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Integration within the Scholarship of Teaching:

When Teachers become Learners in Foreign Disciplines

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Four years ago I was involved in a project on our campus to revise the promotion and tenure criteria for judging scholarship and teaching in our school of education. We had the usual differences of opinion on the scholarship of discovery, teaching, and application but since we were all faculty in a school of education we found common ground fairly easily compared to some of the discussions I have observed across campus. But when we moved to a discussion of the scholarship of integration we had trouble coming to a mutual definition and vision of how the scholarship of integration would be demonstrated in our field.

Boyer (1990) defines the scholarship of integration in the following way: “By integration, we mean making connections across the disciplines, placing the specialties in larger context, illuminating data in a revealing way, often educating nonspecialists, too. “ (p. 18) My understanding of the scholarship of integration envisioned colleagues who were doing interdisciplinary work which interpreted and integrated original research. My position in our discussions was that this was typically done by senior colleagues who were the renaissance men and women of the academy. I suggested that only someone with a very broad understanding of multiple disciplines could possible pull together truly divergent content in significant ways. Some of my younger colleagues disagreed with me (perhaps it was an age discrimination issue) and we never really resolved the question. Now as the managing editor of the *Journal of Scholarship of Teaching and Learning* the issue of integration has raised a number of important questions for me. During the past year I have thought about integration not only as one of Boyer's four types of scholarship but also in light of the importance and challenge of integration within the scholarship of teaching.

Each spring the member of the Faculty Colloquium on Excellence in Teaching (FACET) of Indiana University meet for a professional development retreat to discuss, demonstrate, and learn new approaches to teaching. Each year I am impressed by the variety of teaching pedagogues used by expert teachers in every imaginable discipline. The following fall I try to integrate some of the new strategies I have learned into my classes. I value my weekend retreat with my faculty colleagues from the eight campuses of Indiana University because they all are passionate about teaching and they each have a slightly different view of how to facilitate learning. I have gained a great deal from professors of music, art, sociology, geology, information processing, and dozens of other disciplines and I have found the teaching approaches which are common to their discipline may be new to me. I appreciate their devotion to teaching and their expertise in part because I cannot find the time to review the teaching literature in their field and, since they are expert teachers, I willingly become their student.

I like to think **JoSoTL** affords a wider audience some of the same opportunities - - to make connections across the teaching disciplines, to place teaching our discipline in a broader context, and to educate all of us to approaches from disciplines in which we are not specialists. Conferences and other forums (such as **JoSoTL**) which invite colleagues to discuss teaching across disciplines are attempting to integrate pedagogies from diverse disciplines to improve teaching in all disciplines. But just as it is difficult to agree on a definition of the scholarship of integration it is also challenging to come to common ground on integrating the scholarship of teaching across disciplines.

During the past year I have sent out dozens of manuscripts for review. The reviewers for **JoSoTL** are all teaching award winners who are members of FACET. They come from many discipline with a wide variety of methodological expertise but a common passion for pursuing excellence in teaching and facilitating student learning. For the first issue of **JoSoTL** I sent each manuscript to two reviewers assuming I would receive similar feedback which would make my job as editor fairly simple. I was surprised to find broad discrepancies; it seemed that there was very little agreement by the reviewers as to the specific criteria to judge SoTL even though we all used the six standards of scholarly work presented in Glassick, Huber, and Maeroff (1997). As a new field, the scholarship of teaching and learning is still somewhat elusive which makes assessment difficult but at the same time presents some interesting advantages. I realized from reading the feedback from the reviewers that we could learn from one another across disciplines.

As we publish the first issue of the second volume of the **JoSoTL** I would like to share what we have learned about the SoTL from those who have submitted manuscripts and from those who have reviewed these manuscripts. The most important lesson I have learned in my role as managing editor is how much I have to learn about how my colleagues teach and what they view as the scholarship of teaching and learning. Just as I have learned from my interactions with my colleagues at the FACET spring conference I can also learn from reading the scholarship of your teaching. When I focus solely on the pedagogies of experts in my discipline I may be missing innovative approaches which can be applied to my discipline. I have recently begun to implement case studies in my teaching which I learned from colleagues in law and medicine: expert teachers in these disciplines have been using these approaches for decades.

One of the important reasons for **JoSoTL** is it gives those of us who are committed to improving teaching the opportunity to integrate the learning we gain from colleagues in other fields into our own teaching, and to build on their work. The essence of scholarship is to create a knowledge base by making our work accessible to our colleagues for their review and learning. An important benefit of the scholarship of teaching is it allows us to integrate knowledge of the teaching-learning process into our discipline from colleagues who may have a different perspective because of the pedagogical knowledge base from their field. What is common practice in some fields (e.g., case studies in medicine and law) may be rarely used in other fields, or at least unknown to some teachers in a different field. This infusion of established pedagogue from other disciplines into our classrooms is one of the missions of **JoSoTL** and we invite colleagues to submit manuscripts that educate all of us to these approaches. While case studies or problem based learning may be common practice in medicine it is valuable to read an article describing the application of case studies or problem based learning to another field. Broadening the knowledge base to include the assimilation of an approach into another field is an important contribution to integrating the scholarship of teaching.

We can learn a great deal by broadening our horizons beyond our own discipline but there are problems inherent when we venture beyond our field of specialization. Each of our fields has it's own vocabulary and approaches to teaching and scholarship. Our students refer to this as jargon (for them, a very negative connotation) and our role is to educate them to the vocabulary of our world. We are comfortable living within the environment of our expertise and may find it awkward to venture into a field new to us - much like our students. Since the scholarship of teaching is a relatively new endeavor the vocabulary (dare we say jargon) and criteria is still being established and we find the amalgamation across fields difficult. For the first two issues of **JoSoTL** we based our criteria for the review process on the six standards of scholarly work presented in Glassick, Huber, and Maeroff (1997). This was certainly a good place to begin but we found the review process difficult because of differences across disciplines in what was considered scholarship. I suppose this should have come as no surprise given the vast discrepancies that always occur during campuses discussions of the Boyer model of scholarship. We assumed the six criteria would give our reviewers a common foundation that would minimize differences, but the differences across disciplines was more than expected. It seems many reviewers were holding the same standards for the scholarship of teaching that they held for the scholarship of discovery within their disciplines. This raises the important question: Should the standards be different?

As the editors of the *Journal of Scholarship of Teaching and Learning* our mission is to encourage teachers to become involved in the scholarship of teaching and learning movement. Certainly an important aspect of this movement is to further excellence in SoTL but we also believe it is important to create a venue which educates our colleagues about SoTL and also invites them into the discussion on effective teaching. To further this mission we have modified the format for the second volume of **JoSoTL**. We are still using the six criteria of Glassick, Huber, and Maeroff (1997) but we have modified these criteria somewhat to match three different types of submissions we believe are appropriate for **JoSoTL**: traditional research, classroom action research, and essays on SoTL.

To assist authors in submitting their manuscripts, and facilitate the review process, we have devised a set of rubrics for each of the three formats (click here for the reviewer's rubric) and have included an article (click here for Gwynn's article) by Gwynn Mettetal, one our co-editors, describing the differences between classroom action research (CAR) and traditional research. We hope the rubrics, and Dr. Mettetal's article, will not only assist authors and reviewers in the review process but also encourage more of our colleagues to be involved in SoTL. Scholarship of teaching and learning is not a spectator sport, it is a process which is learned best by active participation. Just as we are encouraging our students to be active learners we, at **JoSoTL**, want our readers to be active learners of SoTL. Let me start the active learning process rolling by giving some suggestion to help the spectators get into the game:

Introductory Reflective Critique - My own research examines metacognitive awareness in students and I have found my best students "know when they know." Effective learners have a good sense of their mastery of the material they are studying. I have found good teachers possess this same metacognitive awareness of the effectiveness of their teaching. To begin the SoTL process begin to write down your reflections on your teaching and consider the effective and ineffective strategies you use in your teaching. You don't *have* to share these with colleagues but making your reflections "public" is the first step in scholarship. These reflections inevitably lead to your teaching goals and help you to focus on what you want to change in your teaching to bring about changes in student learning.

Connections to the Knowledge Base - Scholarship is based on, and eventually builds on, the knowledge base of the field. To be a scholar in any field we must be aware of the work of those who have gone before us. To be a scholarly teacher one must be aware of the knowledge base of the pedagogue of teaching. Just as we began learning the knowledge base of our academic discipline with small steps, we should begin to learn about the knowledge base of the pedagogue of our field in small steps. As Dr. Mettetal points out in her article, the review of the literature in classroom action research is much less thorough than in traditional research. The first step in the scholarship of teaching and learning for many faculty may be classroom action research: you don't need to be "the expert" to enter the discussion and begin to build your knowledge base.

Methods and Results - I suspect many faculty are hesitant to get involved in the scholarship of teaching and learning because they hold the same rigorous research standards for potential SoTL projects that they hold for their own traditional research. We believe classroom action research is a good place to begin SoTL because the methodology and analysis of results are less rigorous and more focused on practical significance than statistical significance. Once you find practical results that give direction to the research on your teaching you may become motivated to become more demanding in your standards. This does not dismiss the value of your classroom action research. Classroom action research is worthwhile but readers should be more cautious about the generalizabililty of the finding of CAR.

Reflective Critique - The editors of **JoSoTL** are putting a great deal of emphasis on reflective critique for traditional research, classroom action research, and essays on SoTL. We believe all SoTL should have practical applications and the most important analysis and commentary on those applications should come from the teachers involved in the research. It is not uncommon for basic researchers to be cautious about suggesting how their findings could be used in practice. We hope scholars of teaching and learning will go out on a limb and discuss: their unexpected finding and possible interpretations; the limitations of their study within and across classroom setting; potential implications for practice in similar classrooms and in diverse classrooms; and potential implications for theory and pedagogue.

What we are trying to do in the second volume of the *Journal of Scholarship of Teaching and Learning* is to invite more of our colleagues into the discussion. The SoTL is a growing movement that we believe has room for many levels of expertise across all disciplines. Each spring I feel fortunate to have the opportunity to meet with colleagues from many different disciplines at our FACET retreat. Their expertise and perspective on teaching has given me a new appreciation for the contributions of the many disciplines within a university. Unfortunately, not all faculty have the opportunity to spend an extended weekend with teaching colleagues from many disciplines. We hope the *Journal of Scholarship of Teaching and Learning* gives our readers the chance to learn from other teachers and to teach other teachers.

In the academy we value diversity and we challenge our students to seek to understand diverse points of view and be open to the benefits of alternative interpretations of "the truth". Unfortunately, it is not uncommon for us to view the world through the eyes of our discipline *and* the generally accepted approaches being used to teach our discipline. But the standard approach to teach psychology today is different than it was twenty years ago and it may be the case that what is popular in psychology today is now passé in sociology or English. When we read about pedagogies from our colleagues in other disciplines we deepen our understanding of the teaching-learning process and broaden our horizons on what is possible in our own teaching. One of the goals of the *Journal of Scholarship of Teaching and Learning* is to give our readers the opportunity to see what colleagues in other disciplines are doing in their classrooms.

When Boyer spoke of the scholarship of integration he was referring to integrating content across disciplines; I believe it is also important that we integrate pedagogies of teaching across disciplines. Maybe I was wrong when I intimated that integration was done primarily by the renaissance men and women of the academy. When we are open to learn from all our colleagues, of any age, in any field, we can all grow in our teaching and our knowledge of the teaching-learning process. I'm sure my junior colleagues will take the opportunity to point out the foolishness of my thinking . . . I'll remember to learn from their teaching.

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The Journal of Scholarship of Teaching and Learning (JoSoTL)

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The What, Why and How of Classroom Action Research

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Abstract

The editors of *JoSoTL* have received many inquiries about classroom action research (CAR). What is it? Why should you consider doing it? How do you do it? How does it differ from traditional research on teaching and learning? This essay is an attempt to answer those questions. I will also discuss why CAR is an excellent expression of the scholarship of teaching and learning, accessible to teachers in all disciplines.

What is Classroom Action Research?

Classroom Action Research is a method of finding out what works best in your own classroom so that you can improve student learning. We know a great deal about good teaching in general (e.g. McKeachie, 1999; Chickering and Gamson, 1987; Weimer, 1996), but every teaching situation is unique in terms of content, level, student skills and learning styles, teacher skills and teaching styles, and many other factors. To maximize student learning, a teacher must find out what works best in a particular situation.

There are many ways to improve knowledge about teaching. Many teachers practice personal reflection on teaching; that is, they look back at what has worked and has not worked in the classroom and think about how they can change their teaching strategies to enhance learning. (Hole and McEntee (1999) provide useful steps for enhancing such reflection. A few teachers (most notably Education professors) conduct formal empirical studies on teaching and learning, adding to our knowledge base. CAR fits in the center of a continuum ranging from personal reflection at one end to formal educational research at the other. CAR is more systematic and data-based than personal reflection, but it is more informal and personal than formal educational research. In CAR, a teacher focuses attention on a problem or question about his or her own classroom. For example, does role-playing help students understand course concepts more completely than lecture methods? Which concepts are most confusing to students? (See comparison chart at www.iusb.edu/~gmetteta/Research_about_Teaching_and.htm)

Action research methods were proposed by Kurt Lewin in 1946, as a research technique in social psychology. More recently, Donald Schön (1983) described the reflective practitioner as one who thinks systematically about practice. Classroom Action Research is systematic, yet less formal, research conducted by practitioners to inform their action. The goal of CAR is to improve your own teaching in your own classroom (or your department or school). While there is no requirement that the CAR findings be generalized to other situations, as in traditional research, the results of classroom action research can add to the knowledge base. Classroom action research goes beyond personal reflection to use informal research practices such as a brief literature review, group comparisons, and data collection and analysis. Validity is achieved through the triangulation of data. The focus is on the practical significance of findings, rather than statistical or theoretical significance. Findings are usually disseminated through brief reports or presentations to local colleagues or administrators. Most teachers, from pre-school through university level, can be taught the methods of action research in a single course, a series of workshops, or through extensive mentoring (Mettetal, 2000). For more information on traditional educational research, see texts such as Educational Research (Gay and Airasian, 2000).

The boundaries between these categories are not distinct. Some CAR projects may become comprehensive enough to be considered traditional research, with generalizable findings. Other CAR projects may be so informal that they are closer to personal reflection. In this essay, I will describe the prototypical CAR project.

Why do Classroom Action Research?

First and foremost, classroom action research is a very effective way of improving your teaching. Assessing student understanding at mid-term helps you plan the most effective strategies for the rest of the semester. Comparing the student learning outcomes of different teaching strategies helps you discover which teaching techniques work best in a particular situation. Because you are researching the impact of your own teaching, you automatically take into account your own teaching strengths and weaknesses, the typical skill level of your students, etc. Your findings have immediate practical significance in terms of teaching decisions.

Second, CAR provides a means of documenting your teaching effectiveness. The brief reports and presentations resulting from CAR can be included in teaching portfolios, tenure dossiers, and other reports at the teacher or school level. This information can also help meet the increasing requirements of the assessment movement that we document student learning.

Third, CAR can provide a renewed sense of excitement about teaching. After many years, teaching can become routine and even boring. Learning CAR methodology provides a new challenge, and the results of CAR projects often prompt teachers to change their current strategies. CAR projects done as teams have the added benefit of increasing peer discussion of teaching issues.

How do you conduct Classroom Action Research?

Classroom action research follows the same steps as the general scientific model, although in a more informal manner. CAR methods also recognize that the researcher is, first and foremost, the classroom teacher and that the research cannot be allowed to take precedence over student learning. The CAR process can be conceptualized as a seven-step process. (For more detailed information about conducting CAR research, see authors such as Bell, 1993; Sagor, 2000; and Hubbard and Power, 1993)

Step one: Identify a question or problem.

This question should be something related to student learning in your classroom. For example, would a different type of assignment enhance student understanding? Would a strict attendance policy result in better test scores? Would more time spent in cooperative learning groups help students understand concepts at a higher level? The general model might be "what is the effect of X on student learning?"

Since the goal of CAR is to inform decision-making, the question or problem should look at something under teacher control, such as teaching strategies, student assignments, and classroom activities. The problem should also be an area in which you are willing to change. There is no point in conducting a CAR project if you have no intention of acting on your findings. Larger institutional questions might be tackled, if the institution is committed to change.

Finally, the question or problem should be feasible in terms of time, effort and resources. In general, this means to think small--to look at one aspect of teaching in a single course. Angelo and Cross (1993) suggest that you NOT start with your "problem class" but rather start with a class that is progressing fairly well. As you become more comfortable with CAR methods, you may attempt more complicated projects.

Step two: Review Literature

You need to gather two types of information, background literature and data. The literature review may be much less extensive than traditional research, and the use of secondary sources is sufficient. Sources such as Cross and Steadman (1996) or Woolfolk (2000) will often provide background information on learning, motivation, and classroom management topics. Another source is the Educational Resources Information Center (ERIC) database, which contains references to a huge number of published and unpublished manuscripts. You can search the ERIC database at http://ericir.syr.edu/. Your campus' teaching and learning center should also have many useful resources.

Step three: Plan a research strategy

The research design of a CAR study may take many forms, ranging from a pretest-posttest design to a comparison of similar classes to a descriptive case study of a single class or student. Both quantitative and qualitative methods are appropriate. The tightly controlled experimental designs of traditional research are rarely possible in a natural classroom setting, so CAR relies on the triangulation of data to provide validity. To triangulate, collect at least three types of data (such as student test scores, teacher evaluations, and observations of student behavior). If all data point to the same conclusions, you have some assurance of validity.

Step four: Gather data

CAR tends to rely heavily on existing data such as test scores, teacher evaluations, and final course grades. You might also want to collect other data. See Angelo and Cross (1993) for a wonderful array of classroom assessment techniques.

(Be sure to check with your Institutional Review Board for policies regarding the use of human subjects. Most CAR with adult students will be exempt from review as long as you do not identify individual students.)

Step five: Make sense of the data

Analyze your data, looking for findings with practical significance. Simple statistical analyses of quantitative data, such as simple t-tests and correlations, are usually sufficient. Tables or graphs are often very helpful. Qualitative data can be analyzed for recurring themes, citing supporting evidence. Practical significance, rather than statistical significance, is the goal.

Step six: Take action

Use your findings to make decisions about your teaching strategies. Sometimes you will find that one strategy is clearly more effective, leading to an obvious choice. Other times, strategies may prove to be equally effective. In that situation, you may choose the strategy that you prefer or the one that your students prefer.

Step seven: Share your findings

You can share your findings with peers in many ways. You may submit your report to JoSoTL, which has a special section for CAR reports. These articles will typically be from 4 to 8 pages--shorter than the typical traditional research report. Most CAR reports are appropriate for submission to the ERIC database (instructions for submission can be found on the ERIC website at: http://ericfac.piccard.csc.com/submitting). You might also share your work at conferences such as the International Conference for Teacher-Researchers (http://www.educ.ubc.ca/ictr2001/) or at regional conferences for your discipline. Most disciplines sponsor a journal on teaching, although CAR may be too informal to meet publication requirements.

Judging the quality of CAR projects

Although CAR projects are not as comprehensive as traditional educational research, their quality can still be assessed using the guidelines of Glassick, et al (1997) in Scholarship Assessed. I recently worked with colleagues to develop an evaluation plan for the CAR projects of K-12 teachers in a local school district (Mettetal, Bennett and Smith, 2000). The resulting rubric has been adapted for JoSoTL and is used by our reviewers for CAR, traditional research, and essay (http://www.iusb.edu/~josotl/rubric/rubric.htm).

Classroom Action Research Rubric

Criteria for Quality Proposal and Projects

	Needs Improvement	On Target	Exemplary
Goals	Goals are not clearly identified.	Goals are identified and relate to teaching and learning.	Goals are clearly stated, relate to teaching and learning and will inform action.
Background Information	No reference to previous research or theory.	Two to three references to relevant research or theory.	Integrates and synthesizes four or more sources of relevant research or theory.
Methods	Less than three sources of data.	Three sources of data from current classroom.	Many sources of data from current classroom (case study) or data that are compared with data from another relevant source (i.e., last year's class, another class in the school, state data).
Results	Results are not communicated in an appropriate manner.	Communicate results through themes, graphs, tables, etc.	Results identify key findings. Communicate results clearly and accurately through themes, graphs, tables, etc.
Reflection	Little or no relevant discussion of teaching and learning related to one's own classroom.	Discusses how results affect one's own teaching and learning in classroom.	Discusses how results affect own teaching and learning in classroom and implications for teaching setting (i.e., other classroom, schools, district, etc.). Also, identifies future research questions.
Presentation	• Paper not clearly written • Results are not shared with other audiences.	• Paper clearly written • Results shared with a local colleagues	• Paper is clear, insightful, and comprehensive • Results are shared with a wider audience.

This rubric shows that it is possible to meet the standards of Glassick et al (1997) within the context of a classroom action research project. One of the most difficult criteria to meet is that of presentation, since there have been few forums for the publication of CAR projects. JoSoTL hopes to correct that problem.

Conclusion

Classroom Action Research fits comfortably under the umbrella of Scholarship of Teaching and Learning. Along with traditional educational research and course portfolios, CAR is a way of systematically examining teaching to gain new insights. One can certainly be an excellent teacher without engaging in CAR (or other types of SoTL), but participation in some version of SoTL enhances one's knowledge of the profession of teaching.

CAR is very attractive to faculty at all types of institutions. Those at primarily research institutions may welcome the opportunity to look at teaching with the same scholarly eye that they use for disciplinary research. Those at primarily teaching institutions (including vocational tech and community colleges) usually lack support for disciplinary research. They may find that their institutions provide a rich source of CAR data and that administrators appreciate these research endeavors.

The editors of JoSoTL agree that Classroom Action Research is an appropriate form of the scholarship of teaching and learning. JoSoTL is eager to receive submissions of CAR articles and will evaluate them using the rubric provided here.

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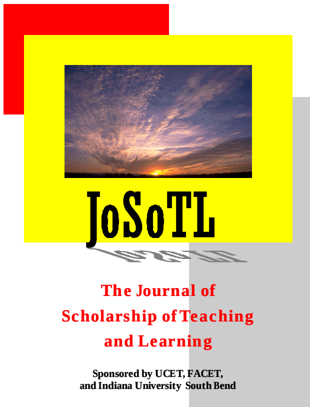

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Novice Instructors and Student-Centered Instruction: Identifying and Addressing Obstacles to Learning in the College Science Laboratory

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Abstract

We identify and analyze some widespread problems with the implementation of student-centered instruction in introductory college science and mathematics laboratory courses. Specifically, we observe potential problems with interactions between the instructor and individual students, interactions between the instructor and small groups of students, and the instructor's ability to monitor the learning environment. We describe our underlying assumptions regarding the purpose and nature of student-centered introductory college laboratory course, and analyze the problems that we identify using these assumptions. We provide practical suggestions for dealing with each category of problems.

Introduction

As Elizabeth Hazel notes in (Hazel, 1993, p.155):

> "Laboratory work is the hallmark of education in science and technology based fields. Student laboratories are a costly resource yet their educational potential is often not fully realized in practice. It is timely that their design and delivery and the forms of student assessment used be examined critically for their contribution to high quality learning."

In this article, we focus on the delivery and facilitation of learning experiences in the context of the college science laboratory. Specifically, the purposes of this article are to: (1) identify and analyze problems with the implementation of student-centered instruction (SCI) in introductory college science (by which we mean science and mathematics) courses, and (2) to suggest some solutions. The difficulties that we describe were observed in student laboratories from a variety of fields (biology, mathematics and physics). In particular, we focus on forms of interactions between the instructor and students that may diminish the quality of the learning experience for the students, specifically those that are ubiquitously observed and correctable. (The specific areas of instructor difficulty are summarized in Appendix A.) We provide a large number of suggestions for ways that instructors can alter their behavior in introductory college science and mathematics laboratories that may alleviate some of the difficulties that we perceive.

Student-centered instruction is as much a collection of assumptions about the purpose and nature of instruction as it is a collection of instructional techniques. Felder and Brent characterize student-centered instruction as follows:

> "Student-centered instruction is a broad teaching approach that includes substituting active learning for lectures, holding students responsible for their learning, and using self-paced and/or cooperative (team-based) learning. Other ways to center our teaching on students include assigning open-ended problems and those requiring critical or creative thinking, reflective writing exercises, and involving students in simulations and role-plays." (Felder & Brent, 1996, page 43)

There are many reports of the success of SCI from experienced instructors who are skilled in its use, (Felder & Brent, 1996; McKeachie, 1994; Johnson et. al., 1991; Davidson, 1985; Heller et. al., 1992; Novak, 1993). However, on many college campuses (especially research-oriented universities with large numbers of undergraduates) these experienced individuals are not the ones who lead the introductory level labs. Instead, student learning in the introductory laboratory is often facilitated by inexperienced instructors who often have little or no teaching experience, training, or well-developed ideas about how to conduct their lab (Case, 1989).

As noted elsewhere, (Felder & Brent, 1996; DeLong & Winter, 1998; Prestine & McGreal, 1997), SCI is not an easy philosophy and set of techniques for instructors to effectively use. If used improperly, the positive learning outcomes that have been described in the literature are unlikely to be realized. Indeed, DeLong and Winter document instructional problems encountered by graduate student instructors when attempting to use student-centered methods in pre-calculus and calculus classes (DeLong & Winter, 1998). Similarly, in our observations of math, biology, and physics laboratories, we note that as laboratory instructors attempt to use student-centered methods to facilitate learning in laboratory courses, they also act in ways that may not accomplish the goals that they are trying to implement. Our observations and the suggestions we make provide a guide for teachers who want to improve their skills in SCI and for those who are preparing future faculty to use SCI.

METHODOLOGY

Data Collection and Analysis

This study was initiated in January 1999, and represents a body of data collected throughout 1999. Qualitative methods allow us to develop sufficiently detailed information about college science laboratories. Our methods are best described as clinical observations (Romberg, 1992). Our analytical method is a grounded research method (Glaser & Strauss, 1967) with the sorting of observations and creation of analytical categories conducted by the entire group of investigators. In total, we collected data from 40 laboratory sections. Our team of observers included two biologists and two mathematicians, with occasional assistance from faculty in other disciplines.

The main source of data was the notes made by observers during visits to laboratory sections. About 30 of the 40 observations were made by pairs or trios of observers. The presence of multiple observers for each laboratory session was an important feature of our approach. An obvious benefit is that with more observers, there is the opportunity to "triangulate" observations and interpretations (Asiala et. al., 1996).

The observers' notes were coded in a preliminary fashion by sorting episodes of classroom activity into the categories of "effective" and "problematic." The main criteria for sorting classroom episodes in this preliminary analysis was whether the methods or outcomes of the episode were consistent with the observers' assumptions about the nature and objectives of the introductory college science laboratory (see Section 3).

The episodes in the problematic category were then grouped according to the nature of the classroom activity described in each episode. For example, interactions between the instructor and small groups of students were grouped together. Within each of these new groupings, the episodes were examined to identify the problems that occurred in many different classrooms with many different instructors, and in different disciplines. The groupings and recurring problems were then ranked according to perceived importance. The main assumptions that underlie these rankings are recorded in Section 3.

During the first phase of data collection (Spring 1999), no follow-up interviews of instructors were held. During the second phase of data collection (Fall 1999), we conducted follow-up interviews with instructors to discuss the observations. As part of the preparation for these meetings, we prepared suggestions for each instructor. We grouped these suggestions to correspond with the persistent problems that we had identified.

The narrative vignette presented in this article were created directly from the notes compiled by one of the observers. This vignette was reviewed by the other team members who observed the laboratory session described to ensure that it was an accurate portrayal of the laboratory session. We composed several vignettes to illustrate the laboratory environments that we observed. In the interests of space, we have selected one vignette to include in this article.

While this vignette is broadly illustrative of many of the difficulties that we observed, it does not represent every single problem.

The Nature of the Classes Observed

We observed introductory math, physics and biology laboratories and biology sessions devoted to problem-based inquiry (referred to hereafter as seminar). Generally, the classes consisted of some kind of introductory lecture together with individual, pair, or group-based activities. The introductory lectures were usually no longer than ten minutes in duration, and were sometimes extemporaneous in nature. Some instructors also concluded the session with a lecture in which they attempted to either complete the lab for the students or summarize major points from the lab. This was only common in the introductory biology labs and seminars. Generally the mathematics and physics labs did not have any definite conclusion. Students usually just trickled out of these labs when they thought that they had completed all of the tasks for the lab session.

The activities for each lab or seminar were all designed by experienced faculty (usually faculty who had taught some component of the course). The activities were designed to deepen students' comprehension of the subject matter discussed in the lecture component of the course, or to guide students in the discovery of scientific or mathematical knowledge. In both the biology and mathematics courses, the lab TAs were introduced to the activities in a preparatory meeting the previous week.

During laboratory group work, students normally were divided into groups of three or four. While the students worked, instructors would circulate and try to clarify specific issues. Ideally, the instructors would provide guidance and hints, try to correct misconceptions, and ensure that the pace of the class and treatment of the subject matter were appropriate for the course. The biology labs and seminars visited were led by a single instructor and typically included about twelve students. The physics labs visited were also led by a single instructor and typically included between twenty and thirty students. The mathematics labs visited were the largest, including approximately thirty students each and led by an instructor, sometimes with an assistant.

The Subjects

The majority of the laboratory and seminar classes visited were led by graduate student instructors with little or no teaching experience. Several classes visited were led by more experienced graduate student instructors. In several of the mathematics laboratory sections visited, the lab was led by an advanced undergraduate (usually a senior) who had several semesters of experience as a lab assistant. Three of the mathematics laboratories visited were led by mathematics faculty members.

ASSUMPTIONS ABOUT THE COLLEGE SCIENCE LABORATORY

Observational data of the sort that we have collected will admit multiple interpretations, according to the assumptions on teaching and learning that researchers employ, (Geertz, 1973).

Our assumptions about learning have profoundly shaped our selection of areas of difficulty and the suggestions that we have offered. We agree (Asiala et. al., 1996) that it is important for researchers to make these assumptions explicit.

Assumptions on Learning in College Science Laboratories

In regards to the purpose of the college science laboratory, we assert that students should: (1) learn content in a meaningful, non-arbitrary, non-verbatim way; (2) spend as much time as possible involved in activities that focus on higher order thinking skills (Bloom et. al., 1956); (3) develop and practice a repertoire of non-routine problem-solving skills; (4) learn technical skills and the use of equipment, (Hazel, 1998); (5) appreciate the application of scientific knowledge and methods, (Hazel, 1998); (6) learn to work cooperatively with colleagues, developing teamwork skills, (Hazel, 1998); and (7) foster student autonomy and self-direction.

Assumptions about these purposes should be consistent with assumptions about the nature of student learning in laboratories. Our assumptions about learning include that: (1) students should be motivated to learn the content in ways that are meaningful (i.e. so that the learner is able to modify his or her existing conceptual framework to accommodate the new material (Winter et. al., 2000; Ausubel, 1963); (2) students can learn from each other, and through interactions with their peers students may construct meaningful understandings of the subject matter (Novak, 1977); (3) students tend to be able to understand material when new material is related to old material; (4) learners' efforts to place new material in relation to existing conceptions may be facilitated by the intervention of a suitably knowledgeable and properly prepared instructor (Novak, 1977); and (5) learning is an active process (often, but not necessarily, physically active).

Assumptions about the Desired Characteristics of Laboratory Instructors

We contend that ideal laboratory instructors should: (1) prior to intervening, have some idea of what the learner is thinking and what the learner is trying to do; (2) have his or her own conceptual framework that accommodates both the material that students have already learned and the material that the students are currently trying to learn; and (3) be able to facilitate interactions not only between themselves and students but also among students to encourage students so that they may work to construct meaningful understandings of the laboratory subject matter.

INTERACTIONS BETWEEN INSTRUCTOR AND STUDENTS

We present our data in the form of a vignette that provides a context in which to discuss the problem areas we identified. We selected this vignette to illustrate these problem areas, but these problems were not isolated incidents but widely observed in each discipline. We then provide potential solutions at the end of each section.

The events described in the vignette below represent a significant portion of an introductory biology seminar on dating phylogenetic hypotheses using fossil, biogeographic, and molecular clock data (see Appendix). The episodes described took place after the instructor had attempted to conduct a class-wide discussion of phylogenetic hypotheses and the kinds of data that can be used to build these diagrams. Seminar ended with a short discussion that took place immediately after the events described. We have assigned the fictitious names 'Alice,' 'Ann,' 'Alan' and 'Anthony' to the students from group A, and the names 'Ben' and 'Brad' to students from group B. While there were four students in group B, the vantage point of the observers was such that the conversation of two of the students could not be recorded.

> The instructor erased the board as the students began to work, and then began walking between the two groups. The students [group A] asked each other if the material on the handout was correct or not, and finally Alice asked the instructor, "Is this 350 million supposed to be 350 million or 150 million?" The instructor walked over and confirmed that the date was 350 million. Alice then turned to the last page of the handout and said, "See, these don't make any sense."
>
> "Shouldn't the one beginning with 'a' come after the one beginning with 'p' ?" asked Ann.
>
> "They're missing the intermediate," suggested Alan.
>
> These questions and comments were directed to the other members of group A. The instructor hung around in the space between the two groups, and waited for students to ask him a question directly.
>
> The instructor walked over to group B, and looked at what the students were doing. The students were not discussing their work with each other. The instructor looked at the work that the students had written down and asked one of them:

Instructor:	Therefore, which node should have branched off before that time?
Ben:	Did this mean that they found the fossil?
Instructor:	Yeah, they found that fossil. If you find a fossil within this clade, when did they branch off?
Ben:	. . . (only has a second or two to answer)
Instructor:	In terms of the nodes.
Ben:	. . . (only has a second or two to answer)
Instructor:	You found a fossil that looked like this ancestor, so what does that mean?
Ben:	The fossil came after the ancestor?
Instructor:	Yeah.

> The instructor returned to group A and asked, "How's it going?" Alice responded that they were confused by the units - groups or species. The instructor answered and then returned to group B. The instructor noticed that one of the students in group B had finished with the fossils, and was now working with the biogeographical data. The instructor asked:

Instructor:	Was that guy on one big island?
Brad:	. . . (no reply)
Instructor:	Here's the thing, there was one common ancestor. Did it arise on just one island or did it arise on two different islands? Does that help it to make sense?

> Some of the students in group B were ready to begin their molecular clock calculations, and they asked the instructor how to do this. The instructor told them to calibrate the clock by looking for the node that they knew the best, and then to look for a place where the two families have been separated. The students began calculations while the instructor watched. As the calculations progressed, the instructor asked the students in group B a string of questions, to which the students really seemed to be trying to respond. The instructor looked at the results of the students' calculations and remarked, "I think your 100 is good, but there's more data that you need to take into account. Hold on a minute I'll just need to check on these other guys."

In the meantime, group A had been struggling with the molecular clock data. Alice and Ann tried to talk it through to make sense of the data, while Alan listened to the conversation and occasionally said something. The fourth student, Anthony, did not appear to be participating in the conversation at all. Typical contributions to the conversation were along the lines of, "I think you take five percent of this . . . I don't know," or, "I got ninety but I don't know if it's right or not." The instructor glanced briefly at the table, and then went back to group B. Seeing that group B was struggling with the molecular clock data, the instructor stopped the class and began an explanation of the molecular clock calculation on the chalk board.

After the explanation, group A appeared to be at exactly the same point as they had been for the last ten minutes. The instructor returned to work with group B. After five minutes, the instructor walked over to group A and began to walk back to group B when Alice said:

Alice:	We've been using 95 million for this clade.
Instructor:	(Didn't recognize student was addressing him.) Hmm?
Alice:	We've been using 95 million for this clade.

The instructor looked at the calculations that Alice had written, and explained a point about one of the calculations.

This vignette illustrates several persistent areas of difficulties that arise from interactions between the instructor and the students when the students are principally occupied with their learning activities. We group these difficulties into two categories, according to whether the 'unit' that the instructor is attempting to interact with is a small group of students or an individual student.

Interacting with small groups of students.

Cooperative learning is a well-described form of SCI. As noted by many authors (Felder & Brent, 1994; Johnson et. al., 1991), cooperative learning is not simply students working on activities while sitting together in groups. Instead, cooperative learning involves a number of important ingredients including interdependence, individual accountability, face-to-face interactions, use of collaborative skills, and group processing (Felder & Brent, 1994). As the vignette illustrates, instances of cooperative learning were not commonly observed.

Felder and Brent (Felder & Brent, 1994) suggest benefits from cooperative learning that are consistent with the assumptions about the nature of the introductory science laboratory that we described in Section 3. For example, working together may encourage students to actively work at constructing meaningful understandings. Additionally, students may benefit from the explanations given by others and may persevere longer with learning activities if they have access to the thought processes of other students. In order for these benefits to be realized, it is important that the instructor carefully observe both the students' work on learning activities and his or her own forms of behavior as a participant in the learning environment (DeLong & Winter, 1998). For example, instructors who hope that having students work together will enable some students to learn from other students undermine this objective if they are constantly interfering with students.

We perceived two major categories of difficulties with instructors interactions with groups of students: (a) instructors failed to encourage student-student interaction when this was appropriate and (b) instructors' ways of involving themselves in students' work could discourage students from interacting with each other.

(a) Instructors failed to encourage student-student interaction

In many of the seminars and laboratories that we observed, instructors missed opportunities to encourage interactions within groups. In the vignette, for example, the attention that the instructor pays to group A is simply to respond to Alice's questions. At all other times, the instructor is either busy with group B or else is simply waiting for a student to ask a question. While the instructor is responding to Alice's questions about molecular clocks and checking her calculations, Anthony has been silent and has not contributed anything to the group's effort for some time. The instructor does not seem to notice.

We note that student participation in a group's efforts may take many different forms, with physically active forms of participation being the easiest to detect (e.g. speaking, operating experimental equipment, analyzing results). We also recognize that there are a variety of learning styles, and that some students simply may not do well in a highly participatory interactive learning environment, legitimately preferring to work on their own, (Felder, 1993). We saw little evidence to suggest that many instructors were sufficiently well acquainted with their students to recognize that this was the case. Some quiet students withdrew from participation in the group (and presumably stopped learning), perhaps due to the pressure not to reveal that they had fallen behind, or else due to the pressure not to slow the other students down (for example, Anthony's withdrawal from the group in the vignette). Because a silent, withdrawn student is often a student who either needs some help to work through the material or needs help to find ways to participate fully in the group's work, we feel that it is important for instructors to look for such students and to find ways to include them in what the group is doing.

Related to this is the point that many of the instructors we observed may not actually know what cooperative learning is (c.f. Johnson et. al., 1991; Felder & Brent, 1996; Reynolds et. al., 1995), and may feel that simply having students working and sitting together represents a cooperative learning situation. For example, the instructor in the illustrative vignette may actually think that all is well with group A, because someone (Alice) in group A seems to be producing answers at approximately the rate that the instructor expects. However, our observations (e.g. Alice and Ann cannot find a way to do their calculations that both agree is "right," Alan can't make any suggestions about how to proceed at all, and Anthony is completely withdrawn from what the other students are doing) reveals that very little cooperative learning is taking place.

When we have observed classes whose instructors seemed not to encourage student-student interactions, we have suggested:

• When possible. encourage students to position their desks so that they are facing each other, and so that all members of each group are in the “inner circle.”

• Try to notice whether or not students are participating in discussion and questions to prompt group discussion.

◊ Think of ways to engage disinterested students who may have been excluded from the group due to dominating members. One method might be to ask directed questions to the disengaged students that will require a response, not to you but to the group. For instance, "<Student 1's name>, share with the group two ways that <Student 2's name> might test his hypothesis."

◊ When you interact with a group, try to draw quiet people into the discussion by specifically asking them a question.

(b) Instructors ways of involving themselves in student work could discourage students from interacting with each other

In most of the classes that we observed, the instructors were somewhat self-conscious, but not really conscious of themselves. That is, instructors tried to project a professional and helpful image, and were certainly aware of the presence of observers in the classroom (self-conscious), but instructors often seemed not to be aware of conspicuous patterns in their conduct in the classroom (conscious of self), especially when these patterns had an arguably deleterious effect or seemed unfair to some of the students in the class. Our observations suggest that this “consciousness of self” can impact student learning.

(b)(i) Instructor spends conspicuously more time with some groups, even when other groups are clearly struggling

One aspect of a lack of consciousness of self that we observed repeatedly was the tendency of instructors to spend more time with some groups of students than with others. For example, in the illustrative vignette, the instructor spends considerably more time with the students in group B, rather than the students in group A, and interacts with the students in group B on different terms. The instructor engages the students in group B in extended conversations about the results that they are obtaining from their work on the learning activities (see the conversations that the instructor has with Ben and Brad). On the other hand, the instructor asks group A only if everything is “okay.” Towards the end of the vignette, the instructor does not realize that one of the students (Alice) actually intends to be speaking with him when she asks about her calculations. When the instructor is working closely with the students in group B on interpreting and using the data from molecular clocks to date the nodes on a phylogenetic hypothesis, the students in group A have clearly reached a situation where they have not made any appreciable progress for some time. Students in this situation can benefit from careful and judicious guidance from the instructor to help them examine the work that they have done and identify the avenues that are still open to them.

These were not isolated instances; we observed similar scenarios in many of our laboratory and seminar visits. In response, we suggested the following to instructors:

• Keep making some kind of contact with each of the groups when you come around to visit them. Many times that you ask the students anything - even if it is just, “Is everything okay?” - students have questions.

• Intentionally balance your time among groups. Obviously sometimes one group will require more attention than another, but often multiple groups need extensive help. Even if you can't get to another group immediately, acknowledge that they are struggling and confirm to that group that you will be with them as soon as possible.

• Try not to get “bottled up” with one group for a really long time.

◊ Get students going, and then check back with them a few minutes later.

◊ Ask the students to pool their thoughts and let you know when they have done this - you’ll be back then.

(b)(ii) Instructor emphasizes instructor-student interactions rather than encouraging student-student interactions

In the vignette, the instructor seems to be quite conscious of the need to facilitate a learning process within a group of students. For example, in the conversations noted with Ben and Brad, the instructor seems to be making a genuine effort to help these students deepen their understanding of interpreting and dating phylogenetic hypotheses by asking them probing questions. Unfortunately, this instructional behavior was not replicated in all seminars and labs. On the contrary, in many cases, the instructor seemed to feel that the best approach was to try to explain everything over and over again to students, sometimes altering the explanation. One of the fundamental problems with this method is that it places the focus on the instructor talking at students rather than on students discussing with each other.

As we stated earlier in this article, we have assumed that students learn by constructing their own understanding. According to such a paradigm, students’ poorly formed conceptions of the subject matter are not simple misunderstandings to be corrected by thorough explanations on the part of the instructor. Rather they are the products of the students’ constructive learning processes (Finkel & Monk, 1983). The instructor needs to recognize the attempts of groups of students to make sense of the material as important steps in constructing meaningful understandings, rather than assume that the students have misunderstood (DeLong & Winter, 1998). Instead of repeating previous explanations, or perhaps rewording previous explanations, the appropriate course of action in the constructivist paradigm is for the teacher to use his or her expertise to guide the students’ learning process (Mintzes et. al., 1998; Smith, 1994; Connell, 1998; Chickering & Gamson, 1991).

When we have observed instructors who have shown a persistent tendency to supplant groups’ efforts to make sense of the material for themselves, we have suggested:

• Try to encourage students to speak to each other, as well as supplying you with explanations.

◊ When a student has asked you a question, you could respond with a question like, “Did anybody else make any progress on this?” “Was anyone else able to work this out?”

◊ When you see a group of students who are working individually, ask one of them to summarize the progress that the group has made for you.

◊ If students are asking you if they have the "right answers," first of all ask the other students in the group what they got for an answer.

(b)(iii) Group has a "spokesperson," and instructor just tends to interact with spokesperson

A persistent pattern that we noticed in many different classes was that interactions between the instructor and groups of students are always with the same student from each group. For example, in the account of the biology seminar given here, the instructor's interactions with group A are always interactions with Alice. Note that it is not by the instructor's design that this is the case. Most of the interactions between the instructor and group A are initiated by Alice, so it is somewhat understandable that the instructor would respond to her questions. While we are not advocating that instructors ignore students' questions or requests for clarifications or asserting that the fact that students ask questions is problematic, we have observed potential problems with this "spokesperson effect" when it leads to the exclusion of some group members from full participation in learning.

Our impression is that the main goal of many students that we observed was to complete the activities (i.e. to obtain "answers" acceptable to the instructor) as quickly and easily as possible. With this imperative, it is easy for students who do not think or read as quickly to get left behind by the faster members of the group. We suggest that individual students are often reluctant to speak out when they feel themselves falling behind, and may prefer to remain silent even though they are well aware of the fact that they do not understand what the other members of the group are talking about. When the overriding goal of the group is completion of activities as quickly and with as little fuss as possible, there is an additional pressure not to speak out, as this might slow the other students down and "waste" their time. We believe that this may be what is going on in the vignette while group A is struggling to complete the activities on molecular clocks. Alice and Ann are trying to get answers that "look right," Alan listens, trying to understand what they are doing, and Anthony says nothing, clearly having fallen behind the others.

In this scenario, by responding exclusively to the spokesperson when interacting with the group, the instructor may be actually exacerbating the situation of other students in the group who have fallen behind, and who are no longer able to learn in that situation. By speaking only with the group's "spokesperson," the instructor misses opportunities to focus the group's activity on learning, rather than on just completing the activities as quickly as possible, and also misses opportunities to include all of the students in this learning process.

We note, however, that we have also observed classes where the "spokespeople" were careful to spend time communicating their ideas to the other students in the group. That is, after conferring one-on-one with the instructor and developing an understanding of the point they were stuck on, the spokesperson then taught the other students in his or her group the lessons learnt. Although this is certainly preferable to the situation described above, we suggest that all students should be encouraged to work to develop their own understandings of new material and to contribute to the understanding of other group members, rather than relying exclusively on their peers to sort everything out for them.

In classes where we have observed deleterious effects of group "spokespeople," we have suggested that instructors:

• Try to vary the directions that you approach groups from, so that you can get beside (and more easily interact with) all students in a group.

• Intentionally attempt to draw all members of the group into interaction

• When answering questions from individuals within a group, include the entire group in your answer. One way to do this is by actually posing the same question or a rephrased version of the question to another group member.

Interacting with individual students.

A persistent theme in the difficulties that we perceived involving instructor-student interactions was the predilection of many of the instructors to simply tell students what tasks to carry out in order to produce answers or even to tell students what answers to record in their work. We feel that this kind of instructor-student interaction (especially when it is the only or predominant form of instructor-student interaction) potentially diminishes the value of the laboratory for students.

For example, in many of the classes that we visited, we noted that both instructors and students focus on getting "right answers" and this overshadowed many of the interactions between instructor and students. One of the major implications of the constructivist framework is that students are unlikely to create meaningful understandings if they are always simply provided with "right answers." Instead, students need to engage in a process of inquiry in which they attempt to formulate theories to explain the phenomena they encounter, and then test their theories, (Dubinsky, 1998; Smith, 1998). Instructors would recognize this form of student behavior as a necessary part of a learning process, and encourage students as they work. Just as the students should be expected to spend quite a lot of their time constructing meaningful understandings of the subject matter, instructors should expect to spend quite a lot of their time recognizing and supporting students' efforts to learn. This conception of what the instructor should be doing in the laboratory can have quite different implications from the view that the instructor's primary role is to dispense bits of knowledge in the form of answers to questions that students are not able to immediately formulate an answer for themselves.

The main categories that we perceived here were that: (a) instructors and students tend to de-emphasize conceptual learning in favor of "getting the work done," (b) instructors lack the experience in using questions to guide students and to promote conceptual learning, and (c) instructors do not develop a clear picture of what students understand.

(a) **De-emphasizing conceptual learning in favor of "getting the work done"**

The vignette shows an episode where the students may be engaged in a constructive learning process. In the first part of the seminar, where the students in group A are trying to make sense of a phylogenetic tree, the instructor waits for the students to ask questions directly. Whether or not the instructor interprets the students' activity as an important part of a learning process or not, we feel that his actions at this point were appropriate, as we feel that it is important for the students to engage in a process of inquiry, rather than to simply receive "right answers" from the instructor. Likewise, later in the vignette, Alice and Ann are trying to make sense of some data about molecular clocks, with little (or no) involvement of the other members of their group. When Alice goes on to ask the instructor about their calculations, the instructor looks at the calculations and then tries to explain something that he feels will clarify the calculation for the students.

As we have noted, inquiry-based learning is often a new and somewhat uncomfortable activity for many students, (Bookman & Blake, 1996; Bookman & Friedman, 1994ab, Schoenfeld, 1985). It forces them to engage in a tentative, speculative, and somewhat open-ended activity rather than the more prescribed, rule-bound activities to which they may be accustomed. For example, the dialog that Alice and Anne conduct in the vignette contains as many statements of uncertainty ("I don't know") as it does statements about using molecular clocks. Clearly, these students are engaged in an activity where they are attempting to obtain an answer that seems "right" to them, but they are also engaging in an activity where they need to construct understandings of how molecular data is used to date biological events. When the instructor does interact with the students, he focuses simply on the final product of these interactions. The instructor does not, for example, ask the students to recreate their thought processes and relate these. Furthermore, as seen in the vignette, this is a process that two (of the four) students from group A are engaged in, while the other two students do not seem to be very fully engaged in this learning process, perhaps simply waiting for the other students to figure it out, or perhaps for the instructor to provide the class with a method for performing these calculations.

According to our observations, although the instructor realized that when the students seemed to be discussing the content among themselves, it might be best for him not to interfere too much, he did nothing to recognize the potential value of the process that the students had engaged in, and did nothing to encourage students as they worked. Recognizing that Alice and Ann were both involved in a potentially valuable attempt to make sense of the molecular clock data - and telling the students that their activity was valuable - may have helped these students to persist with their attempts to make sense of molecular clock dating, and may also have helped to draw the other two students (Alan and Anthony) back into the discussion.

In order to recognize and value students' genuine efforts to engage in inquiry-based learning, we have suggested the following to instructors:

- Instead of just telling a student whether the answers obtained are right or wrong, try to get her to tell you how she obtained her answers. This will give you an opportunity to examine the student's thought processes and understandings, and can help you to see exactly where the student may have gone wrong.

- Regularly check on the progress of each student in the class.

- Recognize when a student has done something significant, or has improved over time, and communicate this recognition to him or her.

- When a student gives an incorrect answer, try to first point out something that was right about it before prompting him or her in a new direction.

(b) Lacking the experience to use questions to guide students and to promote conceptual learning

The formulation and use of guiding questions as a method of facilitating inquiry-based learning has been advocated by many authors (Schoenfeld, 1990; Krantz, 1993; Skemp, 1975; Mintzes et. al., 1998; Case, 1991) The difficulties that many instructors have in formulating "good" questions has also been recognized by several authors (DeLong & Winter, 1998; Napell, 1976). We observed several difficulties with the ways instructors used questions.

(b)(i) Tending to tell the students what to do, rather than attempting to guide them

In typical college instructional situations, time is usually an important factor. When coupled with the fact that students will usually be examined (at least indirectly) on much of the factual content and techniques developed during lab and seminar times, both students and instructors feel pressure to ensure that all of the information that they will be "responsible for" come exam time has been covered. In such scenarios, the instructor arguably does have an obligation to make all relevant information readily available to students, and simply telling students this information may be the most expedient way to discharge this responsibility.

This tension to make all information available to students before the end of class is apparent in the vignette. Sensing that students are unable to work with the molecular clock, both instructors turn to whole class discussions in the last few minutes of class to explain the methodology and to provide an example for students to follow.

Although this is not always inappropriate, sometimes it is. In an effort to give instructors some guidance about when to explain and when to use guiding questions, we have made the following suggestions:

- Ask students to describe the intellectual content instead of having to explain everything yourself. This is not to say that you should never explain anything, just to let the students explain the things that they are capable of explaining and save your efforts to think up really clear explanations for the really hard stuff.

- When you interact with a student, try to help the student work out the problems for himself, rather than just telling students what procedure to follow. For example, (1) ask the student what parts of the lab he has been able to figure out and which parts he is stuck on or (2) formulate questions which will help the student to recognize what information she needs to solve a problem, find the information she needs, and then recognize how to use that information to understand the part of the lab she is working on.

(b)(ii) Formulating questions to ask students and waiting for responses

Many instructors that we observed instinctively recognized that they could focus students' attention and learning by asking questions that stimulated students to think about the content in a new or novel way, or to make connections between the material that they were working with, and other concepts that had been introduced into the course. However, many of the instructors that we observed, while fully intending to stimulate students' thinking in productive ways, had difficulty formulating and using questions effectively.

Some of these difficulties can be seen in the illustrative vignette. For example, the instructor has observed Ben's work on dating a node on the phylogenetic tree, and seen a problem. He attempts to guide Ben's thinking by raising the point that there is another node that should have already branched off, but Ben has not taken this into account. Instead of simply telling Ben this, the instructor asks a question, "Therefore, which node should have branched off before that time?" Ben does not answer immediately (he asks a question about the nature of the evidence which the instructor answers). The instructor then followed up by asking his initial question again. We find the instructor's actions up to this point to be excellent, and very supportive of a process of student inquiry. However, as he attempts to follow up, the instructor asks questions that Ben will likely have to think seriously about, with hardly a pause to allow Ben to think. Likewise, the instructor quickly rewords his questions, presumably to try to help Ben make sense of the question more easily. However, the instructor may actually be making things more difficult for Ben, because by rapidly asking a string of questions, Ben does not have a chance to think carefully about the first question he was asked, let alone the subsequent string of questions. In the end, the instructor asks Ben a much simpler question ("You found a fossil that looked like this ancestor, so what does that mean?") that is much more immediately related to facts that the student can recall with little or no thought.

In most instances that we observed, the questions that the instructors were attempting to formulate were very intimately associated with the actual content that the students were studying at the point in time. Because good questions depend upon the precise nature of the subject matter of the lab, the intentions of the instructor and the cognition of the learner, we are unable to produce a recipe for generating good questions under any circumstances. Some of the specific suggestions that we have made to instructors who have struggled with the formulation and use of questions are:

• As part of your preparation for class, spend some time anticipating areas where students may get stuck and formulating some probing questions to guide them through these parts of the exercise.

• Try to use some questions that ask the students about the intellectual content they are supposed to understand, instead of explaining the intellectual content and asking, "Does that make sense?"

> ◊ Observe and listen to the students for a little while to see what they are working on. Compose a question that goes a little beyond what the students appear to have explicitly worked out. If they can answer that question quickly and correctly, then it is a good bet that they have a clear picture of what they have been studying.
>
> ◊ Suggest a modification of the data or model that the students have been using, and ask the students how their conclusions or answers would change.

• When you ask a probing question, students will probably have to think about their answers. Give them plenty of time to do this before rephrasing, repeating or answering the question yourself.

(c) Not developing a clear picture of what students understand

Constructivist theories of learning generally agree that the most important information that an instructor can have before attempting to help a student learn is an accurate picture of what the students know (Novak, 1993; Mintzes et. al., 1998; Skemp, 1975). While thorough knowledge of the learners' thoughts, (Schulman, 1986; Thompson, 1992), is an ideal, the practicalities of a college classroom make this ideal difficult to attain. In the course of our observations, however, we noted that sometimes instructors paid close attention to what the students were trying to do, whereas other times, the instructors seemed to take little notice of the students' work, focusing instead on the answers that the students developed, or on other tasks such as arranging the physical environment of the classroom. All of the instructors that we observed seemed to want to help students learn. However, when instructors attempted to assist or guide students with little or no idea of how the students were thinking about the content, the instructor's efforts often helped students very little.

An example that occurs in the illustrative vignette is the conversation between the instructor and Ben. By asking a question, Ben has clearly indicated to the instructor that he was not in a position to respond meaningfully to the instructor's question. Instead of recognizing this, and trying to build a picture of what Ben understands about using fossil evidence to date the nodes on phylogenetic trees, the instructor simply repeats his previous question. The strategy that the instructor eventually settles on is to "dumb down" the question to a level that requires only the most basic understanding on the part of the student. We suggest that by taking a little time to develop a more accurate picture of what Ben understood and how he understood it, the instructor would have been in a position to help Ben answer the original question, rather than resorting to low-level questions to produce the illusion that the student is actually making a connection. Here, the instructor is doing the intellectual work; all that the student is doing is voicing some of the words in the place of the instructor.

When we have observed instructors who do not realize the important role of determining what the learners think is going on, we have suggested that the instructor make a conscious effort to watch and listen to the students. We have found it helpful to suggest particular areas of student-student interaction that instructors might pay close attention to:

- When you are observing a group of students try to notice what the students are doing in terms of:

◊ Are the students interacting with each other?

◊ Where are the students in their work on the lab? Are they on schedule to complete their work?

◊ Are the students getting near (or at) points of the lab that you can reasonably expect them to have trouble?

◊ Is the "product" that students are completing appropriate given the goals of the particular lab session, the wider goals of the course, and up to the standards of intellectual or mathematical rigor expected in this course?

MONITORING AND THINKING ABOUT THE TEACHING AND LEARNING ENVIRONMENT

In addition to difficulties that arise from interactions between instructors and students, we also regularly observed difficulties in instructors' abilities to monitor and think about the teaching and learning environment. In an activity based classroom, two types of goals exist - practical goals (management goals such as completing activities in the time available) and learning goals (such as students being able to use their knowledge in new situations or being able to clearly communicate what they've learned) (see appendix). While instructors are expected to achieve both, the time constraints of a lab session require them to make trade-offs. For example, with only 15 minutes remaining, an instructor must decide whether to rush students to complete the exercise or to allow them to continue struggling to understand a difficult concept. Thus, instructors must manage time appropriately, monitor intellectual activity, and adjust their plan to meet as many of the practical and learning goals as possible.

Our idea of monitoring and thinking about the teaching and learning environment is perhaps better understood using analogies from soccer or basketball. When dribbling, the player must know where the ball is and she must also know where all the other players are so that she can pass the ball. Likewise, while paying attention to the practical goals, an instructor must know if students or groups of students are achieving the larger learning goals and, if not, adjust so that these goals will be achieved. While it is difficult to do both of these at once, this is, nonetheless, a skill needed by SCI instructors.

Since most of the instructors we observed were inexperienced, they were often at a loss for how they should occupy their time. They tended to recognize that they should be doing something but their choices of what to do were frequently inappropriate. For example, several instructors invested their energy in organizational tasks, sorting through student papers, organizing overhead transparencies, or taping posters from group work onto the wall. While it is necessary to give small groups time to begin working together, it is difficult at best for an instructor to monitor and alter the teaching and learning environment if he is distracted from important cues by organizational tasks.

Based on our observations, components of this category include (a) not paying attention to students' intellectual activity and (b) making inappropriate use of time available in the lab.

(a) Not paying attention to students' intellectual activity

(a)(i) Instructors do not recognize that they should monitor students' intellectual progress.

Many instructors who fail in this category simply do not recognize that they should monitor the intellectual progress of the class as a whole. For instance, in the vignette, the instructor did not notice Anthony's non-participatory body language. Anthony sat away from the table and at times even put his head down. Thus he achieved neither practical nor learning goals. In other labs, the instructor invested up to one third of the time in the presentation of background information. In addition, instructors often made no attempts to include students in discussion or to ask them questions to test how they were progressing in their learning. We have observed instructors who have prepared extensive notes about what they will present to the entire class but who have apparently not attempted to predict what interactions within small groups may take place or points within the exercise where students will struggle. After lecturing, these instructors seem to breathe a sigh of relief as if to say, "My job is now done."

Similarly, instructors often hover around small groups of students, waiting to be asked a question. This happened in the vignette, where the instructor hung around in the space between the two groups and waited for students to ask him a question directly. We have witnessed this on other occasions as well where instructors stand several feet away from groups, don't say anything, don't look at what students are writing down, and stare into space. It seems possible that they are behaving this way out of hesitancy to disrupt group activity. However, without getting close enough to the group to gain information from what students are saying, what the students are writing, and how the students are sitting, it's unclear that the instructor could really know what's going on.

When we have observed instructors who fail to recognize that they should monitor the intellectual progress of students, we have made the following suggestion (note that portions of this suggestion were also mentioned in section 4.2(c)):

- When you are observing a group of students try to notice what the groups of students are doing in terms of:

Are any of the students struggling or lagging behind others?

- ◊ Is each student in the group contributing to the discussion?
- ◊ Are any students in the group off-task?

(Note: for additional suggestions see section 4.2 (c))

(a)(ii) Instructors tend to use only the most able students in the class as an indicator of how students are doing.

Another common mistake made by instructors who do not monitor and think about the teaching and learning environment sufficiently is that they receive their information about how students are doing primarily from the star students. The root of this problem is similar to that of the "spokesperson effect" described in Section 4.1(b)(iii). Whether by design or by circumstances (such as the physical layout of the room), many instructors that we observed tended to approach a group of students by walking towards the group’s “spokesperson.” Other students in the group may lack the confidence necessary to ask the instructor a question about the material. Since they don't say anything, the instructor may overlook these students and fail to receive important information about how they're progressing through the practical and learning goals.

When we have observed instructors who use only the most able students as indicators of progress being made, we have made the following suggestion:

- Look at how the "regular" students are doing as well as the "stars" of the class. Talk with all students from time to time. Don't just take the stars assurances "everything's fine" at face value all the time.

(a)(iii) Instructors miss students' requests for help

A prime example of missed requests for help can be taken from the vignette. Near the end of this vignette, Alice asks the instructor a question as he is leaving the group. The instructor does not realize that Alice has asked him a question, and Alice is forced to repeat herself. The instructor seems surprised that Alice has a question. We suggest that such problems may be related to those discussed in (a)(i) above. Instructors who hover at a distance from groups also tend to make this mistake. Again, this prohibits instructors from receiving cues about intellectual progress - verbal cues such as students sitting silently rather than discussing or whispering to each other "I have no idea what this means!" and non-verbal cues like students making eye contact with the instructor or sitting back from the table in frustration.

When we have observed instructors who miss students' request for help, we have made the following suggestions:

- Observe someone else's lab and concentrate on what students are doing.

- Look for signs of groups telling you that they want you to interact with them:
  - ◊ Obvious: raised hands.
  - ◊ Not so obvious: three or four students all reading silently, sitting back from table or desk.
  - ◊ Eye contact from individuals.
  - ◊ Little evidence of written work or accomplishment of experimental tasks.

(b) **Making inappropriate use of time available in the lab**

In planning and executing a successful collaborative learning lesson, instructors must also consider the role of time, the limiting factor in achieving both practical and learning goals. A common observation that we made is that time runs out before all of the goals of the laboratory are met. We have observed two different scenarios that lead to this same result.

We have observed that poor planning or execution in the way time is used at the beginning of class makes it almost inevitable that time will run out at the end. If an exercise is designed to involve students for 40 minutes and 20 of those minutes are used by the instructor, then students will not have time to complete the practical goals, and the learning goals will likely suffer as well. Time is often consumed at the beginning of class for other reasons as well, such as instructors tending to logistical details (e.g. what assignments are due and when). In contrast, instructors who effectively manage time at the beginning of class often do two things:
(1) They list assignments and due dates on the board at the front of the classroom and remind students to read the board and be aware of upcoming deadlines; and
(2) They skip lengthy introductions, provide a few concise comments about the goals and purpose of the day's activities, and immediately get students to work on the exercise.

Secondly, some instructors tend to get bogged down with groups that are stuck on a concept they don't understand and end up spending an inordinate amount of time helping them. A variety of factors may contribute to this problem. Certainly, the nature of the material being covered may be difficult for students to grasp within a limited amount of time. Although the curriculum used in the settings we observed is designed with time constraints in mind, there is no perfect curriculum. Inevitably, some student or group of students will struggle to achieve the learning goals. It also seems to us that running out of time at the end is confounded by poor interactions with groups of students or individual students (discussed at length in Section 4.1 and 4.2).

Sometimes it is the best choice for instructors to reassemble the entire class and explore a concept together instead of allowing the students to keep working in small groups. Often the instructors we observed did not recognize when they had arrived at this point. We are not saying that instructors should turn to class-wide discussions and mini-lectures at the first signs of struggle on the part of groups. Rather we are advocating that they be aware of the point at which students have done all that they can in groups and need the instructor to intervene with the entire class to help make sense of an idea.

When we have observed some of the problems that have just been described, we have made the following suggestions:

- When introducing a topic, consider directing your introduction specifically to what students will need to know to work with the exercise. Determine the time that should be allotted for this introduction, then practice to ensure that it will fit within this time slot.

- Be prepared to adapt the exercise to accomplish the most important goals as time begins to run out. For instance, if all of the groups seem to be struggling with the same part of the exercise, perhaps group work could end 10 minutes earlier than you planned in order to work through the problem as a class.

- Leave some time at the end of class for a final wrap-up discussion. This may help the students to synthesize the information that they have been working with.

- When appropriate, reconvene the entire class earlier to discuss problems as an entire group.

CONCLUSIONS

In this study, we have observed certain widespread difficulties encountered by novice instructors in their interactions with groups of students, interactions with individual students, and monitoring the teaching and learning environment. These difficulties are summarized in Appendix A (following the references).

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The difficulties we have described are difficulties that we have observed in a number of active learning environments in biology, mathematics and physics and may be more closely connected with the form of learning environment, rather than any particular area of subject matter. With this understanding, we suggest that the origin of the kinds of difficulties that we have described lie not only with the difficulty of the subject matter, but in large part with the instructor's ability to create and sustain a learning environment that encourages and supports students' efforts to learn.

During the second phase of observations, we conducted follow-up interviews with many of the instructors. Based on our observations, our assumptions about the college science laboratory (see section 3) and the follow-up interviews, we suggest that three related limitations may be at the root of many of the classroom difficulties that we have reported.
These are:

(1) the instructors lack of knowledge of pedagogical techniques (such as what cooperative learning entails) or lack of practical experience of how to implement these techniques;
(2) the instructors lack of knowledge of how students learn; and
(3) the following underlying assumptions held by many science instructors and students:
    (a) Dissemination of information and creation of understanding amount to the same thing.

(b) All of the information must be conveyed to students during the limited amount of time that is available. The conveyance of this information is the responsibility of the class instructor during class time.
(c) If students have not been specifically alerted to items of information then they are not under any obligation to examine that content. Conversely, exam writers are under the obligation not to include any questions on the exam that address issues that students have not been specifically alerted to.

These assumptions exert a powerful influence over the kinds of activities that occur in college classrooms. Through the follow-up interviews that we conducted with instructors, we feel that these assumptions may be responsible, at least in part, for the reluctance to facilitate student learning, and instead to simply convey answers to students. The instructors tended to view themselves as lecturers, task managers, or authorities of the knowledge of their discipline rather than facilitators of student learning processes. If this is true, it helps to explain some of the choices that instructors make regarding how they use their time during lab. Because the instructors we observed have succeeded within the educational system, they may fail to recognize the steps that less successful learners must go through to gain a working knowledge of new material.

We feel that instructors need to:
be aware that inquiry-based learning activities are often quite disconcerting for students, especially if those students view the main reason for their attendance at the lab or seminar as the collection of important facts that they will be asked to recall (Bookman & Friedman, 1994a),
encourage students to spend a lot of time engaged in the construction of their own understandings of the subject matter, and
recognize when students are engaged in processes that may lead to meaningful learning, and encourage them as they work

Because the categories of difficulties we discussed were based on the empirical data gathered in our observations, we do not claim to have produced an exhaustive list of difficulties faced by inexperienced instructors using SCI. For instance, we have deliberately not addressed issues that arise when the instructor chooses to adopt a more traditional role of lecturer or discussion leader, as these problems have been identified and extensively discussed elsewhere (Krantz, 1993; McKeachie, 1994; Morganroth-Gullette, 1982; Lambert et. al., 1996; Resnick, 1989; Christensen et. al., 1991). We note that even in student-centered laboratories, occasions exist when it is appropriate to deliver short lectures- for example to bring closure to a session by summarizing key concepts. In the situations that we observed, the difficulties were typical of the problems experienced by inexperienced lecturers (Krantz, 1993).

A natural next step in this program of study might be to construct a preliminary model of how the laboratory instructors think science should be taught. This model could be refined and tested through a program of structured or semi-structured interviews of laboratory instructors. Possible questions that seem natural to include are as follows: How do instructors characterize cooperative learning? What do they view as the learning goals of the laboratory? What types of pedagogical models have they experienced? Such a tool would allow us to develop and analyze the underlying causes behind particular instructor behaviors and would inform us of how we might better train laboratory instructors.

While the focus of this work has been on the difficulties encountered by instructors, it is important to point out that we have observed many successes within math and science laboratories. We observed instructors who recognize the need to use questioning as a teaching tool, students who take on the responsibility of teaching other members within their group, and instructors who are keenly aware of students' intellectual processes. While not the subject of this manuscript, these observations and similar ones have been used to develop a series of principles to guide instructors in a collaborative learning environment (Winter et al., 2000). Our experience suggests very strongly that all laboratory instructors have the potential to facilitate student learning in the college-level science or mathematics laboratory.

Based on both the research literature and our observations of well-implemented SCI we believe that the potential of this approach to enhance student learning in college science and mathematics laboratories is clear. However, existing references and training programs (Case, 1989; Caroll, 1980; Lambert & Tice, 1993; Nyquist et. al., 1989) appear to do little to prepare inexperienced instructors to function as facilitators of learning in a SCI setting. We hope that the results reported here will not only serve to inform the efforts of individual laboratory instruction, but also to help create training programs that will enable all instructors to build the skills and notions of teaching and learning needed to adeptly facilitate student learning in a laboratory setting.

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Appendix A:

Summary of Potential Problems with Student-Centered Laboratory Instruction.

INTERACTIONS BETWEEN INSTRUCTOR AND STUDENTS

1. Interacting with small groups of students.

    (a) Instructors failed to encourage student-student interaction

    (b) Instructors ways of involving themselves in student work could discourage students from interacting with each other

        (i) Instructor spends conspicuously more time with some groups, even when other groups are clearly struggling

        (ii) Instructor emphasizes instructor-student interactions rather than encouraging student-student interactions

        (iii) Group has a “spokesperson,” and instructor just tends to interact with spokesperson

2. Interacting with individual students.

    (a) De-emphasizing conceptual learning in favor of “getting the work done”

    (b) Lacking experience to use questions to guide students to promote conceptual learning

        (i) Tending to tell the students what to do, rather than attempting to guide them

        (ii) Formulating questions to ask students and waiting for responses

    (c) Not developing a clear picture of what students understand

MONITORING AND THINKING ABOUT THE TEACHING AND LEARNING ENVIRONMENT

(a) Not paying attention to students' intellectual activity

    (i) Instructors do not recognize that they should monitor students' intellectual progress

    (ii) Instructors tend to use only the most able students in the class as an indicator of how students are doing

    (iii) Instructors miss students' requests for help

(b) Making inappropriate use of time available in the lab

Appendix B: Introductory Biology Seminar Curriculum
"The Rate of Evolution"

The items contained within this appendix made up the packet that was given to Introductory Biology seminar instructors several weeks prior to the day they were to teach this seminar in the fall of 1999. The packet included a mind map that details goals for the seminar and a possible format for teaching it, mentor (teaching assistant) notes that provides background on the methodology addressed in seminar as well as an answer key, and the actual in-class exercise that students received.

Seminar 6: PBI #3 The Rate of Evolution -- Mind Map -- Fall 1999

Learning Goals:

- Build on lab to understand that phylogenetic trees provide relative relationships between taxa
- Introduce three techniques that are used to place dates on lineages
- Apply hypothetical data to date a given phylogeny

Practical Goals:

- Discuss methods of dating

Format:

- The mentor may begin this seminar by having a brief discussion about the questions that were at the end of the lab exercise and talk about the trees the students developed both using morphological and chromosome banding patterns.
- The discussion can then turn to the idea that once a phylogeny has been established, how do we go about placing dates on that phylogeny.
- After introducing the three techniques used for dating lineages the students then turn to applying these techniques to place dates on a hypothetical lineage using various forms of data. Probably because the concept of the molecular clock is less familiar than contental drift or fossils, students last year tended to struggle more with these data, unsure how they were useful in determining dates. It might be worth weighting this technique a bit more in the introduction.
- You may divide the section in to small groups to discuss the data. Each group goes through the fossils, biogeographic information, and molecular clock data to establish ranges of ages for the nodes on the phylogeny. Last year some mentors found this especially useful because groups tended to use the data slightly differently, especially from the molecular clock, leading easily into a discussion of the strengths and weaknesses of each method.
- One key point to make with this data-set is that specific dates for each node cannot be established. Instead, what we can do is narrow the time window for when each of these events must have occurred.
- The mentor then re-groups the section for a general discussion on what the students have found. This discussion offers the opportunity to talk about the underlying assumptions for each technique (e.g. there is a degree of uncertainty in dating fossils using radioisotopes that will then translate into uncertainty in calculating dates at different nodes).

Seminar 6: PBI #3 The Rate of Evolution -- Mentor Notes -- Fall 1999

NOTE: The students should determine the upper and lower bounds for the age of each node

Fossil Dating:

The most common method for dating fossils and rocks uses the rate of decay of radioisotopes. The basic idea is that radioactive isotopes (uranium, thorium, rubidium and others) are incorporated into rocks as they form in proportion to their presence in the environment. Each type of radioactive isotope then begins to decay at its own constant rate, becoming, by this process, a stable isotope. These decay rates can serve as "radiometric clocks" because the absolute ages of rocks can be calculated from the proportions of radioactive and stable isotopes present. For example, uranium-238 spontaneously decays into lead at a slow but precisely known rate. By knowing this constant rate and by comparing the amount of ^{238}U still present in a rock with the amount of lead derived from its decay, the age of the rock can be estimated with less than a 5 percent error.

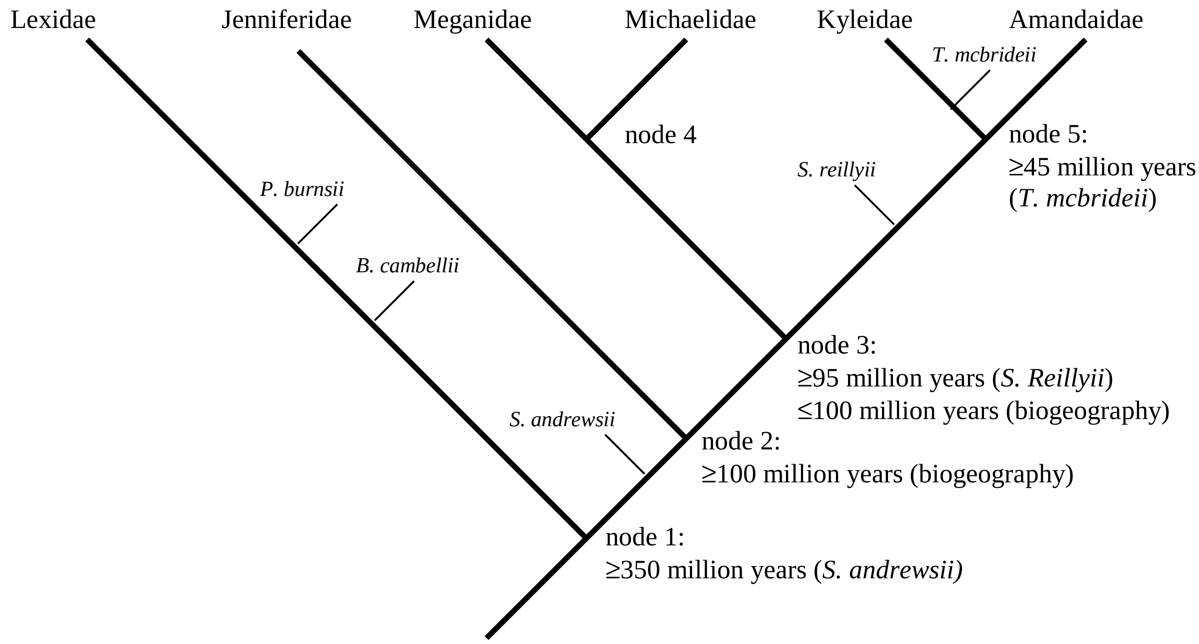
Vicariance Biogeography:

Disjunct distributions of organisms can occur when widespread ancestral forms are separated by some geological event, like the separation of continents. Vicariance biogeography uses the study of plate tectonics and other dynamic geological processes as a tool to explain the distribution of taxa. Under strict vicariance hypotheses, the cladistic relationships among related disjunct taxa should mirror faithfully the historical relationships among the geographic regions occupied.

In this exercise the taxa of Meganidae, Michaelidae, Kyleidae, and Amandaidae are all part of a single clade. This means that there must be derived characters that unite this group that originated between **node 2** and **node 3**. Because there are members of this clade on each land mass, the land masses must have split after this clade originated (after node 2). Because there are not members of Meganidae and Michaelidae on the rectangle land mass (or Kyleidae and Amandaidae on the oval land mass) the land masses must have split before these two terminal clades originated (before node 3). Although once the landmasses split the lineages evolve independently, we cannot necessarily place the splitting of the land masses at a node because there may have not been any divergence between the clades until sometime later.

Molecular Clocks:

The substitution of one nucleotide for another may take thousands or millions of years (with the exception of viral genes). The number of nucleotide substitutions between two sequences is important to molecular evolution because it is used to compute the rate of evolution, to estimate divergence time, and to reconstruct phylogenetic trees. The process of measuring nucleotide substitutions in DNA sequences is much more complex than what we present to the students. To compare sequences, one must first align the sequences, determine if multiple substitutions have occurred at any site, and determine whether changes have occurred in coding or non-coding sequences. Protein-coding and noncoding sequences are usually treated separately because they usually evolve at different rates.



<u>Molecular clock data:</u>

The narrowest window of time that we can use to calibrate the molecular clock data is for node 3. There are a number of ways to calibrate the molecular clock. 1. Use each set of data to calculate ages (0.1 and 0.09 for *K* <u>and</u> 100 million years and 95 million years). 2. Average *K* values and the range for the node. We have 2 estimates of *K* for this node (0.1 and 0.09) and these can be averaged to 0.095. We have a range of time for this node that is between 95 and 100 million years and these can be averaged to 97.5 million years. From this we calculate a rate of change that is 0.095 substitutions per site/97.5 million years. We can then use this to calculate the time since divergence for

Kyleidae and Amandaidae:

(0.05 substitutions per site) * (97.5 million years/0.095 substitutions per site) = 51 million years

Using molecular clock data we now date node 5 at 51 million years.

Amandaidae and Jenniferidae; Kyledae and Jenniferidae; Meganidae and Jenniferidae:

(0.296 substitutions per site) * (97.5 million years/0.095 substitutions per site) = 304 million years

Using molecular clock data we now date node 2 at 304 million years.

NOTE: These numbers are estimates that depend on how accurate the different measurements that contribute to the calculation are (e.g. the range for the dates of the fossils is ±5% which means that the "date" of the fossil is not exact).

NOTE: The calculations that the students make will be different if they decide to use the clock data for node 5 based on the fossil dates that limit this node to between 95-45 million years old!!

For example:

1. Using 0.05 substitutions per base/45 million years gives a date for node 3 of 81-90 million years.

Meganidae:Amandaidae=

(0.1 substitutions per base) * (45 million years/0.05substitutions per base)= 90 million years

Meganidae:Kyleidae=

(0.09 substitutions per base) * (45 million years/0.05 substitutions per base)= 81million years

2. Using 0.05 substitutions per base/95 million years gives a date for node 3 of 171-190 million years.

Meganidae:Amandaidae=

(0.1 substitutions per base) * (95 million years/0.05 substitutions per base)=190 million years

Meganidae:Kyleidae=

(0.09 substitutions per base) * (95 million years/0.05 substitutions per base)= 171 million years

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Teaching the Multicultural Learner: A Musical Theory Approach to Pedagogical Practices

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Abstract

This article integrates college student development theory, multiculturalism, pedagogy, and student learning style concepts with concepts from music theory to provide a conceptual framework that will assist the instructor and multicultural student in the classroom teaching and learning process. A number of suggestions are offered in an effort to promote the connection of theory to practice for all instructional leaders concerned with addressing the academic and social issues confronted by the traditional college student in general and the multicultural college student in particular.

"We are your symphony…"—Mr. Holland's Opus

During one of our many lunch breaks, intermittently infused with diminished chords, syncopated rhythms, and melodious lyrics, my colleague and I discovered that certain aspects of the fundamental tenets of music theory closely paralleled the basic components of pedagogical classroom strategy. Although my area of concentration focuses on higher education and college student personnel and my colleague's, K-12 business and vocational education, we both agreed on the similarities of our approaches to student learning and the underpinnings of music theory.

The line from above, advanced by a protégé of the infamous Mr. Holland in the highly acclaimed film *Mr. Holland's Opus*, captures the spirit and essence of our intended pedagogical practices. We view our students as a symphony, a symphony to be played using the rules advanced by the theories governing a musical performance, a symphony composed of diverse instruments and diverse sounds, but each adding to the harmonious tune directed by the musical conductor. This paper integrates concepts of college student development, multiculturalism, pedagogy, and student learning style initiatives we employ in the classroom with a number of the terms and concepts articulated in musical theory to uncover the instructional needs of the multicultural learner. Our musical model serves as a metaphor for the array of classroom instructional strategies we use to touch the hearts, minds, and souls of our students.

The Foundational Elements

Just as the musician composes the musical score, the educator composes the instructional plan to create a successful learning environment. Before the musician can even contemplate engaging in the arduous task of composing a tune, he/she must tackle the fundamentals of music theory; similarly the classroom instructor must tackle the fundamentals of classroom pedagogy. Like the musician, the teacher is guided by fundamental rules. Both must learn to enhance their creativity, seek paradigm shifts, and develop patience with ambiguity in the endeavor to master their respective crafts. To that end, the creation of harmony, both within the classroom and within the concert hall, is an effort requiring the synergistic workings of many constituent parts. We have sought to highlight a number of these parts from both music theory and classroom instructional practice to elucidate our point.

The first constituent components we examine are the grand staff and the human aggregate. The grand staff provides the template for the display of musical notation, while the classroom provides the template for the display of human aggregate characteristics, the human aggregate being the collection of characteristics of members within a particular setting (Moos, 1986).

For example, the inclusion of the bass and treble clef symbols on the grand staff serve as a means to determine musical pitch; likewise, the inclusion of student demographic and psychosocial characteristics in the classroom determine student (human aggregate) behavior. As the grand staff provides a virtual guide for the designation of musical pitch, the human aggregate provides a guide for the development of an overall classroom ethos. Moos (1986) noted, “The character of an environment is implicitly dependent on the typical characteristics of its members” (p. 286). Without strict adherence to the influence of the grand staff from the perspective of music, and the human aggregate from the perspective of instructional processes, the production of a harmonious outcome will not ensue.

To create effective learning environments, instructors must determine how the human aggregate’s collective characteristics influence student behavior. Students bring an impressively large number of diverse background knowledge and prior learning experiences to the classroom environment. The instructor may or may not wish to recognize the influence of these experiences; however, they should recognize that these very experiences ultimately dictate the nature of the environment. Instructors can use these idiographic examples of pluralism to enhance the experiences of all classroom learners.

Additionally, instead of thwarting students’ attempts at sharing their individual experiences and perspectives, instructors should use these opportunities to enhance course subject matter and classroom rapport. “We must open ourselves to learn from others with whom we may share little understanding” (Delpit, 1995, p.131). An instructor who embraces this notion creates value for each learner involved.

The second constituent components under investigation include musical time signature and classroom learning style. Time signature indicates the number of beats in a measure of music and informs the musician of note to beat ratios. Beat values vary in time duration just as the student learning process is time dependent. Kolb’s (1983) model of experiential learning functions in a similar yet distinct manner, it provides a structure for determining time and pace of classroom involvement.

Kolb’s model provides a way to adjust instructional practices to coincide with the time required for students to successfully engage in the learning process, a virtual metronome setting the tempo of the pedagogical cycle. “No matter what students’ interests are or how they are motivated, if they spend the amount of time they need on the learning task, they will learn to criterion” (Block, 1971, p.32). The time signature informs the cadence and duration of notes within a composition where as the dimensions of Kolb’s learning cycle informs the cadence of the delivery of varied instructional approaches.

Kolb’s theory establishes the importance of constantly adjusting instructional elements to meet the various learning style needs exhibited in the classroom (Evans, Forney, & Guido-DiBrito, 1998). To create instruction that addresses the needs of learners within the multicultural classroom environment, it is necessary to use information about individual learning style preferences to design curriculum and experiences that provide support and challenge. Thus, we assert that instructional processes incorporating the four learning styles articulated in Kolb’s model (accommodator, diverger, converger, and assimilator) will not only address the needs of all classroom learners but will also increase the instructor’s connection with students and provide them with a challenging learning climate (Evans, et al., 1998).

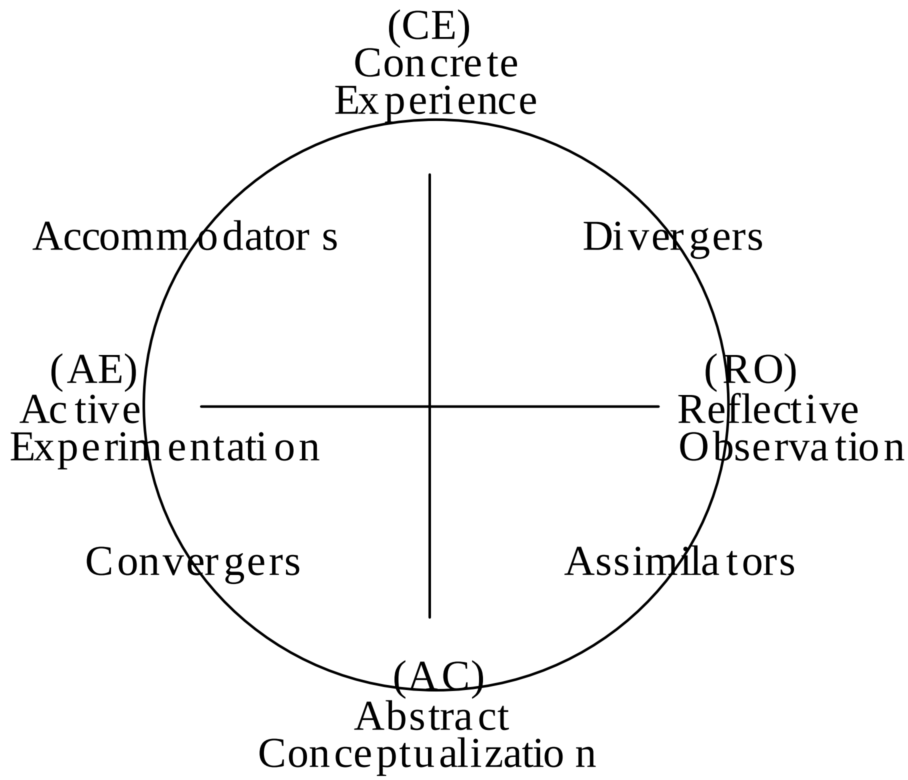

Figure 1:
Kolb Learning Styles

For example, there are few circumstances where lecture is effective as the primary mode to deliver classroom material. Students exhibiting various learning style preferences will digest content presented in lecture format differently—in different contexts, in different modes, at different rates. Therefore, in order to avoid neglecting our students with learning style preferences that may run counter to our teaching style preferences, we have used the four dimensions cited in Kolb's model to offer some suggestions: (a) The accommodators' proclivity for concrete experiences and active experimentation may be addressed through the incorporation of group activities. (b) The divergers' preference for concrete experiences and reflective observation may be addressed through case studies. (c) The convergers' need for abstract conceptualization and active experimentation may be addressed through problem solving activities. and (d) The assimilators' desire for reflective observation and abstract conceptualization may be addressed through data analysis (Kolb, 1983). Thus, as Kolb's learning model sets the cadence and tempo for the classroom learner, concomitantly the time signature sets the cadence and tempo for the musical composition.

The engaged listener would classify a musical piece maintaining a unimodal pitch as dull and uneventful. The same concept applies in the classroom environment. To engage the classroom learner is to engage the classroom learner's individual personality traits, thus leading us to the third component parts of our model, accidentals and student personality traits.

Accidentals, designated by flat and sharp signs, modify musical pitch, while personality traits modify a student's orientation to learning. To that end, we have associated musical accidentals with the six personality types displayed in Holland's (1973) theory of vocational personalities and work environments. Holland's six personality types (Realistic, Investigative, Artistic, Social, Enterprising, and Conventional) provide a means for categorizing student personality traits. According to Holland, an individual's activities, interests, and behaviors are a direct reflection of his/her personality type. Similarly, the pitch assigned to a musical note is a direct reflection of the corresponding accidental.

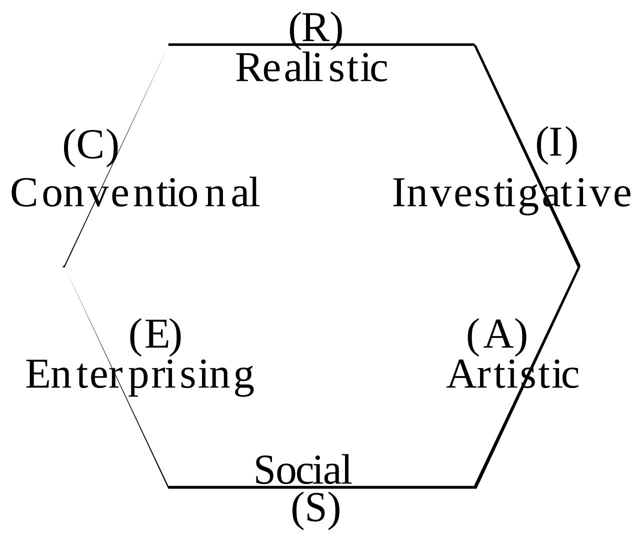

Figure 2
Holland Vocational Interest Types

To address classroom learning from a perspective incorporating student personality types, Holland's (1973) model indicates preferred activities associated with each type: According to the model: *Realistic* personality types exhibit a preference for activities that entail the explicit manipulation of objects; *Investigative* personality types favor activities that require problem-solving skills; *Enterprising* personality types embrace activities that require them to manipulate people or situations for goal attainment; *Social* personality types are inclined to engage in activities that inform, train, or enlighten others; *Artistic* personality types fancy activities that elicit their creative competencies to develop an art form, process, or product; and *Conventional* personality types value activities that require traditional competencies to solve everyday problems.

By recognizing different personality types, we celebrate diversity and promote learning in the multicultural classroom environment. Celebrating diversity calls for demonstrable behaviors that not only allow for differences but also foster interdependence. It is not

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simply creating tolerance for diversity, but rather full acceptance of divergent points of view (Smith, Wolf, & Levitan, 1994). To establish successful multicultural learning environments we must reject the notion that students should adjust to the norm of the teacher (Delpit, 1995; Wlodkowski & Ginsberg 1995; Anderson & Adams, 1992). Differences should be viewed as enriching and instructors should provide opportunities that engage and reward diverse displays of academic and social behaviors.

The grand staff, time signature, and accidental all work together to establish clear guidelines for composing music. In a multicultural classroom, human aggregate, learning style, and personality style traits establish guidelines for pedagogical practice. We have incorporated a number of elements from both areas to reveal the parallel nature of these two diverse fields in an effort to show how pedagogical practices can be enhanced to meet the needs of all learners. The incorporation of theory provided us with the necessary scaffolding to construct a system of practical knowledge that will be useful for the researcher as well as the classroom practitioner. Yet, we would be remiss if we did not address perhaps the most salient constituent components of our model. We have elected to treat these components, the musical notes and classroom variables, in a separate section as they serve to tie our previous discussion together.

The Notes

Although the basic elements of music provide the rudimentary elements for composition, it is the musical note that can be freely manipulated to create harmony, melody and song. Just as the musical note is manipulated on the grand staff, a number of variables are manipulated in the classroom environment to enhance student learning, growth, and development.

The composer constructs the musical piece by placing notes on the lines and in the spaces within the grand staff. Each corresponding position indicates the accompanying pitch the instrument or vocalist will produce. Through the manipulation of note positioning and/or accidental designation, diverse pitches and tones are developed—with the creation of music serving as the outcome. In a similar capacity, instructors engage in the art of manipulation in the classroom. Instead of the musical note, their variables consist of an array of student and classroom based factors that collectively influence the learning environment.

For example, musical notes are identified by alphanumeric characters (A, B, C, D, E, F, and G), each note/character identifying a distinct pitch. To produce a tune, the musician will form chords using note combinations (C, E, G; A, C, E; or B, E, G), sometimes two, three, four or even more notes at one time. By linking note combinations (chords) together in succession, diverse sounds and blends are created to generate music.

The classroom instructor engages in the same process. In the classroom, students are identified by certain demographic characteristics; in addition, students are impacted by various instructional elements. These characteristics and elements essentially serve as the notes the teacher manipulates in the instructional setting. Student demographic variables, representing the notes placed in the spaces of the grand staff include (a) culture/ethnicity, (b) gender, (c) disability, and (d) age. Instructional elements, representing the notes placed on the lines of the grand staff include (a) content, (b) instruction, (c) assessment and evaluation, (d) classroom dynamics, and (e) student-instructor rapport.

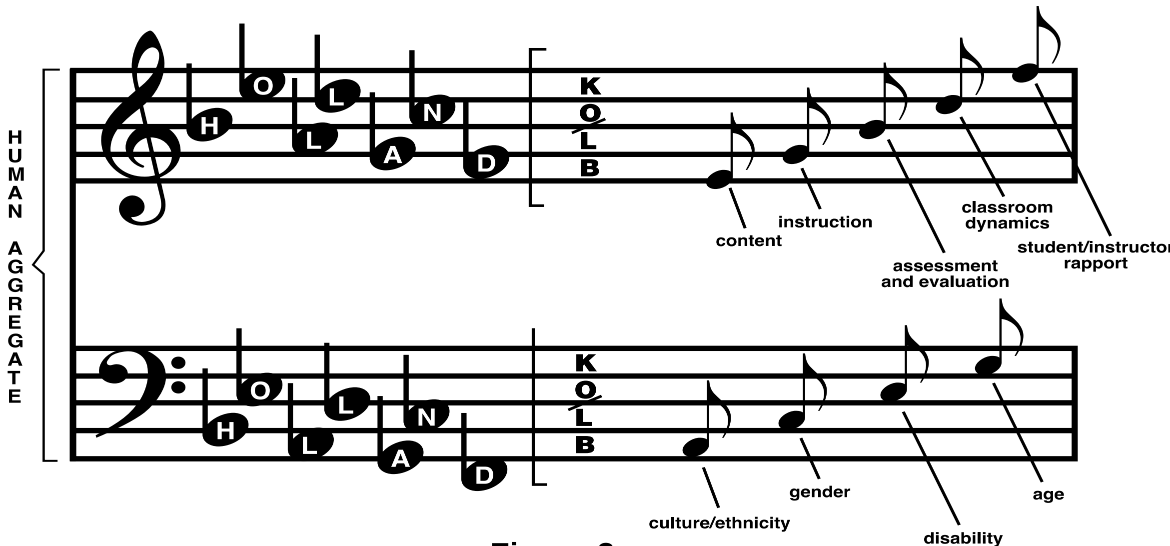

Figure 3
Bonner and Hairston
Musical Model

Like note combinations and chord formations in music, the classroom teacher engages in the teaching and learning process in a similar vein. An A, C, E, or D, F, A, combination of musical notes mirrors an age, content, and instruction, or a gender, disability, rapport combination in the classroom. The lesson to be gleaned from this comparison is that the musician and classroom teacher share similar strategies in their progression toward outcomes, the major difference being one in the concert hall and the other in the classroom.

Conclusion

The key to creating effective musical compositions as well as effective classroom learning environments lies in the adherence to the foundational elements previously identified in this investigation. The manipulation of basic musical elements, like the manipulation of classroom instructional elements serves to create harmony. Although adjustments are sometimes necessary, accomplished musicians, like skilled instructors possess the power to re-invent their respective environments to elicit intended outcomes—whether a melodious interlude or collaborative instructional setting. Both the musician and classroom instructor engage in intricate and complicated processes that require an acute sense of theoretical and practical knowledge to function.

Our musical model, which includes college student development, multiculturalism, pedagogical and student learning style data, in conjunction with music theory influences provide the classroom instructor with a unique perspective on creating a classroom environment conducive to student learning, growth, and development. We have presented a number of theories both from a musical and educational perspective, but the overarching premise of this study is to reveal how these two broad paradigmatic areas can be integrated. A willingness on our part as classroom instructors to meet the needs of all our learners will not only open our eyes to new ways of teaching and new ways of knowing, but will also move us beyond the classic "banking concept" of the teaching and learning process we often engage in with our students (Freire, 1993). As classroom instructors and the proponents of this model we say, "Let the music play as a background sound and as a partnership between the composer and the performer, and let teaching resound as a composition of precepts and experiences shared between the teacher and the student."

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Do Students Want To Be Active?

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Abstract

While the literature on active learning demonstrates positive results, adopting this model of teaching involves change for students and faculty. This study examines the reactions of 113 students after a one-semester experiment involving active learning in the classroom to determine student attitudes toward changing classroom expectations. The results, while positive, also indicate areas that need to be addressed by faculty as they change their teaching style to assist students in the transition.

Introduction

The literature on active learning is positive about the benefits of engaging students in the process of their own learning (Bellamy & McNeill, 1994, Page, 1990). Definitions of active learning may differ, but there is some consensus that for a professor to say they are doing active learning in a class the students must be reading, writing, discussing or actively engaged in problem solving activities (Bonwell & Eison, 1991). Overtime, many classroom activities have evolved under the rubric of active learning. These range from brief interventions such as concept quizzes where the class is given a brief quiz after a short period of lecture, to more longitudinal interactions as peer instruction which involves students teaching students (Mazur, 1997) to totally redesigning the class model as in collaborative learning models (Johnson, Johnson & Smith, 1991). Ruhl, Hughes & Schloss (1987) demonstrated that students provided with three two-minute breaks during the course of a lecture did significantly better on free recall and comprehensive tests. This study demonstrated that allowing students to interact with each other for six minutes in activities involving problem solving resulted in an increase in student learning.

Despite strong evidence, active learning is still relatively new to some faculty. Bonwell and Eison (1991) identified six barriers to faculty adopting this mode of teaching, one barrier being fear of change. But what about the students in the classroom? Change is difficult for them as well, more so because they often do not have control over whether or not to be part of a change model. This reality can be a factor in determining whether or not a faculty member maintains the active learning mode past an initial trial period. How do students perceive the shift from a more traditional model to actively being engaged in learning in the classroom? Do they enjoy coming in and “interacting” with material and each other or would they rather sit quietly and take notes (and perhaps sleep)?

In an applied science department in a Research I institution that is piloting a model of education grounded in the theory of active learning, we decided to find out. At the end of the first semester of this pilot project, students from five active learning based classes, from sophomore to senior level, were surveyed about the new style of teaching. Prior to this new model, the majority of classes the students had been exposed to were in the traditional chalk/talk lecture format. Pilot classes ranged in degree of “active” from traditional lectures with a few small group or individual activities such as think-pair-share or concept quizzes, to classes that were redesigned to be project-based. The faculty who taught these courses were interested in the students' reactions to this new form of pedagogy. Felder and Brent (1996) demonstrated the transition to a more active, student-centered learning environment could be difficult and problematic in sciences classes. At our institution there were many anecdotal complaints from students to their advisors and student services personnel about the affective quality of the classroom experience. Students complained the classroom environment left them feeling extremely stressed and intimidated by faculty and fellow classmates. They often expressed the concern that if they did not understand something in class they were too intimidated to ask for clarification since they perceived asking questions as being a sign that they were not as smart as their classmates. In other words the classroom climate for learning was negative both in terms of their relationship with their faculty and their peers. This experiment in changing the teaching approach in the five pilot classrooms was one venue the department was experimenting with in the hope that it would help alleviate student dissatisfaction with the classroom atmosphere. The faculty were not concerned with measuring the learning outcomes in classes which had modified their pedagogy. The graduation and placement rate at this institution was in the high 90th percentile and 97% of the students who were accepted to the university came from the top 10% of their high school graduation. Therefore, while the background and experience brought to the classroom was variable; it can be assumed that the ability level of the students across the five classes was fairly consistent. The faculty involved in the pilot study were interesting in examining the effects of changes in the curriculum on the quality of the educational experience as perceived by students: does an active learning approach contributed to a more positive classroom environment.

To measure if students felt that this new model of classroom teaching created this more positive environment, we administered an anonymous survey to students using the following four questions:

1. Discuss the relative strengths and weaknesses of the active learning teaching techniques relative to traditional blackboard/lecture format.

2. Discuss the effect of the active learning techniques on their perceived ability to understand material relative to traditional blackboard/lecture format

3. Discuss the inclusion of active learning techniques and their effect on the enjoyment level of the class.

4. Reflect on their experience as a learner, and describe how they perceived the changed teaching methods matched their style.

Methodology

The above survey was distributed at the last class of the semester to the five pilot classes. One hundred and thirteen responses were returned from a possible one hundred and fifty six. Qualitative methodology was utilized because it is an analysis mode designed to describe different perspectives of the same event and help understand how individuals interpret their social context which was the major thrust of this research (Bogdan & Biklen, 1992). The data was coded to see what themes emerged from the student's response to active learning in the classroom. Because there was a single researcher, the transcripts were coded using Miles & Huberman's (1994) check coding process. In this qualitative methodology a single researcher codes a transcript until there is 90% reliability in the codes. This process was repeated throughout the analysis. Codes were reviewed for redundancy and collapsed under appropriate headings.

Coding categories were analyzed and the resulting themes were generated into a report format for the department. Faculty from the pilot courses then reviewed the report prior to its dissemination to see if the results matched their perceptions of what was occurring in their classroom.

Results

The students' responses were enlightening, dismaying, helpful, and hopeful at the same time. Four important themes emerged from the analysis: (1) the students had an overall positive attitude toward active learning, (2) active learning was perceived to enhance their ability and efficiency in studying, (3) active learning was perceived to improve the learning environment, and (4) active learning promoted their thinking about their learning and thus helped them to better understand their individual learning style.

The negative perceptions were manifested in three areas. Students reported concern about: (1) the in-class time these activities took, (2) fear that they would not cover all the material in the course, and (3) anxiety around change in classroom expectations.

Listen to the students' voices as they tell us how they felt about the experience of active learning in an educational environment that had previously been predominately lecturing.

In responding to the strengths and weaknesses of active learning, students were overwhelmingly positive. Less than 10% of those who answered the survey mentioned only weaknesses.

Students in classes that were project- based with real problems presented by industry partners were the most enthusiastic.

> *"Three words – <u>real world experience</u>! I cannot emphasize the value of learning through doing, and the experience capitalizes on every possible facet of this concept. The (active learning) idea is very strong, very very strong. I've learned to deal with many real-world problems and issues that are inconceivable in a traditional lecture/blackboard environment. This class has been the single most educational experience I've undergone here. Furthermore, this class has been the most exciting class I've had."*

> "Very good. Stronger than other classes in the fact that it is hands-on experience which is very important. You can compare it to (this class in the past) and you get to do hands-on work and that makes this class better, you have integration of material."

But even students in the classes that involved lecture with think/pair/share activities or concept quizzes still valued the experience.

> "The (new techniques) breaks up the monotony, changes the focus, which helps keep us awake, let's us see whether or not we're processing information correctly and let's us have it explained differently by peers."

Students also viewed active learning as a "connecting mechanism". For some of the students it helped connect and integrate the course material in a more coherent fashion, and for others, it allowed them to connect in a more personal way with their faculty.

> "(Active learning) helps me see the relationship between what we're doing (in class) and real life. It cements what we do"

"In class exercises are good because you put the material into practice right away. I feel a better relationship with the professors."

However, as in all change, there was resistance and concern about changing the expectations. The largest impediment to embracing active learning from a student perspective was the time element. Half of the students who answered the survey felt that engaging in active learning exercises in class took away from the time that could be used to gather more factual information. This was expressed by fear that they would not cover all the subject matter in the syllabus or that taking time to do something would negatively impact workloads in projects that were team based. Interestingly, no student mentioned the amount of material that might be learned or that their retention would be different, only the amount covered.

"Fun and helps me learn but TOO TIME CONSUMING"

"I think that the active learning approach may be hard to swallow at first. It stimulates more motivation in the individual but the weakness is that many times more motivated individuals (in a team) might do more work than the less motivated ones"

There is also a degree of anxiety in some of the techniques that the faculty utilized to get them involved in the more lecture-based classes. The most disliked activity was a technique called cold calling which refers to randomly calling student names from a deck of cards and reading quizzes. Students felt these techniques increased their anxiety.

"I don't like cold calling, the lectures are fast enough that sometimes it's hard to keep up at the simplest level and then if you get called on it's frustrating to have to try and answer a question"

Lastly, it is a matter of perspective!

"New techniques are sometimes stressful, you actually have to think actively in a class!"

In assessing if students felt that the active learning techniques improved their ability to study more efficiently, students were overwhelming positive. As they described their experiences, the new techniques created a cycle which made them feel more secure (see figure1) and led to more efficient studying and more effective studying.

"This is a good way to check my understanding of the material along with homework.

"Examples and working them in class are improving my ability to absorb and learn the material in class instead of taking notes and having to go over them in detail later (when I can't ask questions). Stopping to work an example gives me time to ponder the material and formulate questions. Most of my time in the traditional method is spent copying the notes on the board"

For a few students though, it appears to be a matter of change. These students felt the active learning techniques did not match their learning style or else created new and different expectations about the classroom culture that made them uncomfortable.

> *"No (active learning) didn't help, but I think I'm being reluctant to change.*
>
> *"I'm a big fan of blackboard use because it actually puts the student through the thinking process, rather than just putting up pages of equations on the overhead."*
>
> *"No they're not helping. Usually even if I get lots of sleep, I simply don't feel like actively participating in class because it requires too much effort"*

In answering the question about whether the learning environment was more enjoyable, answers varied positively along a continuum from less boring to actually fun. Students expressed the feeling of a less pressured classroom atmosphere and the enjoyment of learning and working with peers.

> "Absolutely! While I sometimes fear being called on if I'm lost on a concept, it keeps me alert. I also derive immense satisfaction and learning out of figuring out a problem in class and explaining it to partner next to me"
>
> *"As I said, I enjoy the class a lot. Equations are actually fun and I feel less pressure in this class because we're all working together"*

The few negative responses in this category were basically around the anxiety of cold calling and reading quizzes. But even students who were ambivalent about these techniques still had some positive feelings

> .
> "The method (active learning) makes it frustrating at times since you're not sure where to go next, but ultimately the sense of accomplishment achieved is greater"
>
> *"Reading quizzes are a subject of dread, but other than that the added elements make the class more interesting"*

Finally, students were asked to reflect on what had occurred this semester and describe how they learn and how the active learning techniques related to that style. Almost to the person, these students described themselves as hands-on learners and the active learning techniques made them more aware of that fact. These techniques also encouraged them to think about the material in more creative ways. A student best summarized this who said:

"I best learn in an environment where I am asked to think for myself and come up with solutions. When I feel encouraged to think a lot and be creative and work the problems out, I learn far more than when I am asked to memorize solutions. I like how (with this method) we're given credit if we come up with some weird idea and fail to succeed in the task. You really encourage us to think for ourselves in addition to remembering formulas and such"

Limitations

While the faculty involved in these courses felt positive about the results and agreed to continue teaching in this model as well as encourage their colleagues to adopt some active learning techniques, there are some limitations that must be taken into account.

There is an issue of compatibility in the findings because of the various degrees of active learning that faculty chose. As the data indicated the more active the class, the more enthusiastic the students were, but part of that enthusiasm could be ascribed to the type of projects students were assigned. Having authentic problems presented to them from industry could be strong contributing factor in their feeling toward the teaching methodology.
There may also be a bias in the questions that were presented to students. Faculty had informed students at the beginning of the semester that they were trying a new type of teaching methodology that they hoped would improve the class for students. But the faculty did make it clear when they distributed the questionnaires that the answers would be totally anonymous, and that the students' candid responses were important in the decision process of whether to continue with this type of teaching. The faculty involved in their courses were not themselves totally convinced that active learning would create an improved classroom environment. These faculty were top researchers, but they were also caring teachers who were concerned about the students' negative attitude toward their learning environment and did approach this semester as a true experiment.

Further Reflections

The themes indicate that students feel that active learning has real value to them and to the improvement of the environment in which they learn. They felt positive when these techniques helped them 'own' material in a way that made it easier to interact in class, study, and problem solve with peer. They also felt that these techniques provided a closer relationship to the professor who they now perceived really cared whether or not they got something out of class. Through the active learning techniques students were better able to connect to the material in the course and to the faculty member teaching it. Students also reported that the material they learned in class was more useful when tackling problems out of class. Perhaps most importantly for these students and this faculty, student reported feeling better about their classroom experience. They enjoyed working with their peers and felt a sense of achievement when they accomplished a difficult task together. With active learning techniques they were able to get to "know" the student at the desk next to them and develop a more collegial/team-based style of learning. This skill of working in teams is often part of the hidden curriculum that never makes it to the formal curriculum because it is assumed students will learn to do this in some mysterious way. Active learning techniques make the learning of team work more overt, especially if students are then asked to reflect on the cooperative aspect of the exercises.

But the data also illuminate the challenges ahead. The most important need to be addressed is the inability of some students to deal with change. Many of these students come to higher education with expectations of very passive classroom experiences and those expectations must be uncovered, probed and altered. For some students it may go as far as the necessity to reframe what learning is: learning is not about “covering material” or “gathering facts”, learning is about integrating and using information in a meaningful way. Learning is also about feeling comfortable in the learning environment. There are a number of ways to help students cope with this change. Students need to understand from the very first day what is being done in the classroom and more importantly why it is being done. While the students surveyed here were told that the style of teaching used in the class would be different, they were not told the value of this new style in improving the learning environment. This cognitive or affective value is often obvious to faculty who use it, but for many students it is something new and different. By continually clarifying and reinforcing the purpose of active learning exercises and tying these activities to the learning objectives and environment of the class, students are made aware of the assumptions by which the faculty member conceives and conducts the class.

Secondly, students need to be made aware of what they are gaining by engaging in active learning activities in the classroom. Briefly surveying students about their attitudes, asking them to keep learning journals, and engaging in dialogue between faculty and students about the cognitive and affective results of classroom activities are all ways to have student appreciate and understand, at a metacognitive level, that by actively engaging in their own learning they are understanding and often learning by interacting with the content and with their peers. Again, it returns to the idea of communication between students and faculty. The students may realize they feel more confident about their learning and more comfortable with the learning environment, but they may not be able to identify why. Making this connection more clear for students will ease the transition.

Lastly, faculty need to understand that in the process of change there is always going to be some level of resistance. This is often manifest in the form of negative teaching reviews. Administrators who recognize and validate that students go through stages of change, will make it easier for faculty to continue to practice and perfect a different style of teaching free from fear of initial negative student evaluations impacting their promotion or tenure.

The thematic findings of this study were actually a pleasant surprise. It was anticipated that resistance would be much higher after only one semester, especially as this institution has a first year model where courses are conducted in large lecture halls with little student involvement in the class. The culture of passive learning is very strong by the second year. Yet with rare exception, students were comfortable, and in many cases enthusiastic, after just one semester about participating in an active learning environment. As one student so eloquently put it: “They (active learning techniques) ask me to embrace the knowledge such that I can begin to work with it which makes me much more careful about understanding!”

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Web Sites

http://www.ntlf.com/html/lib/suppmat/74vark.htm
http://www.active-learning-site.com/

Figure 1

Active Learning Cycle