was inside:

> *100-level:* John and Eric get into a dialogue conversation that only consists of the word "dude" which they chuckle about after its completion.
>
> *200-level:* Don, Jessica, and Peter get four model kits together in an attempt to figure out their nearest neighbor's problem. They are briefly distracted when they realize that the Styrofoam balls stick to Don's fleece jacket so they start throwing them at him.
>
> *300-level:* Amy's group gets the idea from the other section to unscrew the back panel off of the lab bench. For no other [apparent] reason than to see what's behind it. They're using spatulas from their drawers and Swiss Army knives to undo the screws…Once they are able to get it off and look inside they try to get a pipet that is stuck under the drawer. They realize that it won't come out without breaking it and decide to put the panel back on…Amy can't get the panel lined up right to fit the screws back in. They struggle with it for a good ten minutes before Lynn has to get on the floor on her back and push the panel up with her feet while Amy puts the screws back in.
>
> *400-level:* The rest of the group talks about how Sissy wanted to use a "scary font" on her lab report for today since it was Halloween.

These antics are similar to those found in "killing time" but were not the consequence of downtime that occurred within an experiment, and were actually performed while they or their group members continued to work on the laboratory task at hand. These were not distractions due to a lack of things to do, but intentional sidebars to interject "fun" into "work." Consequently, these activities and conversations did not sacrifice the completion of the on-task activities, and in fact happened concurrently. For example, the conversation illustrated above which only consisted of the word "dude" was performed as the two group members walked to the hood, measured the chemicals needed, and added them to their flask before moving on to the next part of the experiment, illustrating that many "off-task" interactions happen even while "on-task" activities are being performed.

The code "Background talk," which refers to conversation about hometowns, personal hobbies and interests, academic minors (since they are all chemistry majors), and general getting-to-know-you topics, was most frequent in the lower-level classes where students were less familiar with each other.

100-level: As they are cleaning up Lori and Kathy talk about their high school experiences and what stupid things their teachers did. One thing was the fact that they used glass burets with "stoppers" that fell out. Another teacher put Na metal into water and not the other way around so flames end up scorching the ceiling.

200-level: Tammy says that there is a certain order to adding reactants but Bonnie says it all goes into solution anyway so just mix it, it doesn't matter. [The researcher] asked her if she was the type of person who mixed her peas and carrots on her plate. She says "oh, yeah and I add them to my mashed potatoes". At this point Jeremy steps in and says "how can you do that?”

As can be seen by the gradual decrease in text units per session with increasing course level (Table III) and the fact that “background talk” is not merely limited to pre-college experiences, the data in this category suggest the evolution of a community of students who become more familiar with each other as the students progress through their academic careers. If a community were not established and progressing, and students were unfamiliar with one another at each stage of the program, one would expect to see “background talk” prominently in all of the courses regardless of level.

The code containing the largest total number of examples is “social commentary”, which encompasses conversations of a personal nature about society, men, women, sex, politics, and the day- to-day issues of life — college life in particular. Students discussed issues ranging from marriage to the fact that they overslept because the power went out in the residence halls.

100-level: Becky, Katie, and [the researcher] started talking about lack of sleep and having to get up for a 7:30 [lab] and Becky mentions how she was so proud of herself for not going out to a frat party last night because she knew she had to be up for lab.

200-level: [One group] talk[s] about parking tickets. Apparently Lizzie got one a few weeks ago but couldn't find her checkbook. Once she found her checkbook she lost the ticket. She now found the ticket and has to pay for it.

300-level: Amy, Jerome, Lynn, and [the researcher] get to talking at the beginning of lab about babies (Jerome's roommate is a father and Jerome missed seeing the baby the other night since he wasn't home). Eventually the conversation led to birth weights and how the average is so much higher than it used to be.

400-level: One particular conversation [in the group] revolved around a friend of Sissy's from high school who apparently is going to be married or was married recently and how Sissy keeps hoping that she will wait to have children until after she graduates 2 years from now.

> She also wants her friend to have a career since she will be the bread winner in the marriage (her husband is a social work major).

These conversions were unrelated to chemistry, and resembled the topics that groups of individuals at this age might discuss while going out to lunch, or at a party. As one would expect, the number of text units per session increased with the level of course. This illustrates a shift in social interaction from primarily “background talk” in the lower level courses, to a more personal nature in “social commentary”. When the text units from these codes were compared with the interviews, it was clear that the students considered the classroom laboratory an environment in which they can interact and behave on a social level. Inasmuch as the primary goals of the laboratory are traditionally thought to focus on academic issues, the social aspect of the laboratory classroom that was apparent from the field notes was explicitly addressed in both the individual and focus group interviews.

Student Interviews

Two predominant themes emerged from the interviews and supported the findings from the observations. First, the students were social in the laboratory as a means of making the best of a forced situation. Although these students were chemistry majors, they were not particularly interested in spending their time in the classroom laboratory environment. They therefore entered into social interactions while simultaneously performing on-task activities in order to make the situation tolerable. Bonnie, for example, who was a 200-level student, stated in her individual interview:

> So I look at it as teamwork, and you have to get along with the people around you ... I think it's social because you, I mean you have to do [group work]…why not have a good time while you're there? You know, I mean if you're gonna just be biting your nails and you know, getting all mad for three hours isn't going to make the three hours go any easier. So you know, why not have fun while you're there. I mean … what we're doing isn't really hard.

Bonnie felt the tasks at hand in the classroom laboratory were not particularly challenging and she was required to work with other people in her lab section, so the only way to make it bearable was to joke around and have fun. This attitude was shared by Ed and Amy, 300-level students:

> Amy: I think that's why people are really social in lab, it's because like in a lab you can, having to cook something for like an hour. Well ok, so you either sit there...doing nothing, read the paper or you go talk to people … I don't know like, if you just sat there and did nothing I would be upset with myself, but it's a lot better if I have my buddies there because at least we can talk.
>
> Ed: Yeah, I just think … it's characteristic of everything, that it's more bearable if you're having fun, you know and, sitting there just starting and watching things boil, you know that's not fun for anyone, not even me. And uh, I would say it,

> wouldn't that be characteristic of every lab that you, you start talking to people when there's nothing else to do?

Similar comments from the other classes provided insight into reasons for the social atmosphere evident in the observation data. The social aspects of interactions in the laboratory classroom, however, go beyond simple boredom. Once students acknowledged in their interviews that the lab was social, they went on to note that the social atmosphere developed in the classroom laboratory extends beyond the lab courses and evolves over the course of their academic careers.

> *100-level:* And the situation with [my one partner] has been really good with me, because like, we became lab partners and we started dating, so it's kind of a nice situation for me.
>
> *200-level:* When comparing to taking classes at [the local 2-year college] you couldn't become like, friends with anybody in your class because…these weren't the people that you were going to call up later on that night and try to get help from or anything like that. Or, call them up and be like, hey let's go watch a movie or something like that, or see them everyday because you know, they live an hour away from where you lived…[It was] completely different, not as much fun.
>
> *300-level:* I made my friends my freshman year in freshman chemistry you know, and it's just so much easier to go talk to people…it seemed like they were always a lot more willing to help [than professors]…it was just, I don't know, a lot more social and open.
>
> *400-level:* Like I know with my group we've been lab partners since like, forever you know. And it was like we'd said before, when you start out as a freshman…and we all know each other and we all get along and there's like little groups you know, friends that have developed from these classes and you know you're just, when you're in a group with these people you're social with them.

The second major theme that emerged from the individual interviews stems from the extended social interaction between students, and was termed the "chemistry mafia". This term originated from Ed, a student in the 300-level class, to describe a group within his particular graduating class of chemistry majors:

> I think the group, like the chemistry mafia kind of hangs out. There's like a core group and I go and do p-chem with them, and I'm friends with all of them but like, we don't hang out and stuff.

"Chemistry mafia" was used by the students to refer to a specific, tight-knit group of students who, through their interactions in shared courses, developed relationships based not only on academic assistance but social companionship and emotional support fostering a better work and learning environment. This idea is developed further by Bonnie who, while not in the 300-level class at the time, was taking physical chemistry with the group of students Ed labeled as the mafia:

> We're in a pack. I mean, there's 20 of us in [this] pack. Ed put it best, we're the chemistry mafia, we are!...I feel, I have a lot more gusto to go up to a TA or a prof and say, “hey I [don’t understand]”, and if I didn't have a group backing me up I probably wouldn't do that. And I know that if I have a thought like that, I have a whole bunch of people to ask and say hey, what do you guys think about it? You know, give me some feedback; tell me how you would do this.

The key element to this group clearly stems from the social interactions between students as they progress through their coursework. A good example of this is a discussion Sandi, a 300-level student had in her interview:

> I guess it's just started from like, my freshman chemistry. We've all been together since then and we all pretty much know what's going on in each other's lives…[and] the more people we meet in lab the more people, our group expands out.

Theodore, a 300-level student, emphasizes the importance of the social aspect in his group interview:

> Well, I think it's, it's helpful to be social because I mean, if you know you have to get something done then of course you're not just going to be talking, talking about things that aren't relevant to lab. And then you know like, if you're friendly with the people that are in your group and other groups then you can ask them and see what's going on, things like that. So that's actually very helpful. 'Cause if you’re in a situation where you feel kind of like, almost scared to talk to somebody else and you need help or you want to do this, you might not actually do that and, and that's not really helpful to yourself. So I think it's good.

Theodore admitted that the students in his class of chemistry majors talked about chemistry issues as well as social issues, but he felt this group of students was more at ease asking each other for needed help on academic issues because the social issues that lead to the formation of a community of learners had already been established. For many students this academic help was crucial to their success in chemistry, but they noted they would rather not reveal their academic weaknesses unless they felt they had the support of those around them. Seeking academic help becomes an issue of trust within a community of peers. These students developed their own community of learners, in which they felt secure and could trust other students. Another 300-level student sums this up in a group interview by saying:

> Yeah it's more like people are just, everybody's comfortable ... [the other student’s] group is especially comfortable with each other … they're all friends or whatever. I mean and then our group like, some of us are friends, some of us just know each other and then it just kind of rubs off 'cause they're standing right in

> front of us. I mean so everybody pretty much is comfortable saying whatever, like you're doing this wrong, oh you need to add this.

Because the members of this group were both familiar and comfortable with each other, they had no problem asking for help or correcting their lab mates, ultimately facilitating the learning process for all members of the group. Tammy, a 200-level student discussed friends gained through lab interactions as a resource in her group interview:

> Ok, college is really you learn how to use, you realize all the resources that you have in all your friends…My favorite thing would be to be on instant messenger you know, talking to people trying to figure out some of the [chemistry] problems, being on the phone and doing the homework….It's just, it's funny. And I think it's funny how, 'cause really if you didn't network in college you wouldn't survive.

Bonnie in her individual interview, also discusses the support offered as being part of the group, how it consequently overlaps into the social realm outside of class and relates to survival:

> It's seriously, It's my way of surviving to be in the group. Like if I didn't have study groups like that, I, I don't think I could have made it. [My lab partner] and I are attached at the hip now, because, without you know, to be able to have somebody to go through these class with you. Because chemistry does demand a lot out of you…but my roommate and I were talking about it; she's a management, an accounting major. She's just kind of amazed at how close I am to all my chemistry friends. 'Cause she said, “Yeah we're kind of cut throat, and one wants to beat the other, every man for himself”, and I said, we could take that approach but we're wanting to help each other out, 'cause we all want to make it through here. And the fact that we can work together is just trying to help each other out.

The “Chemistry Mafia” was so pronounced that students who were not involved in the group recognized they were not part of that “crowd” and typically worked on their own outside of class. Charlie, a 300-level student, falls in this category:

> Interviewer: So do you think you would have fit in better with the back groups [of chemistry majors]?
>
> Charlie: I don't know. Well I mean, I don't, I don't really know them guys that well, so I can't say if I would or not. It's hard to say ... See, uh, I started out in chemical engineering, a few years and then I switched to chemistry education and so uh, I guess maybe I, I've seen them in a couple of my classes before but not like, the whole way through.
>
> Interviewer: So has there been a group that you've kind of migrated through your classes with?

> Charlie: Um, yeah, well I don't know. There's, I mean nobody that made the switch [from engineering to education].

This conversation with Charlie originally started with a discussion of his particular lab group, in which he was the only chemistry major. He recognized that the other chemistry majors in the class regularly worked together and were therefore more proficient at getting the experiment done. Because Charlie did not start out in the same classes as the rest of the community of chemistry majors, he felt he was not a part of the "chemistry mafia." He knew that he was on the outside of this social circle and was not sure he would fit in, even if he tried, due to his lack of common experiences with the rest of the group.

Similarly, Anna, a 400-level student who worked with the same partner all semester, confessed in her group interview that she did not learn any more in her class than if she were to have worked alone:

> Anna: I worked with [one guy] the whole time, but we just worked. So we did our, we knew what we were doing going into it, so did it and left. So it would have been the same for me if I did it myself or if he was there.
>
> Interviewer: So it wasn't helpful to have someone working with you on it?
>
> Anna: No, the only way it would be helpful, or make it more interesting is if it's more like, a social group.

In fact, most recorded observations of Anna and her partner pertain to "on-task" activities. She was never observed to have any personal conflicts with her partner, nor did she complain about his level of performance or participation. However, she recognized that it would have been more helpful to her learning if she and her partner had more social interactions.

Discussion

It is clear to anyone who observes a classroom — especially a classroom laboratory — that the atmosphere is social in nature. But this social interaction is not limited to the classroom environment. Latour and Woolgar (1979) suggest that scientific "facts" are constructed through social mechanisms established within the scientific community. Scientists use the approval and social discourse of their peers to shape their perceptions of reality. Consequently, what evolves is a societal understanding of the phenomena under study. In a similar fashion, in can be argued that the social interactions between students in the chemistry classroom laboratory foster their construction of facts — the ones they need to know for a given class. While this study did not specifically assess the amount of learning that occurred, previous research about the effectiveness of group work and simply the fact that students progressed through the class implies that *some* learning occurred. The point of this study was to examine the mechanism of interaction, specifically social interaction, which contributes to the learning – regardless of level – that inevitably occurs. Symbolic interactionism, which shaped this study, is based on the assumption that meanings are socially constructed. Through the use of observations of student behavior and personal conversations with the same students, this study suggests that students who work together in a series of chemistry classroom laboratory courses use their social surroundings to develop and reaffirm scientific facts, as evidenced in their discussions about studying together, in a manner similar to the way Latour and Wolgar posit that scientists construct "scientific fact" in a research laboratory. Consequently, the knowledge that students construct is situated in the participation of social interaction which becomes critical to the success of the students and is integral to the development of becoming practitioners in their field (Lave & Wenger, 1991). Because of this connection between social interaction and knowledge construction, the specific details of the interactions are critical.

Previous studies of the classroom laboratory environment that focused on measures of "time-on-task" and how "productive" students are within the group imply that time off-task is ineffective with regards to the pedagogical goals of group work (Kempa & Ayob, 1991). This study suggests that what seems to be "off-task" time in the classroom laboratory is used to gain the social means, or "social capital" necessary to accomplish all that is asked of them within the major (Coleman, 1988). Social capital is defined as consisting "of social networks, habits of cooperation, and bonds of reciprocity that serve to generate benefits for members of a community…they embody the emotional bonds of group support and trust" (Hosen & Solovey-Hosen, 2003, p. 84). This social capital is then used as a means for accomplishing goals or actions, in this case, completion of the degree in chemistry (Coleman, 1988).

Social capital is also evident in the literature on campus-based support groups for women and minorities in SME majors. These groups have growing prominence on college campuses in the effort to retain students in science and mathematics by instilling a sense of belonging to a community of practice (e.g. Kahveci *et al.*, 2008; Wenger, 2000). The social support and companionship afforded to students in these groups is similar to the support which naturally developed among the groups of chemistry majors involved in this study. Regardless of the topic of conversation among students in a laboratory environment, it is the "off-task" socialization and establishment of social capital that lays the foundation for the socially constructed knowledge we know students acquire through group work.

Conclusions and Implications

The social aspect of the classroom laboratory begins as a mode for passing time and making the best of an undesirable and forced situation. From this social interaction, however, a community of learners evolves. This community consists of students who learn to know each other in their introductory classes and stay together through all they must endure before graduation. They gain the trust of one another through non-academic social interactions, which, in part occur in the classroom laboratory. This interaction occurs concurrently with the on-task activities required of students, and despite the fact that the laboratory is usually considered by faculty to be a solely academic atmosphere. Students, on the other hand, view it additionally as an opportunity to socialize, and it is this socialization that is the basis of the community of chemistry majors which supports the eventual construction of any content knowledge. The community is used as a resource, offers support to its members, and is considered a valuable asset to its citizens; it is so much of an asset, that students who are not a part of the group feel they are at a disadvantage for not belonging as seen with Charlie and Anna.

The results of this study begin to outline the significance of understanding the social aspect of group work. Not only do members of the group work together to accomplish a specific task in the lab, they also develop interpersonal relationships which offer support and encouragement throughout their personal and academic lives. This feature of group work parallels the supportive environment of pre-established peer mentor programs. It is clear from the data in this study that the academic and social worlds of these chemistry majors are intricately entwined and consequently inseparable. Despite faculty efforts and desire to keep students "on-task", it is evident that these are not the only worthwhile behaviors. While the groups in this study were self-formulated, instructors and departments in the future might consider encouraging more social interaction among majors. Within individual classrooms, instructors should allow for a little "goofing-off" between students in lab (within safety considerations). We need to remind ourselves that simply because science is not being "discussed" does not mean that important interactions are not taking place. Allowing "off-task" activities and conversations fosters a sense of community within a group or even a classroom. Other opportunities could take the form of something as simple as having a student lounge for science (or chemistry) majors on the floor of the building where most of their classes are held. This allows for a common meeting ground across the classes and could foster a sense of community program-wide, rather than within specific classes. This, in addition to the social interactions students naturally engage in on their own may initiate the social support students require to survive an academic program.

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Teaching Controversial Socio-Scientific Issues in Biology and Geology Classes: A Case Study

Pedro Reis
Universidade de Lisboa, Portugal

Cecília Galvão
Universidade de Lisboa, Portugal

Abstract

Several educators in science have called for the inclusion of controversial socio-scientific issues' discussion in science curricula because of its potential for creating a more real, humane image of scientific activity and for promoting scientific literacy, an essential tool for a responsible citizenship regarding decision-making processes related to socio-scientific issues. However, despite all the favourable opinions and empirical evidence concerning the educational potential for the discussion of socio-scientific issues, these activities are not part of many science lessons, even when the controversial socio-scientific issues comprise the curricular content and the teachers consider discussion of these issues important.

This qualitative investigation, based on a case study centered on a Biology and Geology teacher, aimed to understand the factors that influence positively the conduction of discussion activities regarding controversial socio-scientific issues. By analysing data from interviews and class observations, it sought to understand the factors that motivate the teacher to implement this type of activity.

This case study shows that the implementation of the discussion activities about controversial socio-scientific issues depends decisively on the teacher's convictions about the educational relevance of these activities and the knowledge needed for their design, management and assessment. The development of these competences was triggered by professional development opportunities in which the teacher experienced new approaches under experts' supervision.

Correspondence should be addressed to Pedro Reis at PedroRochaReis@netcabo.pt, or Cecília Galvão at cgalvao@fc.ul.pt

Introduction

This investigation belongs to a series of studies and interventions aimed at supporting the implementation, in Portugal, of new science curricula, that call for the discussion of controversial socio-scientific issues as a way of preparing students for an active, informed participation in society (Reis, 1997, 2004; Reis and Galvão, 2004a, 2005). These studies intend to understand the factors that influence both positively and negatively the conduction of science class discussion activities regarding controversial socio-scientific issues and, based on this knowledge, to conceive and implement intervention processes capable of providing teachers with the confidence, motivation and knowledge required to use activities of this nature. Accordingly to Cowie and Rudduck (1990), discussion-based "practice is immensely varied but can be roughly sorted into three broad approaches: the discussion of controversial issues; problem solving; and role-play" (p. 807). All these approaches seek to promote learning through the exploration and expression of ideas, opinions and experiences in an environment of collaboration where the discussion is not seen as verbal combat: it is not a question of winning an argument but a process of mobilizing the entire group resources with the aim of increasing knowledge, understanding a given subject or solving a problem.

The controversial socio-scientific issues referred to in this study consist of matters related to interactions between science, technology and society (namely the controversies that arise because of possible social impacts of scientific and technological novelties) that divide both the scientific community and society at large and for which different groups of citizens put forth explanations and attempts to find solutions that are incompatible, based on alternative beliefs, understandings and values (Crick, 1998; Kumar and Chubin, 2000; Oulton, Dillon and Grace, 2004; Rudduck, 1986; Yager, 1992). The controversial dimension refers to "differences over the nature and content of the science such as the perception of risk, interpretation of empirical data and scientific theories, as well as the social impact of science and technology" (Levinson, 2006, p. 1202). These socio-scientific issues are of a contentious nature; they may be analysed according to different perspectives, they do not lead to simple conclusions and often they involve a moral, ethical dimension (Sadler and Zeidler, 2004).

Theoretical Background

The media confronts citizens almost daily with news about scientific issues with controversial social by-products: cloning; the use of stem cells in medical research and therapy; the release into the atmosphere of substances that are harmful for public health, for the greenhouse effect and that reduce the ozone layer; the use of hormones and antibiotics in animal production. This kind of news introduces citizens to a different type of science from the one that is usually presented in science classes. Most formal science education focuses on a conventional, non-controversial, established and reliable science and doesn't discuss its tentative nature while the media's news highlights a "borderline science", that is controversial, preliminary and under debate (Zimmerman, Bisanz and Bisanz, 1999). Therefore, media's news may threaten the conception, shared by many people, of scientific development as a linear process of mere knowledge accumulation, with no crisis, confrontation or controversy. They may threaten also the common conception of science as a socially neutral activity, that ignores the complex relations between science, technology and society and the social, economic, political, moral and environmental implications of scientific and technological knowledge (Reis and Galvão, 2004b).

Nowadays, the media (newspapers, magazines, television, radio and the Internet), taken as a whole, are considered "the most easily accessible sources of science information to the general public" (Lewenstein, 2001, p. 30). Nelkin (1995) declares that: "For most people, the reality of science is what they read in the press. They understand science less through direct experience or past education than through the filter of journalistic language and imagery" (p. 2). In her opinion, the media represent the only contact most of the population has with the rapidly changing fields of science and technology, as well as a major source of information on the social implications of these changes. Even citizens with a scientific or technological career are incapable of following the specialized literature of all scientific fields, resorting to the media to stay informed about scientific progress outside their speciality (Bauer, 1992). However, sometimes the media present a sensationalist image lacking in rigor and stereotyping science and scientists (Nelkin, 1995). Many fiction films describe scientific investigation as an activity that crosses the borders of the admissible, violating human nature and pursuing the quest for new knowledge in secrecy and outside the controls of society (Weingart, Muhl and Pansegrau, 2003). From medieval stories about alchemists to modern films about cloning, the narratives about scientists rarely depict them in a positive way, translating the fear of the power and change that are part of science and resorting to a limited number of stereotypes: the diabolical alchemist; the heroic scientist, saviour of society; the mad scientist; the inhumane, insensitive researcher; the adventurer scientist who transcends frontiers of space and time; the mad, mean, dangerous, unscrupulous scientist exercising power; and the scientist who is incapable of controlling the results of his work (Haynes, 2003). There is empirical evidence that the use of metaphors of great impact in addressing socio-scientific issues (namely in the field of biotechnology, molecular genetics and medical sciences) and in the description of scientists' activity affects the population's trust and conceptions regarding science and, subsequently, the way citizens understand, think about and act upon socio-scientific issues (Liakopoulos, 2002).

All those media influences stress the need that schools promote the discussion of socio-scientific issues and, consequently, the discussion of students' conceptions about these issues and about the interactions between science, technology and society. Conceptions are a fundamental foundation of thinking and acting, providing the means to see the world and organise concepts (Thompson, 1992).

Several educators in science have called for the inclusion of socio-scientific issues' discussion in science curricula because of its potential for creating a more real, humane image of scientific activity and for promoting scientific literacy, an essential tool for a responsible citizenship regarding decision-making processes related to socio-scientific issues (Kolstoe, 2001; Millar and Hunt, 2002; Millar and Osborne, 1998; Monk and Dillon, 2000). They argue that in a democratic society, the public evaluation of science requires the participation and involvement of as many citizens as possible, and this is only possible by understanding what science is and how it is produced. At the same time, several authors claim that the discussion of socio-scientific issues in the classroom has shown to be extremely useful both in terms of learning about the contents, the processes and the nature of science and technology, and in terms of the students' cognitive, social, political, moral and ethical development (Hammerich, 2000; Kolstoe, 2001; Millar, 1997; Reis, 1997; Reis, 2004; Sadler, 2004).

However, the discussion of socio-scientific issues is an uncommon practice in science classes. Some teachers avoid discussing these issues for fear of protests by the students' parents and a possible lack of control during the discussions (Stradling, 1984). Many teachers lack management skills related to classroom discussions and the required knowledge to undertake discussions about socio-scientific issues, namely knowledge about the nature of science and the sociological, political, ethical and economic aspects of the issues at stake (Levinson, 2001, 2004; Levinson and Turner, 2001; Newton, 1999; Reis, 2004; Reis and Galvão, 2004a, 2005; Simmons and Zeidler, 2003; Stradling, 1984). Other teachers feel the restraints imposed by the excessive number of topics in science curricula (Levinson and Turner, 2001; Reis and Galvão, 2004a) or by national evaluation systems that do not value this type of discussion activity (McGinnis and Simmons, 1999; Newton, 1999; Reis, 2004; Reis and Galvão, 2004a). It is also true that many science teachers view science as an objective enterprise free from values. These science teachers see their task as teaching the facts (and not discussing opinions or ethical aspects), shifting the onus for discussion of the social, moral and ethical implications of science and technology to the lessons of their humanities colleagues (Levinson, 2001; Levinson and Turner, 2001). When ethical questions are introduced into the science classroom, they are treated as an initial starting point and presented briefly with little analysis or criticism. All these facts stress the importance and relevance of studying the factors that influence the implementation of discussion activities regarding controversial issues in science classes, whether positively or negatively. Identifying and understanding these factors is decisive for the conception and implementation of intervention processes that help teachers overcome these restraints and support them in planning and carrying out such activities.

Problem and Methodology

This qualitative investigation is based on a case study centred on an 11th grade Biology and Geology teacher from a secondary school in Lisbon area. It aims to understand the factors that influence positively the conduction of science class discussion activities regarding controversial socio-scientific issues. This investigation intended also to study the meaning attributed by the teacher to recent socio-scientific issues, made public by the media, as well as the importance given to the discussion of these controversial issues in her classroom.

The teacher was selected, from a group that had already collaborated with the researchers on previous studies, as a result of her long experience dealing with the discussion of controversial socio-scientific issues in classroom context. The choice of the 11th grade "Biology and Geology" subject resulted from the fact that in a previous study (Reis and Galvão, 2004a) it was considered, by the teachers, one of the most suitable subjects for carrying out discussion activities regarding socio-scientific issues, given the content of the program topics (e.g. genetics and human reproduction) and the students' ages (17 years old). The teacher's name was replaced with a fictitious one in order to preserve her privacy.

Over one school year, the work developed by this teacher in one of her "Biology and Geology" classes was closely followed. Different information was gathered through semi-structured interviews and direct observation of classes. It is important to underline that the teacher was not aware of the reasons underlying the observation of these specific classes or of the specific aims of the study: the investigators only informed her that they intended to study the teaching of “Biology and Geology” subject. In this manner, she was not induced into choosing a certain classroom methodology or strategy. The main objective of the semi-structured interviews was to collect opinions in the subject’s own language, allowing the researchers to intuitively create an idea of the subject’s conceptions on current controversies related to scientific and technological issues and on Biology and Geology teaching and learning. Throughout the study three semi-structured interviews were carried out. The first interview (TI1) took place at the start of the school year and sought to gather evidence about the teacher’s conceptions regarding: a) the nature of scientific and technological knowledge; b) Biology and Geology teaching and learning; and c) recent controversial issues related to science and technology. Its content (developed in a previous study: Reis and Galvão, 2004a) included questions regarding the following dimensions: Professional experience; Attended professional development initiatives on effective methods of engaging students in STS issues; Characteristics of the context where she teaches; Self-concept as a Natural Science teacher; Conceptions about teaching and learning; Conceptions about the nature of science and technology; and Conceptions about controversial issues related to science and technology. The second interview (TI2) was conducted shortly before the observation of a set of classes (14 periods of 50 minutes each) and aimed at promoting a discussion with the teacher about the intent of her observed lessons (Appendix 1). The third interview (TI3) was carried out after the classes and intended to promote reflection about its implementation (results reached, difficulties, successes, etc.). This last interview was based on a sequence of questions (Appendix 2), aimed at promoting the evaluation of the observed classes by the teacher. All the interviews were audio-taped which allowed the researchers to have a record for later transcription and analysis of the entire interview content.

The observation provided direct access to the classrooms, to find out how the teacher behaved in that specific context. Field notes were taken. During the investigation, a sequence of classes, planned and implemented by the participating teacher, was observed by one of the researchers. This sequence, that included 14 classes (of 50 minutes each), focused on topics (mitosis, meiosis and asexual and sexual reproduction) which the teacher considered (during interview TI1) appropriate to address socio-scientific issues such as cloning or genetic engineering. The observation was designed to analyze activities used by the teacher in addressing these topics and to find out whether (and how) she makes use of the discussion of socio-scientific issues. The combined use of observation and interviews provided a substantial amount of information about the way this teacher thinks and acts, and allowed the researchers to find out whether the interviewee’s descriptions (from the interviews) refer to the reality in her classes or to general perceptions of what a good practice should consist of.

The observation did not follow a strict observation schedule. However, special attention was paid to implemented activities, social interactions and students’ engagement level (notes were taken in relation to these aspects). The time spent on each classroom activity was recorded. The investigator adopted the role of direct, non-participant observer.

Transcripts of interviews and field notes were subjected to content analysis through a model of analytical induction (Bogdan and Biklen, 1992), which sought to extract the implicit conceptions about several aspects under study. This kind of analysis involves the classification of meaningful elements, according to certain categories that may bring order to the apparent disorder of the raw data. The category construction process, although essentially intuitive, is influenced by several aspects such as the aims and theoretical background of the study, as well as the researchers' conceptions and knowledge.

Initially, all data were analyzed separately by each researcher trying to identify teacher's conceptions about (1) teaching and learning, (2) the nature of science and technology, (3) controversial issues related to science and technology, (4) the discussion of controversial socio-scientific issues as classroom methodology. The analysis focused also on possible reasons for those conceptions. Following this, the results of the analysis were discussed not only by the two researchers, but also by two other colleagues of the same research centre. The different interpretations and few discrepancies that emerged during the classification process were discussed and resolved by agreement between all four researchers.

Cristina's Case

Cristina has been a Biology and Geology teacher for thirty-three years. She claims to like teaching so much that she "could never have chosen anything else".

After finishing her degree in Biological Sciences at Lisbon University and the practicum, she taught in several regions of Portugal. However, in the past twenty-two years she has worked at a secondary school in Lisbon area.

Her discourse and her work reveal an extremely dynamic, hard-working teacher who enjoys her professional activity tremendously: "What I most like to do is to teach. Therefore, coming into contact with students is the most important thing." (TI1) Throughout her professional life she taught all the Biology and Geology subjects of Basic and Secondary Education curricula and was a practicum supervisor, co-author of four textbooks, department coordinator and responsible for several projects and clubs in the fields of the Environment, Health and Sexuality.

In spite of all her professional life accomplishments, Cristina highlights the internship year and the teaching inservice opportunities she attended at the Calouste Gulbenkian Foundation (three years after working as a teacher) as the most important moments of her professional activity:

> *"(...)* [The internship supervisor] *was a wonderful person and an excellent teacher, I learned a lot from her. (...) We did a lot of practical work; I really enjoyed working that way. (...) We did brilliant things in the internship year."* (TI1)

> *"(...) the Gulbenkian courses* [attended during the holidays] *were an eye-opener in terms of ideas. (...) We stopped 'counting spider legs' and began to look at*

> *Biology differently. We began to use active methodologies (...) and to introduce discussion into the classroom."* (TI3)

She admits that both the internship and the abovementioned courses for Biology teachers were decisive in changing her teaching style, especially as regards the diversification of teaching strategies and the development of the didactic knowledge required for their use in the classroom.

Cristina argues that professional development opportunities only have impact when they involve the teachers in experiencing and discussing the new approaches and methods: "Experiencing is vital. Teachers only change their classroom practices when they personally experience the educational benefits of a specific method or approach" (TI3). Otherwise, in her opinion, the teachers end up implementing the kind of expository lessons they have undergone throughout their schooling. Both during her internship and the Calouste Gulbenkian Foundation courses, Cristina had the opportunity to experience new approaches under the supervision of experts. These opportunities were the catalysts of big changes in her classroom practice. During the internship she developed the necessary competences for planning and implementing practical work with her students, stressing the idea of science as a process. The Calouste Gulbenkian Foundation courses, attended during the summer holidays of three consecutive years, allowed Cristina to discuss Science, Technology and Society (STS) interactions an to experience discussion, role-play, simulation and decision-making activities as a way to have students acquire real understanding of STS interactions and the decision making processes related with science and technology issues. Through the rest of her career she continue to develop competencies in these areas, mainly through the classroom implementation of approaches and activities collected in science education journals and books (TI2).

Conceptions about Scientific and Technological Knowledge

During the first interview Cristina described science as a dynamic process in constant evolution that leads to the exponential growth of knowledge through the discussion of different ideas. Like some authors, she considers addressing aspects of the history of science in classes – namely the evolution of certain scientific concepts – is important to convey an image of science in constant construction (Matthews, 1994; Ziman, 1994). In her opinion, scientific enterprise establishes subtle, multiple interactions with technology and with society, by determining the evolution of technology, affecting citizens' lives and reacting to pressures from society. In her classes, she seeks to present students with this intricate web of influences and the notion that "scientific knowledge changes over time". In her opinion, science has a tentative nature, always adapting to new data and ideas.

Cristina considers science and technology to be complex human enterprises that engender different opinions among their agents, resulting from different beliefs and values. In her opinion, controversial socio-scientific issues cannot be solved simply on a technical basis because they involve other aspects: hierarchies of values, personal conveniences, financial matters, social pressures, and so on. She refers to genetic engineering, the use of human embryos in research, cloning and *in vitro* fertilisation as good examples of scientific or technological issues marked by controversy. The teacher supports the undertaking of research in these fields because of their potential to improve the quality of life of Humankind. However, she warns that scientists' motivations often seem far from noble and that sometimes their ambition comes before their ethics. Therefore, she argues that scientific research should be monitored by ethics committees made up of "specialists of a high scientific and moral standing", in order to stop certain experiments from being carried out such as human cloning for reproductive purposes. She does, however, agree with and accept the production of specific organs, like "a liver or a heart", from human embryos, for transplants.

> *"(...) we know that all scientists should be honest in their work, but some of them aren't. What a scientist investigating the cutting-edge wants is for his work to advance, he's not bothered much with ethical problems. (...) I think some of these studies should be authorised, because they'll have an important impact on humankind.* [Scientists] *should be monitored to see what's at stake. For instance, they shouldn't do human clones: I'm totally against that! (...) But certain things, such as taking an embryo and being able to make a liver or a heart to give some poor soul on his deathbed, I perfectly agree with! So, I think they should be monitored by someone who understands what's at stake and has a strong ethical stance."*
>
> *"In cutting-edge research you can't let each person do whatever he wants, there should be some control because you never know what they might do.* [That control should be exercised by specialists] *who have already reached a certain degree of maturity to be able to evaluate what's at stake."* (TI1)

Besides acknowledging the need for intervention by committees of specialists to control scientific and technological activity, Cristina is also in favour of citizens' active participation in this process. Consequently, one of her priorities as a teacher (accordingly to her own words) is to prepare her students for an active role in decision-making processes related to science and technology (TI1).

Conceptions about Teaching Biology and Geology

Cristina defends that Biology education in general, and the "Biology and Geology" subject in particular, are extremely important to the future of society. She believes that the survival of the human species and the solution of countless environmental problems depend on a science education that promotes the construction of basic scientific knowledge and the development of students' intellectual abilities.

She considers that all citizens should have at least some scientific knowledge regarding (1) the importance of the biological functions, and (2) the role each living being (humans included) has in maintaining life on Earth, as she feels that only through this knowledge will we understand the problems that emerge and decide in an informed manner: "Everyone has the right to scientific knowledge (...) so as to be able to justify their own choices, both in personal terms and in terms of the community." (TI1) As such, she stresses the importance of formal science education but also of scientific information made public through the media:

> "[This scientific knowledge is obtained] *by studying, of course, that's the first thing; furthermore, if there was more information in the media, then citizens would have access to the minimum scientific knowledge required to understand and make choices. For instance, when there are elections you'd know who to vote. I'm talking about things like a minimum group of ecological concepts."* (TI1)

Cristina also believes that citizens' participation in decision-making processes in regard to science and technology also depends on understanding the nature of these enterprises and their interactions with society. To reach this goal, she usually engages her students in activities involving analysis of current socio-scientific issues, discussion and decision-making. In her classes, students have to analyse and discuss real and imaginary cases related with: environmental problems affecting populations; genetic diseases, tests and treatments affecting families; new technologies affecting living beings. In all these situations, students are invited to decide and to justify courses of action based on scientific knowledge and also on their experiences and values. The different options are discussed in the classroom as a way to promote students' knowledge about science concepts and processes and also students' moral development. Through these discussions, students have the opportunity to confront opinions, to know each other better and to share knowledge and experiences in a climate of open discourse, respect and tolerance. In these classes Cristina pays special attention to the mutual influences between science and society, stimulating discussions about the impact of science on society and also the ways citizens can participate in (and influence) decision-making processes about scientific and technological options. One of her main aims is to empower students with competences necessary to actively participate in public discussions and decision-making processes (TI2).

In her classes in general she gives the students practical activities, worksheets and encourages debates or discussions about current issues, "as a way of stimulating their intellectual activity and facilitating their understanding of the concepts involved" (TI1).

Conceptions about the Discussion of Controversial Socio-Scientific Issues in the Classroom

According to Cristina, the "Biology and Geology" curriculum includes only a few controversial topics. However, she defends that the curriculum is not simply a list of topics and it is the teacher's job to work around it so as to include themes that are related to the planned programme units and which may interest the students and be socially relevant. She declares that throughout the school year she always addresses several controversial issues that she considers to be up-to-date and indispensable for students' scientific literacy, while at the same time "completing the programme". As such, Cristina adopts the role of curriculum builder (Roldão, 1999), changing it constantly according to her students' specific interests and competencies and the learning experiences considered to be socially relevant. But, in line with some studies (Levinson and Turner, 2001), she finds that some science teachers are reluctant to address controversial issues, for fear that discussion of these themes might not be welcomed by parents.

> *"A teacher can introduce controversy, if he/she wants. When it comes to reproduction (...), birth control and sexually transmitted diseases aren't part of the programme but I always address them as a complement to the programme. And within birth control: abortion, the use of embryos for research… It's a question of working around the programme. But there are people who are afraid to address these issues.*
>
> *In the 11th grade, I usually devote some of my classes to these topics because I think it's really important to do so. Students rarely know as much as they think they do."* (TI1)

Cristina does not regard the discussion of these topics a waste of time. On the contrary, she believes that discussing controversial socio-scientific issues is very important, both to gain knowledge about current scientific and technological issues that are relevant for life, and to develop skills in terms of analysing and discussing information that is essential to everyone. Therefore, she proposes carrying out discussion activities on themes such as cloning, birth control, *in vitro* fertilisation and sexually transmitted diseases. Through role-play, case studies and decision-making activities she triggers discussion about students' different opinions, experiences and knowledge related with controversial socio-scientific issues. With these activities she expects to develop the knowledge and the competences that, in her opinion, students need to cope with public discussions and decision-making processes. Once again, her opinion about the potential of discussing controversial issues as a classroom strategy shows her deep concern in promoting the understanding of knowledge and the development of intellectual competencies that she considers vital for her students' scientific literacy.

Like certain authors (Osborne and Young, 1998; Solomon and Thomas, 1999), the teacher claims that addressing these issues facilitates the establishment of relationships between the science taught in school and citizens' everyday experiences. She therefore constantly strives to identify contact points between the curriculum of the subjects she teaches and the current socio-scientific issues that are most related to the students' interests and daily lives.

Classroom Practice

This study involved the observation of a 14-class sequence planned and implemented by Cristina. This set of 50 minutes classes focused on programme topics (asexual and sexual reproduction, cell cycle, mitosis and meiosis) which, in her opinion (TI1), enable the introduction of controversial issues, such as cloning or genetic engineering. The observation took place in a single 11th grade "Biology and Geology" group taught by the teacher: the class consists of 19 students, with whom Cristina has a "very good relationship". After the observation of the complete set of classes, the teacher was interviewed about the goals, results reached, difficulties and successes of its implementation. This section presents some information obtained through classroom activities observation and posterior discussion.

For the sequence of classes that was to be observed, Cristina planned a set of activities she felt helped attain a double goal: (1) learning basic concepts of genetics (mitosis and meiosis), which is essential to understand the reproductive and hereditary process; and (2) the "preparation of the students for life" and "for making decisions as citizens", by teaching analysis and discussion skills of current and socially relevant themes.

> *"I would like to educate students not only so they have knowledge in Biology, which is essential nowadays and for their lives also in general, but also so they become useful members of society."* (TI3)

To fulfil these goals, and with the resources available, she proposed a varied set of classroom activities: observing structures and phenomena with lab instruments, group discussions, doing worksheets and viewing multimedia programmes (classroom observations – table 1). She believes each of these activities focus on specific objectives and corresponds to the students' different methods of learning. She believes that learning the rather abstract concepts in question is made easier by observing the structures and phenomena involved, and therefore resorted to textbook photographs and favoured observation of: a) different types of reproduction in species of plants using binocular magnifying glasses; b) cells at different stages in the cell cycle using microscopes; and c) animations of the mitotic process shown in a multimedia presentation. The importance of the phenomena under study was illustrated through examples related to current scientific and technological progress in the field of tissue culture, genetic engineering, gene therapy and cloning.

Table 1
Main activities observed during classes

Class (periods of 50 min)	Main activities and % of classroom time spent on each one
1	• Teacher asking students and discussing their ideas about concepts (13%); • Teacher presenting and discussing concepts through the exploration of images/examples and the establishment of connections with previous topics (24%); • Teacher establishing connections between concepts and real life situations/examples (10%); • Students observing different types of reproduction (in plants, fungus and microbes) with microscope and magnifying glasses (39%); • Teacher recapitulating the main concepts discussed (7%).
2	• Students' recapitulation of the main topics discussed in the previous class (6%); • Students (in pairs) answering questions from textbook (27%); • Students presenting and discussing answers to questions (15%); • Teacher presenting and discussing concepts through the exploration of images/examples (23%); • Teacher establishing connections between concepts and real life situations/examples (8%); • Teacher recapitulating the main concepts discussed (8%).
3	• Students (in pairs) answering questions from textbook (33%); • Students presenting and discussing answers to questions (19%); • Teacher presenting and discussing concepts through the exploration of images/examples (31%); • Teacher recapitulating the main concepts discussed (6%).
4	• Students observing different cells' cycle with microscope (71%); • Students presenting the main aspects of their observations (24%).
5	• Teacher and students discussing a multimedia presentation with animations and films of the mitotic process (76%); • Students recapitulating the main concepts discussed (13%).
6	• Teacher establishing guidelines for a discussion activity on advantages and disadvantages of plants' and animals' cloning (31%); • Students searching information about plants' and animals' cloning (using books, magazines, newspapers and Internet) (60%).
7	• Students selecting, organizing and discussing information about plants' and animals' cloning (Jigsaw methodology) (89%).
8	• Students discussing information about plants' and animals' cloning (Jigsaw methodology) (91%).
9	• Students' groups presenting conclusions to all class (48%); • Students discussing the presented conclusions about plants' and animals' cloning under teachers' supervision (43%); • Teacher recapitulating the main ideas discussed (5%).
10	• Teacher establishing guidelines for a discussion activity about the implications (biological, social, ethical, etc.) of human cloning (15%); • Students (in groups of four) writing a story about the life of a cloned human being (all groups starting from the same initial plot) (81%).
11	• Students' groups presenting the story to all class (71%); • Students discussing the different story plots under teachers' supervision (21%).
12	• Teacher presenting and discussing concepts (meiosis and sexual reproduction) through the exploration of images and the establishment of connections with previous topics (36%); • Teacher establishing connections between concepts and real life situations/examples

	(11%); • Students observing different phases of meiosis with microscope (35%); • Teacher recapitulating the main concepts discussed (11%).
13	• Teacher presenting and discussing concepts through the exploration of images/examples (45%); • Teacher establishing connections between concepts and real life situations/examples (13%); • Students (in pairs) answering questions from textbook (29%).
14	• Students (in pairs) answering questions from textbook (35%); • Students presenting and discussing answers to questions (47%).

In all the classes observed, Cristina was clearly concerned with diversifying strategies and showing the importance of the topics she approached, by establishing relations between these topics and certain current scientific and technological progress. The activities carried out required the students' active involvement in observing structures or phenomena, in researching information, in analysing and discussing socio-scientific issues, in solving questionnaires and in presenting work. Another important aspect of her classes was the kind of oral interaction that was established, precisely because it was not confined to a teacher-dominated question-answer sequence. In several classes, particularly in those that involved discussion, the students dominated the discourse and Cristina remained in a role of tutor. After introducing the topic and presenting the task, she restrained herself from exposing her own opinions, acting as a chairperson with the aims of ensuring quality and fairness in the discussion and helping students to a deeper level of understanding. In the discussions she didn't force students to reach a consensus, protecting divergence of view among them. Her aim was to help students understand and explore the implications of different opinions and actions (TI3).

Aimed at "preparing students for life" and promoting reflection about science, technology and their interrelations with society, Cristina turned to two discussion activities about a controversial issue, linked to the concepts at stake: cloning. In the first activity she intended each group of students to reflect and formulate a critical opinion about eventual advantages and disadvantages of plants' and animals' cloning. To do so she suggested the analysis and discussion of articles published in books, newspapers, magazines and the Internet. This activity was organized accordingly to Jig-saw methodology (Aronson, 1978). At the end, the conclusions of different groups were presented and discussed by all class. The second activity was aimed at thinking about the implications (biological, social, ethical, etc.) of human cloning. Starting from the same initial plot, each group of students made up a story about the life of a cloned human being. Cristina is adamant that these activities will engage the students and help them (1) to build up knowledge that is relevant for the future and (2) develop the ability to think and argue, which is indispensable for taking part in decision-making processes:

> *"In relation to these activities about cloning, this is a contemporary problem and it gives them an idea of the importance of the phenomena that we are studying, allowing them to make decisions as citizens, which I believe is vital. (…) The most important thing is for them to have a range of material from which they can*

> *choose and create an opinion… Because not everything that's in the newspapers is true...*
>
> *(...) It is also important that they prepare themselves to take part in debates. (...) So the subject is important in itself, but so is another thing: the ability to work as a team on a particular subject to obtain data with which they can later argue (...) and base their ideas on. I think this is very important. I think this is a life lesson, not just a lesson in Biology."* (TI3)

The teacher's enthusiasm throughout the observed activities was clear and transmitted to the students. The classroom atmosphere, warm and welcoming as well as intellectually stimulating, helped the rapport between students and teacher. The classes on cloning were particularly spirited, with many subjects being discussed: a) types of cloning; b) the possible applications of cloning of plants and animals; c) the possibility of cloning killers and dictators; d) the relative weight of heredity and the environment in defining the physiognomy and personality of individuals; e) the ethical implications of human cloning; f) the activity of scientists; and g) the role of the scientific community, government and citizens in controlling research. In these classes, Cristina's motivation was particularly high, having taken an active part in the discussions, asking for explanations, presenting information, summarising points of view and moderating student participation.

From these observations, it can be said that Cristina's teaching practice takes into account several elements of what contemporary literature defines as a good environment for learning. According to Simons, van der Linden and Duffy (2000), the long-lasting, flexible, functional, significant, generalised and applicable competencies that are demanded in contemporary society require a type of learning that is research-oriented. This learning should be also focused on real-life problems and cases, involve interaction between many people, and with an implicit motivation capable of arousing interest in students. From the authors' viewpoint, it is only through a more active, hands-on learning process that we meet these new demands.

At the end of these monitored classes, Cristina was visibly happy with the quality of output and interactions, the level of understanding of the subject matter, and the clear "development of a critical attitude towards news items" regarding scientific and technological issues, the level of consideration about the construction and evolution of scientific knowledge, as well as the students' level of satisfaction (TI3). However, she believes she can always do better and next time she would like to show another film illustrating the dynamics of mitosis and meiosis.

Cristina's classes were clearly influenced by her ideas on the nature, the teaching and the learning of science. Bearing out the results obtained by Lederman (1999), the consistency between the teacher's conceptions and her classroom practice seems to have been strongly influenced by the teaching aims she set for herself. Another factor that is in keeping with this aspect was the type of pre- (internship) and in-service education (Calouste Gulbenkian Foundation courses), that allowed her to "learn by doing" (TI1) under the supervision of more experienced colleagues and developed the taste and the confidence to keep trying new approaches, methodologies and strategies in her teaching. As Stofflett and Stoddart (1994) pointed out, teachers who experience active approaches to teaching have a greater tendency to use this kind of approach with their students.

Her ideas about scientific activity, namely about its relations with technology and society and about the provisional, dynamic character of scientific knowledge, are reflected in the strategies she suggested about the controversy regarding cloning and in the way she conducted the discussion of this topic. Unlike other cases described in research (Brickhouse, 1990; Duschl and Wright, 1989; Lederman and Zeidler, 1987), the length of the curriculum and the pressure to cover its contents did not stop Cristina from discussing controversial socio-scientific issues and addressing aspects of the nature of science. Several factors seem to have contributed to this fact: a) the importance she attributes to teaching controversial issues and aspects of the nature of science; b) her intention to explicitly address these topics; c) the level of knowledge about controversial socio-scientific issues and the strategies required to teach these issues; and d) the way she develops the curriculum, adapting it to the needs of each class, in particular, and of society, in general.

In Cristina's case, the impact of her conceptions about science teaching on her practice was clearly felt, namely: a) in the diversification of strategies; b) in the creation and implementation of activities requiring students' active involvement; c) in implementing a teaching method focused on the development of skills and on the construction of relevant knowledge for life; and d) in resorting to current, relevant topics as a starting point for research and discussion activities about the potential and constraints of scientific and technological knowledge.

Final Remarks

Cristina reveals a positive image of science and technology, chiefly because of the role of these fields of knowledge as catalysts for progress and social development. However, the controversy surrounding several current socio-scientific issues fortifies her fears concerning the improper use of science and technology, motivated by the values and interests of specific individuals or groups. Subsequently, in her classes, Cristina strives to develop the knowledge and skills she feels are essential for her students to enable them to understand and evaluate scientific and technological enterprises.

Based on the current controversies regarding scientific and technological issues, Cristina explicitly rejects the myth of objectivity and neutrality of science, admitting the influence of personal, social, institutional, environmental, cultural, ethical, economic and political factors in scientists' activity (an influence that is clear in socio-scientific issues). The teacher considers that these controversies, which the media talk about so often, stem from the diversity of values and interests of society at large and of the scientific community in particular.

Cristina's conceptions about science influence her classroom practice, presenting scientific activity as a complex, dynamic human enterprise that involves value issues and is therefore controversial. She believes that socio-scientific issues are not limited to technical discussions; rather, they involve other aspects (value hierarchies, personal conveniences, financial matters, social pressures and so on) that lead to differing opinions among experts. Consequently, she recognises the importance of involving citizens in the evaluation of the potentialities and limitations of scientific and technological progress and thus seeks to prepare her students for this task. To do so she often resorts to current socio-scientific issues as the starting point for research and discussion activities about the potential and restraints of scientific and technological knowledge. While also addressing the full programme contents, the teacher focuses her practice on the development of relevant skills and knowledge for life.

This case reveals a conception of curriculum as a creator of competencies that stresses the possibility for teachers to manage content and choose the educational experiences according to students' specific characteristics and the unique contexts in which they work. In line with the latter, the teacher assumes the role of curriculum constructor (and not just consumer/executor) and is more concerned with how to develop specific competencies that she considers relevant than with the lengthy curricular contents themselves.

Cristina's classroom practice is influenced by her conceptions about teaching and curriculum and, and by the educational goals she sets for herself. Classroom practice is influenced by: a) an understanding of the curriculum allowing for levels of decision-making suited to the needs of society and of the specific context; and b) a conception of science education focused both on knowledge construction and on the development of skills and attitudes (required for citizens' intellectual autonomy and for exercising their citizenship) by actively engaging students in a varied range of activities.

Her conceptions about teaching and curriculum were strongly influence by the internship and the summer courses organized by Calouste Gulbenkian Foundation she attended early in her career. These situations provided the opportunity to experience, implement and evaluate completely new approaches under the supervision of science education experts.

Cristina's strong personal beliefs (regarding the importance of promoting the discussion of controversial socio-scientific issues and explicitly addressing aspects of the nature of science), together with her in-depth knowledge of the subject matter and the knowledge she has concerning her students, the aims of science education and the strategies to carry it out, allow her to overcome any obstacles to the implementation of discussion activities about controversial socio-scientific issues. Her beliefs and professional knowledge grant her a remarkable capacity to interpret the curriculum so as to address the topics and carry out the activities she considers important and relevant.

This particular case shows that the implementation of the discussion activities about controversial socio-scientific issues depends decisively on the teacher's convictions about the educational relevance of these activities and the knowledge needed for their design, management and assessment. The development of these convictions and competences can be triggered by professional development opportunities in which the teacher experiences new approaches under experts' supervision. The involvement of teachers in experiencing and discussing the educational potential for the discussion of socio-scientific issues can be a positive step forward in changing their teaching styles, especially as regards the diversification of teaching strategies and the development of the didactic knowledge required for their use in the classroom. This is a promising path that we are exploring in the implementation of professional development initiatives aimed at supporting teachers in planning and carrying out both discussion and experimental work.

Appendix 1 – Script of interview TI2

1. What are the general objectives/aims of the unit?
2. Describe the activities planned for the unit.
3. What are the objectives of each of the planned activities?
4. What reasons led you to choose these activities instead of others?
5. What difficulties are you expecting to find? Do you expect your students to experience some difficulty? Explain your answer.

Appendix 2 – Script of interview TI3

1. Are you happy with the way your classes ran? How do you evaluate your classes?
2. Did they go according to plan? Were objectives met?
3. Was students' behaviour/reaction suitable?
    a. If NOT: When? Why? What are the causes?
    b. If SO: Describe their behaviour. Why do you say it was suitable?
4. Next time you address these issues will you do anything different? Why?
    a. With what finality/objectives did you carry out the activity…?

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