Investigative Learning in an Undergraduate Biology Laboratory: an Investigation into Reform in Science Education

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Dissertation submitted to the Faculty of the

Virginia Polytechnic and State University

in partial fulfillment for the degree of

Doctorate of Philosophy in Curriculum and Instruction

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June, 1996

Blacksburg, Virginia

Keywords: Science Education Reform, Socio-cultural, Concept Learning, Computer Mediated Communication, Undergraduate Biology, Authentic Assessment

INVESTIGATIVE LEARNING IN AN
UNDERGRADUATE BIOLOGY LABORATORY:
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(ABSTRACT)

This study examined an innovative, project-based curriculum in a freshman biology laboratory by focusing on how students developed their conceptual understanding of a biological species. A model for learning was posed based on learners working in small groups. This model linked a socio-cultural approach to teaching and learning to conceptual change theory. Qualitative research methods were employed to collect a variety of data. Documentation of this innovative curriculum is provided.

This investigative curriculum incorporated the research practices that scientists use. A wide range of dynamic interactions with students actively investigating problems and sharing both their findings and thoughts during this time occurred. This essentially modeled the authentic practices of scientists. A direct comparison was made with this learning environment and the model for learning. Peer tutoring, cooperative learning, and most importantly, peer collaboration were observed when students grappled with difficult problems for which there was no single right answer. Teachers served as guides in learning, shifting responsibility to the students.

Analysis of student writing revealed richer, more complex definitions of species after the experience of the laboratory project. Several of the students used knowledge gained directly from their experiences during the laboratory project to help elaborate their definitions.

The electronic discussions showed a range of social interactions and interactivity. High quality discussions were found to be rich in scientific thought, engaging discussants by offering information, questioning, and actively hypothesizing. Mediating and facilitating discussions by the participants was found to be an important factor in their success. Groups exhibiting high quality discussions also had a lower response time than other groups, indicating that more substantive dialogues which are rich in thought proceed at a slower pace.

Significantly, an important connection has been made between the socio-cultural approach to learning and conceptual change theory. A closer examination of how small groups of learners develop conceptual understanding is needed. This approach also needs to be extended into other settings where reform in science education is taking place.

Acknowledgements

There are many people who have contributed to the rich path of learning that I have been able to follow these past few years. This study could be viewed as a culmination of that journey, though it really represents more a distillation of my experiences into multifaceted frame. These experiences have shaped my viewpoint and in some cases broadened it as well. I wish to acknowledge and thank some of those individuals who have influenced me.

Having been given the opportunity to engage in exciting research during my first year as a full time graduate student, George Glasson served as an effective mentor who gave me the freedom and resources to pursue many of my own interests. In addition, he provided me with essential feedback that was invaluable in completing this work.

I would also like to acknowledge the cooperation of Art Buikema and Alicia Schultheis for allowing me access to their learning environment. In addition, their helpful feedback greatly facilitated my progress. I am lucky to have experience with these educators as valuable role models.

In addition to George Glasson, committee members Art Buikema and David Taylor provided me with helpful feedback during data analysis. Their encouragement and suggestions not only facilitated my progress, but also encouraged my spirits as well.

Committee members Darrel Clowes and Jan Nespor were quite influential to me as professors helping me to frame my research perspective. This happened well before my study began. I owe thanks to Darrel Clowes for helping me to grapple with a larger awareness I might never have come to know otherwise. I owe thanks to Jan Nespor for causing me to rethink my views on subjectivity/objectivity. My perspective has undergone an important shift due to these experiences and this has strongly affected my approach to research.

Finally, I would like to acknowledge the committtment and support of my wife Marcia, who has helped me reach this goal. Without her, this would not have been possible.

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Introduction and Rationale

The purpose of this study is to examine investigative learning as students in an undergraduate Honors Biology laboratory participate in a project-based curriculum. This curriculum utilizes authentic research practices of scientists as students collaborate to investigate populations of organisms. This collaboration includes consulting resources, dialogue through online discussion groups, and investigative laboratories. The development of the students' concept of species is used as a focus to examine learning. Another aspect of this study is to evaluate the potential of on-line electronic dialogues that are directly related to the project-based unit. The link between this mode of communication and development of the concept of species is explored. This research also considers students' concept development from a socio-cultural perspective.

This research is part of a much larger effort at reform in science education. The particular learning environment studied uses an innovative, project-based approach that encompasses many of the practices recommended by national teams of science educators (National Research Council, 1996; Rutherford, 1989). Such efforts need to be documented as a means of sharing their successes and failures with other educators. With respect to research, these efforts are also rich environments for examining how learning can take place through innovative reform efforts. A strong need exists to examine these environments. Gaining a better understanding of how learning takes place in this context furthers theoretical perspectives of learning as well as helps to promote the science education reform movement.

This study is a natural extension of the previous year's assessment and research of the V-QUEST (Virginia Quality Education in Sciences and Technology) initiative, which was a systemic reform project sponsored by the National Science Foundation designed to promote investigative and interdisciplinary reform efforts in science education. The lab project studied is part of an on-going effort at reform which benefited from the V-QUEST initiative. Much of the research methodology used in this study was developed during the V-QUEST project and stems from the idea that learning is promoted through students engaging in the authentic practices of scientists. In this project, qualitative research methodology is used to gather data that reflects authentic teaching and learning practices. Because of the nature of this research approach, a wide variety of data sources are utilized, such as video-taped records of student labs, files of electronic discussions, and examples of student writing. In this way the richness of the learning environment is represented through multiple data sources which help the researcher gain a holistic perspective on that environment. This poses the real possibility of the researcher becoming entangled in the complexities of the data. New issues that were previously unforeseen may arise, opening up new avenues for research. As a means of avoiding too broad of an approach in this study, students' development of the concept of species was chosen as a focus.

Research Questions

A comprehensive definition of species is multidimensional and requires knowledge of several concepts pertinent to the project-based curriculum being studied. Since a species definition was required initially by the students, having them compose a definition after their experiences with the course provides insight into their learning. For this reason, the following questions were posed:

1. How did students' concept of species develop through the implementation of this project-based curriculum?
2. How did the project-based approach influence learning?
3. How does learning documented through the project-based approach mesh with the goals for the curriculum?

All three questions have both theoretical and practical implications. Theoretical underpinnings are based in a socio-cultural approach to teaching and learning (O'Loughlin, 1992). An emphasis is placed on classroom culture that considers the specific context of the learning atmosphere (Brown, Collins, & Duguid, 1989). This approach can be directly linked to students' learning of concepts through conceptual change theory (Strike & Posner, 1985). Practical implications of this research are connected to collaborative action research (Shymansky & Kyle, 1992), where research results help stakeholders reflect and improve on their practices. Further, qualitative research collecting authentic data also helps in authentic assessment, which can help to drive reform (Champagne & Newell, 1992; Wiggins, 1989).

Limitations

This study uses data collected from three major sources: videotape interviews and records of laboratory instruction, electronic dialogues, and species concept papers. Student participation was consentual, but except for limited interviews after the project, researcher interaction with the subjects was kept to a minimum. The data collected, therefore, gives essentially three "windows" with which to view the project, each uniquely different and limited in its own way. For example, videotape records of students in laboratories for the most part do not capture dialogue between individual students. Data retrieved as text files from electronic discussions occur with less spontaneity than face to face communication and are also limited by the willingness of students to actively participate. Species concept papers can be considered more a snapshot of what the student's understanding is, but may reveal very little about how that student developed that understanding. Conclusions drawn from such data must therefore consider the limitations of each data source. At the same time, these separate data sources provide three perspectives to examine student learning.

Organization of the Dissertation

The dissertation is organized into six chapters. This introductory chapter offers a rationale for the study along with research questions, an overall organization of the document. The first chapter also reviews pertinent literature in a discussion that develops a context for research from learning theory and related research. The second chapter situates the reader by giving an overall course organization, then describes the lab project specifically and the methodology used for the study. The subsequent three chapters present the findings from analyses of the three main categories of data: data from the laboratory project, data from the electronic discussions, and data from the species concept papers. These three chapters offer evidence from three different “windows” and can be viewed as separate components of a larger “research portfolio”. Because the three separate sets of findings require specific methods of analysis, these methods are included in context with each chapter for the sake of clarity. The final chapter summarizes the findings and discusses their relationship to the major questions posed and presents final conclusions along with their significance and implications.

Theoretical Perspective

The shift toward a socio-cultural theory of learning can be examined through tenets of social constructivism as viewed by scholars of L. S. Vygotsky where his theoretical framework is incorporated into a more pragmatic socio-cultural approach (Cooper, 1993; O’Loughlin, 1992; Wertsch, 1990; Wertsch & Tulviste, 1992). Vygotsky, writing in the early part of this century in socialist Russia, theorized that learning is a social phenomenon which begins exterior to the mind (extramentally) when humans interact socially. Afterwards, these experiences are incorporated into the learner’s mind as a function of the learner’s inner speech (intramentally). For learning theorists and developmental psychologists the appeal to such an approach is obvious if one takes into account that prior to this approach, behaviorism and cognitivism had limited success in revealing the complexities of learning (Cooper, 1993). Such a theory offers a new framework which, by its very dependency on language, can be actively employed in a manner that does not require a reductivist approach to the inner workings of the mind. In fact, learning can be directly approached by studying external social interactions. It is for this reason, among others, that "Western scholars, especially those in the United States, have been actively searching for new theoretical frameworks and Vygotsky's ideas seem to address many of the issues that have motivated their quest (Wertsch & Tulviste, 1992, p. 548)."

> In Vygotsky's view, mental functioning in the individual can be understood only by examining the social and cultural processes from which it derives...Namely, it calls on the investigator to begin the analysis of mental functioning in the individual by going outside the individual (Wertsch & Tulviste, 1992, p. 548).

This analysis places extreme emphasis on language, in particular speech and the written word. Humans are inherently social animals whose biological development is inextricably woven with socio-cultural development. Humans are also meaning-making creatures who inevitably use language to construct and reconstruct meaning, first through extramental interactions between individuals and then through intramental interactions.

In addition to the idea that learning is an inherently social process, Vygotsky's concept of a "zone of proximal development" is central to understanding how learning takes place from the viewpoint of a social constructivist. This is defined as the distance between a child's "actual developmental level as determined by independent problem solving" and the higher level of "potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978, p. 86)". The instructional implications of this concept are immense. Instruction should be geared toward guiding the student to the higher potential. It is necessary to first understand what can be expected and then strive to achieve those expectations. As they are reached, the potential also grows-- both levels should be dynamic. Expectations play an important role.

Vygotsky's theoretical approach can be implemented by adding two practical concepts to social constructivism: the role of guided participation (Rogoff, 1990) and the concept of situated cognition (Brown, et al., 1989). Taken together, these allow a framework for a socio-cultural approach that attempts to encompass the complexities of concept learning.

According to Rogoff (1990), "Vygotsky's model for the mechanism through which social interaction facilitates cognitive development resembles apprenticeship, in which a novice works closely with an expert in joint problem solving in the zone of proximal development (p. 41)." The expert need not be the teacher; more capable peers are often the source of guidance in small group settings. The popularity of "collaborative learning" in recent years is evidence of gaining acceptance of this approach. Rogoff (1990) explains guided participation:

> Guided participation involves collaboration and shared understanding in routine problem-solving activities. Interaction with other people assists children in their development by guiding their participation in relevant activities, helping them adapt their understanding to new situations, structuring their problem-solving attempts, and assisting them in assuming responsibility for managing problem solving (p.191).

In this context, Rogoff is referring to young children who are considered novice. Problem-solving for a novice requires guidance to keep the learner on a productive path, otherwise, much time for learning is wasted. Such guidance is helpful to any learner that is novice, be they young child, adolescent, or even adult. The amount of guidance and the ability to encourage participation that the experienced guide delivers is crucial to engaging the learner. Interestingly, Rogoff goes on to explain that these interactions are often intuitive and connected to the context of the activities being negotiated.

> This guidance of development includes tacit and intuitive forms of communication and distal arrangements of children's learning environments; it is often not designed for the instruction of children and may not involve contact or conversation. The model is one of routine arrangements and engagements that guide children's increasingly skilled and appropriate participation in the daily activities valued in their culture (Rogoff, 1991, p. 191).

Once again, there is an emphasis being placed on communication and culture. Using this approach, the teacher or guide must take into account the student's inner speech--what the student is thinking; how dialogue is being internalized. To do this, some understanding and appreciation of the individual history, culture, and society of the student must be considered. Also, it is important to understand other affective aspects of the individual's makeup (e.g. personality traits, moods, and physical health). The combination and interaction of these attributes defy reductive analysis. They must all be considered as important factors that affect learning. The teacher necessarily becomes an inquirer into the thought processes of the student. "Learning and cognition, it is now possible to argue, are fundamentally situated (Brown, et al., 1989, p. 31)."

Concept learning during guided participation requires a learner that participates within a cultural context valued by the individual. During their interactions, learners use knowledge that is necessarily contextualized in their everyday culture. It is continually shaped and restructured from their experiences. From a Vygotskyan perspective, this knowledge is formed from a framework of "inner speech" or language. Brown, Collins and Duguid (1989) take these notions further to describe how knowledge (like language) is absolutely contextualized or "situated":

> All knowledge is, we believe, like language. Its constituent parts index the world and so are inextricably a product of the activity and situations in which they are produced. A concept, for example, will continually evolve with each new occasion of use, because new situations, negotiations, and activities inevitably recast it in a new, more densely textured form. So a concept, like the meaning of a word, is always under construction. This would also appear to be true of apparently well-defined, abstract technical concepts. Even these are not wholly definable and defy categorical description; part of their meaning is always inherited from the context of use. (p. 33)

This is in essence what is meant by situated cognition. A concept cannot be totally separated from its use. Thinking, however abstract the idea, always has a context. An unique, inner dialogue of language is one way of defining thought. An interesting observation here is that people learn words most often in the context of ordinary communication, and they do this rapidly (Brown, et al., 1989). Consider how much of one's vocabulary is obtained by actual reference to a dictionary, for example, or vocabulary building exercises in public school.

Both Rogoff and Brown, Collins and Duguid view learning as a process where the student is an apprentice, guided by an expert, situated in a context that is uniquely complex and dynamic. This is in accord with O'Loughlin (1992) who summarizes a *socio-cultural approach* thusly:

> A *socio-cultural approach* to teaching and learning that takes seriously the notion that learning is situated in contexts, that students bring their own subjectivities and cultural perspectives to bear in constructing understanding, that issues of power exist in the classroom that need to be addressed, and that education into scientific ways of knowing requires understanding modes of classroom discourse and enabling students to negotiate these modes effectively so that they may master and critique scientific ways of knowing without, in the process, sacrificing their own personally and culturally constructed ways of knowing (p. 791).

This socio-cultural approach acknowledges the Vygotskian assumptions about learning and extends them to encompass situated cognition and guided apprenticeship in a student-centered learning environment. Further, a socio-cultural approach takes into account care and respect for students as individuals with unique histories and cultures, which may be quite different from the environment they have been placed in. The learner is viewed as subject, not object. Implementation of such an approach is enormously difficult. O'Loughlin concludes that "the greatest challenge we face in reconstituting our pedagogy is to find a way to step outside our own cultural blinders to think of coming to know as a socio-historically and culturally constituted dialogical process of meaning making (p. 811)." Stepping outside of our blinders is indeed the key to awareness.

Authentic Assessment and Reform

This section provides a background for understanding the research approach taken in this study. This is accomplished by describing authentic assessment practices which help drive reform efforts in science education. Authentic assessment helps to ground instruction in the practices that scientists undertake when solving real world problems. Students engaged in authentic practices produce evidence of learning that is different from traditional forms, such as objective tests. To best examine this learning from the researcher's point of view, it is only natural that this varied array of evidence be studied. This is especially true if the researcher shares a socio-cultural approach to teaching and learning.

Unlike forms of assessment such as multiple choice tests that call for one "right answer" authentic assessment focuses on tasks that employ real world practices. Authentic tasks can be defined as real world, open-ended tasks that require active strategies for solving problems (Champagne & Newell, 1992, p.846). Examples might include designing an experiment, uncovering the reason for a fish kill, or trying to predict population growth in a certain species. Authentic assessment is accomplished by requiring such tasks and documenting and analyzing the learning that occurs. This is congruent with the shift in learning theory underlying the belief that "...complex learning behaviors cannot be decomposed into independent bits of knowledge and skills that can then be tested and the results combined to reflect larger complex behavior (Jorgensen, 1994, p.12)." A truly authentic task in a science class would be students designing their own experiments spurred on by their own curiosity, not merely told to design an experiment. In a sense, how "authentic" the activity determines how authentic the assessment can be (Wiggins, 1989, p. 703). The success of reform from this aspect depends on whether instruction can cause students to become truly engaged in the pursuit of learning, and whether students take on ownership for the responsibility of learning.

Assessing the ability of a student to think requires a variety of strategies. "Subtle methods must be devised to capture the thinking that lies behind a right or a wrong answer (Champagne & Newell, 1992, p.846)." Judging a student's ability on a simple right or wrong answer shortsells the thought processes involved and reduces subjectivity to a purely objective outcome. Students certainly are painfully aware of this.

> There has got to be some other way to test us besides the A, B, C, D answers because even if you are trying to figure out a problem, you get half of it right, and the other half is wrong, you still get the wrong answer, you don't get any credit for your work (middle school pre-service science teacher)
>
> (Glasson & McKenzie, 1995b, *Baseline Data: Undergraduate Student Perceptions*.).

Multiple strategies for gauging learning progress help form a more complete picture of a student's learning.

How then, is authentic assessment connected to reform in science education? If the "...criterion of a good test is its congruence with reality (Wiggins, 1993, p.206)", then alternative assessment should be focused on activities that are part and parcel to the practices of scientists. If this assessment requires students involved in real world tasks, then assessment is in a sense driving reform. Authentic assessment and reform really are integral; as the learning environment approaches real world practices, assessors devise ways of ascertaining whether students are successful in their efforts at behaving like scientists. The task itself is the "test". Taking time out to finish a traditional test would mean taking time away from the relevant task at hand--solving the problem or devising the experiment or observing a phenomenon. From this point of view, traditional assessment means taking time away from scientific learning.

There is a direct and important implication from the above discussion on authentic assessment practices and this research study that investigates student learning. Data collection should be authentic as well. Qualitative researchers examining learning while students are engaged in complex tasks are best served by collecting a variety of data that offers different windows into learning. This can be likened to a portfolio approach to assessment, where "rich collections of evidence" are assorted to show what has been learned and whether a student has improved across time (Collins, 1991). In this respect, the researcher should attempt to collect a variety of data representing the authentic practices that involve learning so that learning can best be represented. However, the researcher not only uses this data to document learning, but examines it rigorously for clues about how learning is accomplished. This analysis progresses when themes are exposed that can be compared to theoretical perspectives. This approach is fraught with enormous complexity and requires focusing on specific themes only after examination, reflection, and subsequent reexamination until critical issues are uncovered and can be synthesized into a coherent picture.

Concept Learning in Science Education

Many studies have focused on concept learning, including many specific studies involving concepts in biology. Adeniyi (1985) and Brumby (1982) investigated misconceptions of students' views on ecology. Bell (1985) and Griffiths and Grant (1985) investigated students conceptions of plant nutrition and food webs, respectively. Marek (1986), and Westbrook and Marek (1991; 1992) looked at student understandings of diffusion and homeostasis. These studies are typical of many that identify students' prior knowledge, which is often viewed as “naive” conceptions or “misconceptions”, and make some attempt understanding why such alternate conceptions are held and how they may change. Findings of these studies are nicely summarized in general terms by Westbrook and Marek (1992):

> 1. Children enter school with errant notions about their environment based on their own judgements. These notions are persistent and resistant to change.
>
> 2. Children develop misconceptions from their classroom science experiences. These misconceptions may arise from a mismatch of concept level and the students' developmental level or may be transmitted by the teacher or the textbook.
>
> 3. Classroom instruction does not always effectively alleviate the science-related misconceptions students bring into the classroom from past experiences.
>
> 4. Students who do "learn" textbook answers concerning scientific phenomena frequently cannot use that knowledge to solve problems related to those concepts.
>
> 5. Errant conceptions of fundamental biology concepts are evident in children at all educational levels (p.52).

These findings emphasize the importance of prior knowledge and beliefs as well as the classroom as an environment that may not be conducive to effecting changes in the way students view biological concepts. Lawson (1992) and Lawson and Thompson (1988) have investigated the reasoning abilities of students learning biological concepts (genetics and natural selection). Lawson (1992) concludes that many college students have “...failed to develop sufficient skill in using important scientific reasoning patterns and that this failure limits achievment as measured by the following ability-related factors:

> 1. The ability to do science (for example, generate and test alternative hypotheses in a systematic and controlled fashion);
>
> 2. The ability to solve problems (for example, predict the ratios of offspring genotypes given parental phenotypes);
>
> 3. The ability to understand and apply biological concepts (for example, evolution and natural selection), and
>
> 4. The ability to discard biological misconceptions (for example, vitalism and creationism) (p.341)."

Lawson's findings, along with the other aforementioned researchers, are the result of research that is focused more on the individual student as opposed to social interactions. They are important in understanding the shortcomings of many current approaches to instruction and therefore represent the important first step-- defining the problems. How can these problems be addressed? How then, can new concept formation in science education be promoted?

Conceptual Change Through Peer Interactions

Conceptual change epistemology maintains "...that the task of learning is primarily one of relating what one has encountered (regardless of its source) to one's current ideas (Strike & Posner, 1985, p.211)." According to Strike, intellectual problems arise from discrepancies between current conceptions and their inability to explain phenomena. Solutions to these problems must fit with a framework of knowledge that is acceptable, therefore, the discrepancy is alleviated when conceptual development or change occurs to help explain it. Strike and Posner go on to say that

> conceptions are a precondition of experience. Seeing is something we do with ideas as well as senses. We cannot see what we cannot conceive. Moreover, people who approach the world with different conceptions will see it differently (p.214).

This last statement is the crucial link of conceptual change epistemology to social constructivist theory. It is the sharing of these different ideas that promotes conceptual development. Vygotskian extramental dialogue affects subsequent intramental speech, resulting in the possibility for new explanations that better explain observed phenomena.

Recommendations for promoting this learning can also be found in studies involving peer collaboration as a means of effecting conceptual change (Basili & Sanford, 1991; Champagne, Gunstone, & Klopfer, 1985; Damon & Phelps, 1989; Lumpe, 1995; Lumpe & Staver, 1995).

Damon and Phelps (1989) important work on peer interactions characterizes three teaching techniques that employ different types of peer interactions: 1) peer tutoring- an experienced peer helps a less experienced one, 2) cooperative learning- working together toward a common goal, and 3) peer collaboration- peers work together to solve problems they may not have solved on their own.

Two indexes of engagement help identify the quality of the interaction. *Equality* occurs when all parties receive direction from each other while *mutuality* occurs when discourse is involved that is intimate and very contextualized (Damon & Phelps, 1989,p.10). Peer tutoring is low on equality because the flow of interaction is one way, in contrast, cooperative learning is more likely to be higher in equality. Cooperative learning offers a wide range of mutuality, but this measure may be lowered when tasks are subdivided with individuals attending to separate tasks. Peer collaboration tends to be higher in equality than peer tutoring and higher in mutuality than cooperative learning because of intense involvement and role changing by those involved. Damon and Phelps (1989) believe that

> Peer collaboration's promise lies in provoking deep conceptual insights and fundamental developmental shifts in perspective. This is because peer collaboration encourages experimentation with new and untested ideas, thereby demanding a critical re-examination of one's own assumptions....The child feels more like a fellow explorer than an isolated incompetent (p.13).

In agreement with Damon and Phelps, Lumpe (1995) believes that "peer collaboration appears to hold the most promise for impacting concept development and problem solving; two goals of the latest reform movements in science education (p.307)."

It is very interesting to note here that peer interactions can be viewed from either a social constructivist or a cognitivist perspective. Lumpe and Staver (1995) refer to a “bidirectional zone of proximal development” which was first described by Forman (1989) where “the roles of teacher and student were assumed at different times by different people (p. 67).” During situations involving peer collaboration, each participant functions as both a guide or teacher and a student, depending upon the specific expertise or knowledge required to help further the understanding of each individual. In this dynamic arrangement, restructuring of existing conceptual frameworks occurs when individuals experience conflict or disequilibration and are alternately guided by the "expert of the moment". Lumpe and Staver (1995) suggest that the effectiveness of peer work may be explained from this point of view.

> Researchers suggest that both Piaget's and Vygotsky's theories may be used to explain the effectiveness of peer work. Conflict serves as a cognitive tool inducing disequilibration while relative differences between peer group member's knowledge base can allow groups to operate within a bi-directional zone of proximal development. Cognitive conflict may be fostered through peer collaboration by engaging students in rich discussions. A bi-directional zone of proximal development may be fostered by having peers assist one another while solving problems and by creating situations in groups where each student must present and attempt to defend their views in an atmosphere of congeniality (p.307).

Once again, the perspective is dependent upon whether the researcher places priority on the individual mind or the social interactions of the individual peers. From my own point of view, it seems only too obvious that priority should first be placed on the social interactions and language of the group, since that is the unit that often initiates the process and can also be most directly studied.

Towards a Model for Learning

A model of learning can be synthesized that meshes nicely with the approach to instruction found in the honors biology lab described in the following chapter. By wedding Rogoff's (1986) framework for guided participation to the views of Damon and Phelps (1989) on peer interactions and those of Strike and Posner (1985) on conceptual change epistemology, a model for conceptual change and learning can be formulated.

In line with a socio-cultural, constructivist perspective, Rogoff (1986), in her research with young children, was able to delineate guided participation with respect to five major criteria:

> 1. A bridge is provided between knowledge familiar to the learner and the knowledge needed to solve a new problem
>
> 2. A structure for problem solving is provided for the learner.
>
> 3. Over time, the responsibility for managing the task is transferred from teacher to learner.
>
> 4. The learner as well as the teacher participates actively in solving the problem.
>
> 5. The instructional interactions may be tacit as well as explicit (p.32).

While the criteria listed above were formulated as interactions between the guide and a student, they also apply to interactions between a guide and small groups of students. Importantly, responsibility in step three above is more easily relinquished by the guide to small groups of students acting as peers who can share that responsibility. With peer collaboration, the teacher takes on the role of a knowledge authority, which may also guide, however, the majority of the teaching and learning happens through interactions with peers. By assuming their own responsibility for learning, the students are also able to assert their own independence as thinkers and learners. This is particularly an important and necessary step for college students.

The following model for learning (Figure 2) represents a synthesis of Rogoff's (1986, 1990) ideas about guided participation, Damon and Phelps' (1989) description of peer interactions, and Strike and Posner's (1989) conceptual change theory. This model is based on the tenets of a socio-cultural approach to learning (O'Loughlin,1992) which takes into account social interactions from a constructivist viewpoint (Vygotsky,1978). The synthesis posed is a model for learning based on the socio-cultural approach to learning that has been expounded upon in the discussion so far. It demonstrates how concept learning can be promoted through a constructivist approach emphasizing peer interactions.

Propositions of the model include the following ideas. The teacher, as a participant guide in learning (Rogoff,1986), situates students to the culture of the classroom and the problem(s) to be solved (Brown et al., 1989). As students become engaged in problem solving, they eventually assume responsibility for learning. During peer collaboration, problems are solved and concepts are learned that would have been unattainable through individual investigation (Damon & Phelps, 1989). During these dynamic interactions, students alternately teach/guide each other, challenging and extending their potentials (bidirectional zones of proximal development) (Forman, 1988; Lumpe, 1995). Conceptual change takes place as existing concepts are restructured to accommodate newly gained knowledge (Strike & Posner,1989).

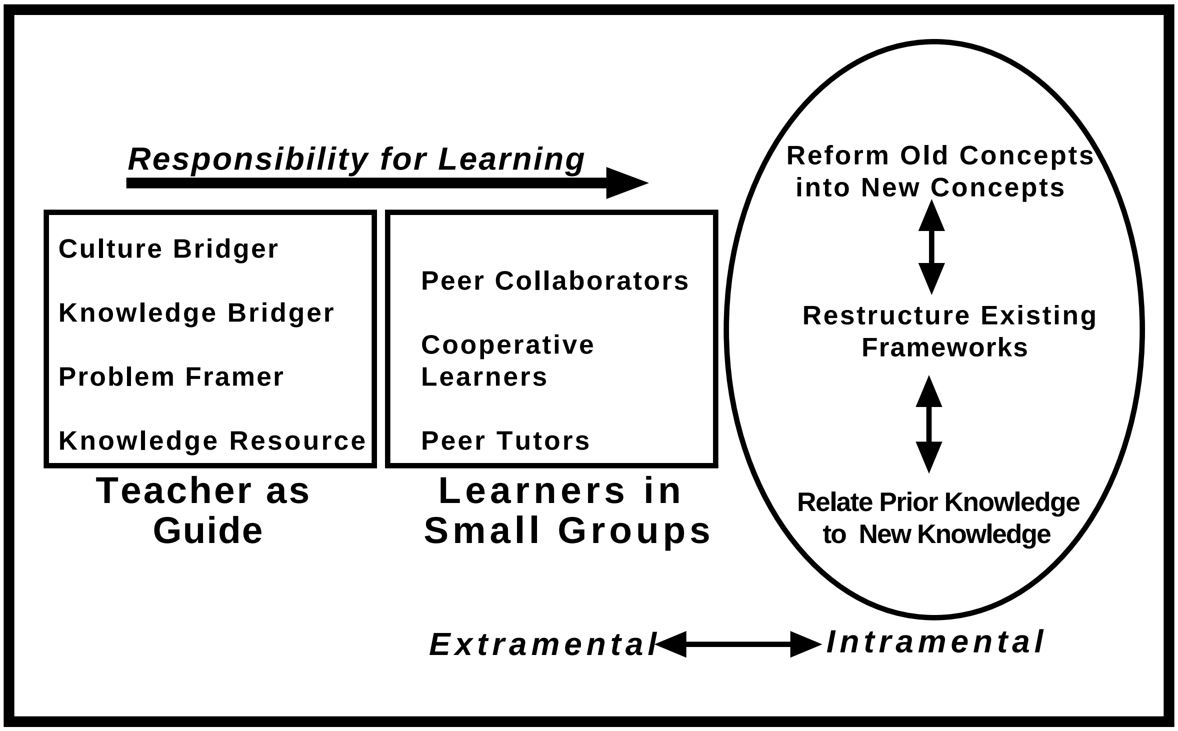

Figure 1
A model for concept learning through peer interactions.

This model has extremely important implications for project-based curricula in undergraduate science education. Implementation of project-based curricula in undergraduate science laboratories has been limited (Leonard, 1989; Seago, 1992; Stukus & Lennox, 1995). Long-term, larger projects that require multidisciplinary approaches more closely resemble the practices of real scientists, however. Complex problems posed offer rich opportunities for peer interactions. It is for this reason that the honors biology lab project was chosen. It offered an excellent opportunity to examine concept learning from the theoretical perspective portrayed in this model for learning.

The next chapter situates the reader by describing methodology and offering descriptions of the course and the laboratory. This is necessary to help in understanding how this learning environment models authentic practice in research. These descriptions are also helpful in understanding how the following three chapters of findings relate to overall efforts at reform in addition to addressing the research questions. From the researcher's point of view, these three separate sets of findings may be considered different windows or lenses through which results are obtained. Taken together, a larger picture can be attained by connecting the findings from this "research portfolio".

Chapter 2

Methodology and Situational Descriptions:
Students, Course, and Laboratory

Data Collection and Methodology

This research has theoretical underpinnings in a socio-cultural approach to teaching and learning (O'Loughlin, 1992). An emphasis is placed on classroom culture that considers the specific context of the learning atmosphere (Brown, et al., 1989). Based on this approach to learning, authentic forms of assessment are used (Champagne & Newell, 1992; Collins, 1991; Jorgensen, 1994; Wiggins, 1993). Authentic assessment involves collecting as evidence direct examples of the students activities as they engage in learning. Authentic learning in science occurs when students employ the real world practices of scientists to discover knowledge. Assessment should be authentic for a socio-cultural approach to learning. This is because the complexities of the learning environment defy reduction to more objective assessment methods.

Just as assessment methods should be authentic, so too should be the collection of research data. A variety of qualitative methods of data collection were employed in an attempt to explore learning in this unique environment. Data were collected in the form of videotaped interviews and laboratory activities, examples of student work, researcher notes, e-mail interviews, and electronic discussions from students. This evidence was examined systematically to determine which aspects were relevant to the focus of this study (development of the species concept) and then assorted to allow review and analysis (Ely, Anzul, Friedman, & Garner, 1991; Erickson, 1986).

Findings are reported both as descriptive, quantitative analyses and as narratives which use the initial analyses as substantiation.

This study is essentially an extension and refinement of experiences and research methods developed from the past year's research on science assessment of the V-QUEST project (Glasson & McKenzie, 1995b). Development of the research protocol and subsequent writing experiences to document learning have served to enrich the researcher's perspective on the reform movement in science education. Further, because the professor being studied, Dr. Art Buikema, continues to be an active participant in the V-QUEST initiative, this research essentially becomes a worthwhile extension of this reform process. This research is needed for a better understanding of learning where reform in higher education is taking place. It is also needed as a more rigorous validation for alternative assessment practices.

Five sources of data were utilized to accumulate evidence: examples of student writing, interview data, videotape records of labs, electronic discussions via Webchat, and researcher notes.

1. Examples of Student Writing

As part of their initial library research assignment, students were required to compose a definition of species. These were short introductory papers, averaging two or three pages each. After their experience in the project-based laboratory, students were again required to compose a paper of their own definition of what a species is. Differences between these two papers were systematically analyzed in an attempt to reflect whether a more sophisticated definition had been developed and whether the lab project had played a part in that definition.

2.) Interview Data

Interview data for this select group of individuals offered rich possibilities for uncovering evidence of learning. Some informal, on-the-spot interviews were conducted during the lab period itself when students had a moment free, for example, while waiting for a particular procedure to finish. These were recorded using video format. Video interviews of some of the student lab groups were conducted at the end of the term during scheduled lab time. These occurred when the project had been completed and extra time remained. These interviews were totally voluntary. During these interviews, students were encouraged to engage with each other in dialogue relating to issues which the interviewer suggested and others that they initiated. Conducted in a very informal manner, open dialogue was encouraged, allowing issues to surface which may have otherwise been overlooked.

3.) Videotape Records and Notes of Labs

Each lab was videotaped. In a few instances, the researcher conducted very short discussions on the progress of the electronic Webchat dialogues, and in this respect played the role of participant observer (Spradley, 1980). This occurred when students had questions about the monitoring and the administration of the electronic dialogues. Students were aware that the researcher was collecting these dialogues as data. Fieldnotes were taken during and after each lab. The Hi-8 videotape record was copied to VHS format with timecode addition. During this process the videotape was viewed for the first time. More notes were taken during this viewing which were correlated to the timecode. This process provided the researcher with a valuable “memory prompt” and was also an important step in the analysis and review of data.

4.) Electronic Discussions Via Webchat

Superficially, the electronic discussions via Webchat software may be likened to other computer-mediated communications (e.g. *Daedalus*). Much research has been done in this environment (*Daedalus* Group Home Page- http://daedalus.com/). Eight weekly discussions for five groups of four students each were possible. The discussion topics were framed as questions which were most often directly related to the lab project and composed collaboratively by the GTA and the researcher. Captured on the professor's Web server, these dialogues were first examined as to their usefulness as a learning forum, then surveyed for instances relating to the development of the species concept. Because the method of data analysis for the Webchat discussions was specific to this type of data, it is included in Chapter 4, prior to the findings from these data.

5.) Student Papers

Student papers defining their concept of species were required early in the term and after the laboratory project. These were collected and copied. Examining these for differences in understanding and relating their ideas to the lab project required a method of analysis specific to these particular papers. This method is presented in Chapter 5, prior to the actual findings.

Researcher notes were taken on-going throughout the study. Researcher notes are stock in trade for the qualitative researcher. Thematic analysis (Ely, et al., 1991) requires compilation, assortment and distillation of notes and data into frameworks which help to reveal pertinent issues, which are then carefully reviewed and analyzed (Erickson, 1986). This analysis can reveal unexpected findings and be cause for reexamination from new perspectives. In this way, new insights are gained.

The Sample Population

Honors students in the study group were all participants in the University Honors Program and were nearly all freshmen, though several were classified as sophomores due to previous college credit earned from their high schools. To qualify for the Honors Program, students must have SAT scores of at least 1300 and be in the top 10% of their graduating classes. Highly motivated students who meet only one of these criteria may also apply for this program. This program has requirements that stipulate the student must maintain a 3.4 QCA, take a given number of Honors courses, and participate in some Honors activities, such as public service, tutoring and study groups. Eventually, Honors students engage in undergraduate research and produce a thesis or enroll in graduate level courses and publicly present research findings. Benefits of participating in this program are many and include priority registration, library privileges accorded to graduate students, assistance in applying for grants and scholarships, and the right to enroll in Honors courses. Diplomas are granted with "Commonwealth Scholar" or "in Honors" for completion of the program. Having greater access to professors in smaller Honors level courses is an important factor for many students desiring this program, according to personnel in the Honors Program office. An amount of faculty interaction normally obtained only by upperclass students can be had by an incoming freshman in the Honors program. Approximately 1000 students are enrolled in the Honors program at VA Tech. This select group comprises approximately 5 per cent of the total student population.

The study group included one laboratory section of Honors Biology (H2984) students. Twenty students (nineteen first year and one second year student) were enrolled in this section and comprised approximately one-half the total enrollment for the lecture section. (Students in the other lab section did not participate in the electronic discussion groups.) Under the auspices of the V-QUEST project, all the students in the study group signed consent forms (Appendix A).

Description of the Course

The Honors Biology course is a demanding course that challenges students to think using an inquiry approach. Enrollment is limited to one lecture section and two lab sections totaling less than fifty students. This gives the professor a chance to have plenty of one-on-one interactions with students. This increased contact time with the professor is a common reason that students cite for taking honors courses, as stated by personnel in the Honors Program.

The requirements listed in the syllabus for the Honors Biology course are a good indication of the emphasis of the course on computer technology (Appendix B). Books and materials required for the course include a standard text (Campbell, 1993a) and writing guide for biology (Pechenik, 1993), an active PID (student internet address), and a copy of the software application Adobe Acrobat. The software allows documents to be transferred and read via PDF (Portable Document Format). This allowed students to perform peer review on written work via computer. All course documents were placed on electronic reserve in PDF format, so students could access them any time, and download them using Adobe Acrobat Reader, a freeware application. The following table lists the documents posted. (Documents pertinent to this study appear in Appendix B and C).

Table 1
Materials on Electronic Reserve

Class contract by Buikema
Peer Review by Buikema
Intro Letter by Buikema
Position Paper by Buikema
Syllabus by Buikema
Discussion Questions by Buikema
Speaker Schedule by Buikema
Revised Lab Syllabus by Slater
Lab: Fish Behavior by Slater
Lab: Report Guidelines by Slater
Lab: Taxonomy by Slater
Speakers by Buikema
Energetics: Anaerobic Metabolism by Buikema
DNA Extract by Slater
GUIDELINES by Slater
Amphipod Lab by Slater

Each document and form offers specific guidelines which are related directly to grades. By signing the class contract the student agrees to adhere to the expectations of the course. This means that, for example, ten per cent of the grade depends upon adequate peer review of other students' written work. It also means that grades received are dependent upon attendance, active participation, and written performance on tests as well as position papers and reactions to speakers (see Appendix B). This explicit delegation of grades to specific performances is especially necessary for the kinds of students who enroll in honors classes. Figure 2 gives a perspective on the organization of the course with respect to structured activities (in class and lab) versus unstructured activities required as integral components of the course. The percentages given refer to the proportion of the final course grade that a particular activity contributes and were taken from the course syllabus (see Appendix B).

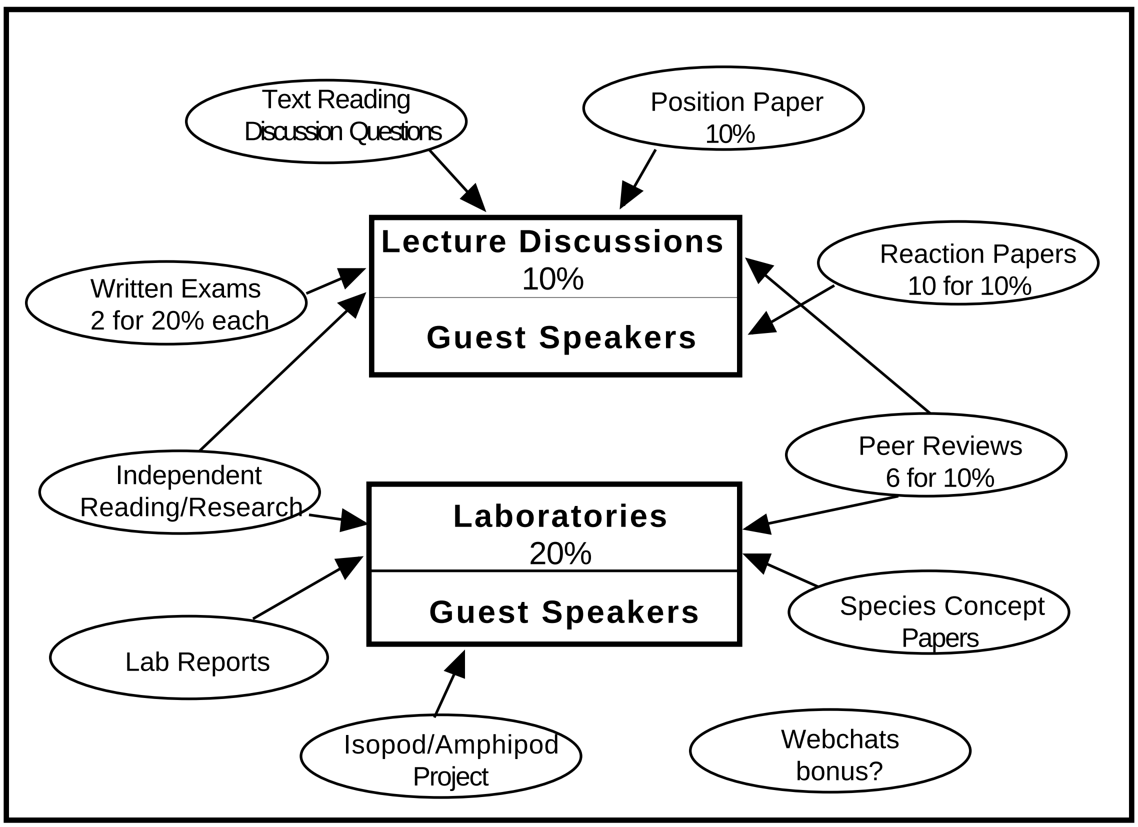

Figure 2
Overall Course Organization
Peripheral unstructured activities account for 70% of final grade.

The lecture portion of the course was based on content reading from the text and amounted to more than 500 pages from the beginning of the book on.

However, the lecture format departed significantly from the typical didactic approach. As part of the course requirements, students posed questions for discussion on a weekly basis from the assigned readings. Then, acting as a moderator/facilitator, the professor either chose questions to engage the class with or students asked their own questions. An open atmosphere resulted that encouraged students to actively think out loud and explore interesting tangents with the professor, as a scientist, openly modeling exploration in thought.

Sample Class Meeting

One meeting of the class was observed to get a feel for how such a class might progress. The topic for the day included photosynthesis, and the first discussion question was "Why is it energetically efficient for a hot climate plant to use 30 molecules of ATP to make one molecule of glucose (compared to 18 for other plants)?". Initially, one student asked a clarification question about the distinction between two distinct biochemical pathways for carbon dioxide uptake (C3 & C4, with C4 plants exhibiting a more efficient uptake pathway in conditions when water must be conserved). Dr. Buikema invited explanations from other students, then extended the discussion into some hypothesizing which was far beyond the realm of applied science. He asked them to consider how they might transform an important agricultural plant (soybean) exhibiting the C3 pathway into a C4 plant that would produce a greater yield. After some open discussion on how this might be attempted or whether it would even be possible, he posed another question: assuming that this transformation could take place, how would the increase in yield be verified? He directed students to work in small groups to design an experiment to measure plant production. During this time, he roamed about the room working with individual groups. Finally, an individual from one of the groups used the blackboard to explain their experimental design. At this point, time ran out. Even from an outsider's vantage point, it was easy to see that this class was spontaneous, unrehearsed and very rich in active thinking.

Description of the Laboratory

The laboratory met for one three hour session weekly. After being given a schedule of lab activities, the graduate teaching assistant was given complete autonomy in organizing and conducting the lab. In addition to Biology (Campbell, 1993a), the course text used as reference, A Short Guide to Writing About Biology (Pechenik, 1993) was also required. Weekly handouts were written by the Alicia Slater, the GTA. The following schedule of labs taken from the lab syllabus was also constructed by Alicia Slater (see Appendix C).

Table 2
Schedule of Labs

1) Aug. 24	The VT Library-- How to find what you're looking for...
2) Aug. 31	What is the mean height of the students in your Honors Biology Lab? Library Paper Due
3) Sept. 7	Aggressive Displays in Siamese Fighting Fish **Do not wear bright colors to lab**
4) Sept. 14	Yuk! What kind of bug is that?
5) Sept. 21	How to tell a Bradford Pear Tree from a Maple Tree... **no formal lab Meeting** Fish Lab Write-up Due
6) Sept. 28	Why do naturally aged wines have only 12 - 14% alcohol even though there may be sugar remaining? (aka Fermentation Lab)
7) Oct. 5	Isopod/Amphipod ecology, molecular biology and geographic barriers to gene flow. Fermentation Lab Write-up Due
8) Oct. 12	Isopod/Amphipod Ecology Isopod/Amphipod Intro. and Methods Due
9) Oct. 19	Isopod/Amphipod Ecology
10) Oct. 26	Isopod/Amphipod Ecology
11) Nov. 2	Isopod/Amphipod Ecology
12) Nov. 9	TBA Full report Due
13) Nov.16	TBA Isopod/Amphipod Peer Review Due
14) Nov.23	**Thanksgiving Holiday**
15) Nov.30	Final lab meeting Wrap-up: student evaluations and comments

The first six labs essentially prepared the students for tackling the Amphipod/Isopod project, which comprised the last seven laboratories. A library experience introduced the students to literature research, and then a lab involving statistical analyses followed. Next, a lab based on observing and recording gave the students an experience in sharing interpretations of complex behavior that was seemingly simple. Two investigations in taxonomy also honed observational skills as well as challenged students to construct their own dichotomous keys. Both these activities helped with the larger project later when students had to identify similar species of arthropods and construct cladograms, which are akin to dichotomous keys. Finally, before the project started, a lab requiring students to design experiments was included. This gave the students the chance to hypothesize and carry out an experiment they designed on their own.

All of the labs listed above fit nicely with the general objectives listed for the lab, which are included in the lab syllabus (see Appendix C):

1) be adept at writing in a concise, scientific manner (this includes familiarity with library resources, proper format and tone for scientific journals)

2) be able to collect, record, analyze and successfully communicate results and conclusions of field, laboratory, and observational data

3) be able to use and construct dichotomous keys for the purpose of taxonomic identification

4) be able to distinguish discrete populations of animals on the basis of morphological data, geographic barriers and molecular data

5) know how to critically review the work of their peers **as well as** offer constructive criticism

While these goals apply to the entire semester, they all impinged upon the project specified in the last seven weeks of the semester, the "Isopod/Amphipod Investigation". From the researcher's point of view, these goals reflect the GTA's interest in emphasizing the practices of scientists.

Writing (goal 1) was stressed throughout the semester and culminated in the more comprehensive report required after the project. Being able to "collect, record, analyze and communicate" data and findings (goal 2) is a necessary set of abilities for scientists in general. Experience in taxonomy from two prior labs (goal 3) was essential for helping identify and study the organisms collected for the project. Goal 4 dealt specifically with the project and points to the need for understanding populations by studying their morphology and biochemistry as they relate to ecology and geographic distributions. Finally, peer review techniques (goal 5) offered the opportunity to learn from one another through constructive criticism. Alicia Slater actively encouraged the students to collaborate as they worked in small groups in the lab. These goals were focused on the discipline enough to encourage content learning, but open-ended enough to allow freedom to pursue individual learning paths.

Description of the Isopod/Amphipod Lab Project

Essentially, the students were given a set of six samples of aquatic arthropods and asked to match each sample to its collection site. To achieve their goal, several different sources of information were required, including:

1.) taxonomy

2.) site descriptions

3.) life history information

4.) geographic distributions (with local geography/topography)

5.) cladistics, and

6.) techniques for comparison of DNA fragments.

Prior labs were helpful in preparing the students for the identification and ecology of the specimens. For constructing cladograms and working with

DNA, guest speakers (graduate students with particular specialties) were brought in. To make the problem more challenging, three of the samples were local populations of the same species (*Gammarus minus*, a small shrimp-like crustacean). Two of these samples came from the same stream while the other sample came from a different watershed With the possibility for a range of genetic variation between samples of the same species, DNA banding patterns using gel electrophoresis became crucial to observing possible differences.

The first labs were involved in identifying the specimens and becoming familiar with collection sites using topographical maps. Information on life history and ecology was researched both in the labs and during time outside the labs. Next, the students were given a session on cladistics both to help them look at the relatedness of the specimens and construct their cladograms, which were required as part of the interpretation of their findings. Finally, techniques for PCR (Polymerase Chain Reaction), RAPD (Random Amplified Polymorphic DNA), and Gel Electrophoresis were introduced in an attempt to isolate, amplify, fragment, and separate segments of DNA for each sample. By comparing the resulting DNA banding patterns, it was hoped that an idea of the relatedness of the samples could be attained.

Such a varied approach to solving a problem gives the students a complex set of data that they must synthesize. They find that scientists use multidisciplinary approaches and that each approach is important for yielding new perspectives for solving the problem. Because the different data may contradict each other, the subjectiveness of science as process becomes apparent. Finally, such a varied approach gives students a chance to be exposed to state of the art techniques few underclassmen get the chance to partake in. The idea that a student can actually isolate and analyze

DNA/molecular data and use it to solve a problem is a powerful experience for that student. The student has become a scientist.

The Course as Whole

The varied activities offered by this course gave students many avenues for learning which encourage collaboration. For example, both laboratory reports and written examinations undergo peer review. It was even suggested that students consult other faculty members when working on their written exams. (This would suggest that exam questions were quite challenging and open-ended, with no absolute answers.) While lab reports were required by each individual, all the labs were undertaken by students in small groups. Further, information was actively shared during Webchat electronic discussions.

Weekly labs lasted three hours, similar in time to three lecture periods each week devoted to discussions and guest speakers. Written lab reports, species concept papers, subsequent peer reviews, and the Isopod/Amphipod project all entailed considerable time in addition to structured lab time. Considering that activities related to the lecture discussions total 80% of the final course grade while only requiring approximately half the total time invested, the amount of time devoted to the labs for only 20% of the final grade was disproportionate. A conclusion that may be reached from this point is that the “doing” of science is indeed a time-consuming affair.

This course is an exciting change from the traditional course format using lecture as a direct transmission of facts and lab as cookbook/confirmatory exercises. With a varied approach emphasizing peer interactions, students become active learners sharing knowledge. By utilizing an open-ended inquiry approach to real problems that scientists encounter, experience was gained modeling the practices of scientists. The opportunity for developing independent thought and research skills necessary to become a scientist was great.

Chapter 3

Findings From the Laboratory Project

Overview

This discussion offers a view of the researcher's perspective into the learning environment of the laboratory during the seven week project investigating aquatic arthropod populations (Isopod/Amphipod Lab). Vignettes were composed from data gathered to represent four of the seven laboratories. After the vignettes are presented, an analysis follows that connects the theoretical perspective outlined in Chapter 1 with activities observed during the lab project. Finally, interview data is used to support the idea that this lab project significantly contributed to learning scientific concepts directly related to understanding the concept of species.

To gain a feel for how the lab was arranged and conducted, the following layout is shown. Each of the five groups of students who worked together is circled, and while they did not always sit at the same location, they did sit at the same area with each other during labs when they needed to be seated. The GTA (Graduate Teaching Assistant) and the two guest speakers occupied the front of the room near the blackboards during presentations. The GTA actively roamed throughout the room during laboratory investigations.

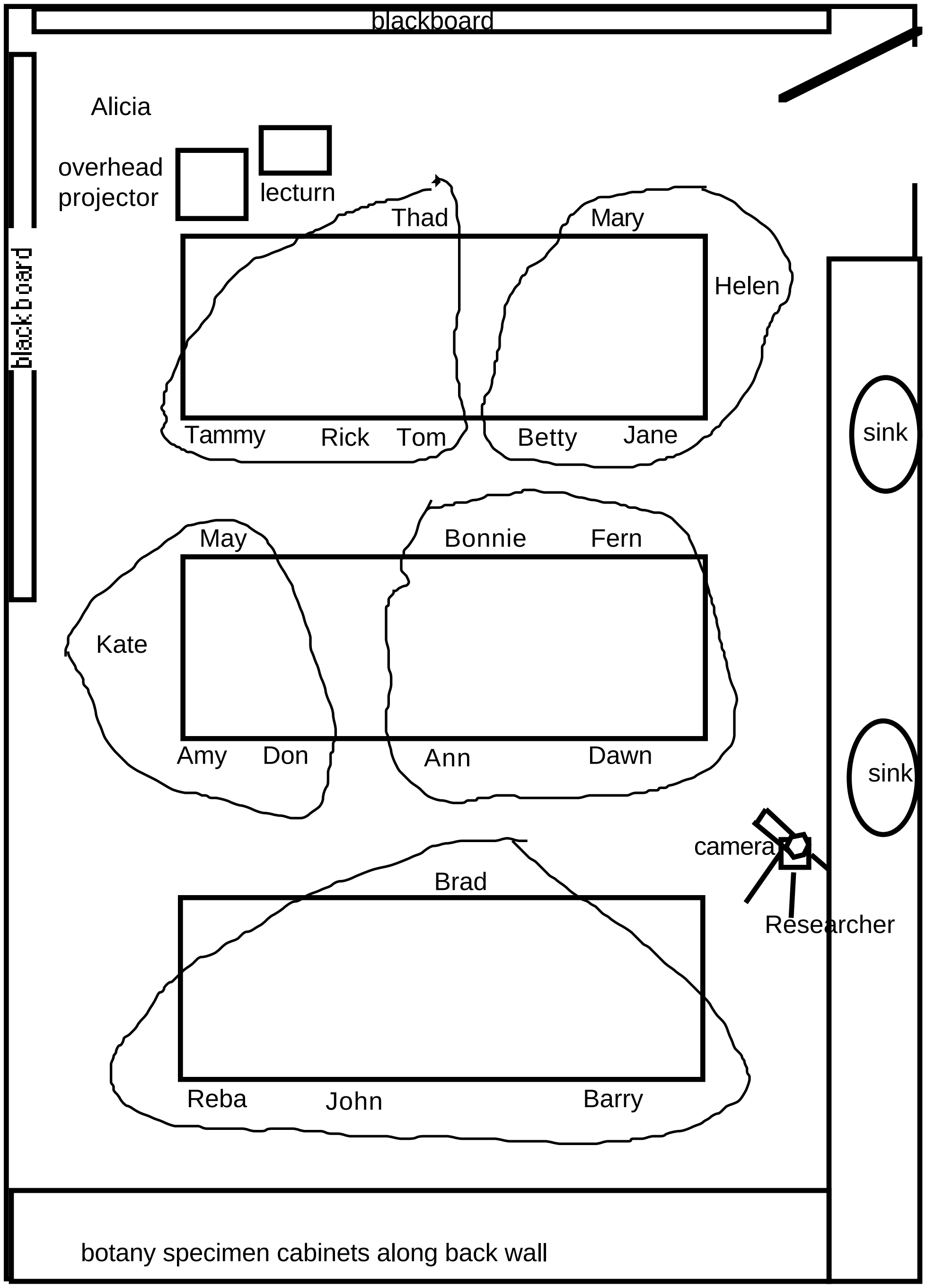

Figure 3
Layout of Laboratory

Vignette No. 1, Oct 5th--Intro to Isopod/Amphipod Lab

The lab began with lots of students shuffling in, a few a bit late. Alicia, the GTA, has handed out papers which they were very interested in looking at, but they did not seem to be anxious to get started. She then introduced me and I talked for about six or seven minutes explaining my role in the project (I had already done this a few weeks prior when I gave them the consent forms) and the Webchat study. I did this by telling them a little more about authentic assessment and the difference between collecting evidence of learning as opposed to assigning grades from objective tests. I emphasized that it was their active participation that we were interested in and that grades would not be part of it. I also read from the handout that Dr. Buikema and I had written explaining Webchat and passed it out.

Alicia then began by explaining the peer review process and making the distinction between how the electronic reserve handouts for the lab are different from the lecture. After this and a few housekeeping chores, she answered a couple of minor questions and began a short discussion on what constitutes a good graph or table. This was accomplished by demonstrating with an overhead a graph that had characteristics she said that communicate the information clearly. These include the use of clearly defined labels and units and an explicit legend. The students are quiet through all of this.

After about fifteen or so minutes into the period, she started introducing the lab project. She mentioned the overall set of activities that they will do over the course of the next several weeks, and said that she hopes to have a guest lecturer next week to explain cladistics, which she is not an expert at. “I just want you to think” she says, and tells them the first step is the lab today on finding out what the organisms are.

To show them where the samples were collected, she sketched site locations on the blackboard and explained each habitat briefly. The importance of life history data was emphasized. As an example, she says that she couldn’t find one of the specimens the first time out but researched its life history and was able to find it on the next try. The organisms she has sampled are amphipods, (*Gammarus minus*) and a mayfly larva (*Isonychia* sp), which are common to local streams. (Amphipods resemble tiny shrimp; mayfly larvae are delicate looking insects with feathery external gills.) Also collected were specimens of aquatic isopods (*Caecidotea*). She suggests library searching and was very honest with them by mentioning her own problems preparing the lab. Also, she reiterated that they must cite at least three literature sources for their first write-up and that they can use one identification guide in the room as one of them. At one point she told them that this is all experimental and they may have unforeseen difficulties. She told them to be patient.

Her directions for starting the lab activity of keying out the specimens and finding the sampling sites on the topo map were very brief. Essentially, she told them to break into five groups of four and be careful handling the specimens since some were in short supply. The three long lab tables in the room were equipped with very nice stereo dissecting microscopes and keys to arthropods. Specimens were on the side table/bench. On the end of the back table were topo maps covering the areas sampled: Blacksburg, Ellet Valley and a site in Russell county where the cave specimen came from.

A group of students clustered around the table covered with topo maps. Rick answered a few questions that I had and I started trying to guide them into a discussion on drainages using the map, because one sample is on the Eastern Continental divide and the others drain into the west, into the New River. I was teaching. It was something that I tend to naturally do. Alicia came by and told me not to give them too many hints and I realized my researcher role again. It was a good thing to happen early on, though I can't help from asking them questions sometimes trying to guide them a bit, or make them think of things they might not otherwise think of.

Though Alicia told them to form groups of five, it did not outwardly appear that this happened. Except for the map area, they almost all worked in pairs at identifying the samples. On the back table, John and Reba worked together, John reading through the key while Reba looked through the scope making the decisions. When the decision became difficult they would both look. John also learned that a fair amount of progress could be made by the process of elimination, looking at the end of the key in places to determine whether or not that path would take them to a species that did not inhabit this region. This strategy of working in pairs, one using the key and the other using the scope was typical for the entire class, with a few cases later on having three students together. Two students on the very back table, Brad and Barry, seemed to peripherally work with the others, but not really do very much work themselves. The other students did not seem to care, being busy with their own work.

Early on, the map area became a social gathering place where about five or six students gathered, tracing over their handouts as they looked over the maps. I interacted with the students around the map table by asking them a few questions about what they were doing and what they were finding out. They were orienting themselves on the map, looking for the sample sites, and tracing along the drainages. Lots of friendly social conversation was also happening. I also found out that two of the students were from New England and their only familiarity with the topography was from tubing on New River.

One couple seemed to be quite meticulous in their efforts at keying out the specimens. Helen was using the key while Mary looked through the scope. They got Alicia to help them at one point because of terminology in the key. Helen seemed a bit frustrated at times and when I asked her if this was pretty easy to do, she says it really is, just detailed. I could not determine what was causing them to be frustrated until finally Alicia came by and informed them that they were keying out different samples of the same species--they hadn't realized that this could be so and weren't believing their findings, even though they were making the appropriate observations and decisions.

Had I not observed in the lab two weeks prior and seen them using the same microscopes and using similar keys to key out aquatic insects, and had I not also known that they had constructed their own dichotomous keys for trees on campus as well, I would have been amazed at the deliberate, concerted effort of these students and their success at identifying the organisms. It turned out that at the end of the period, the different pairs did become groups of four as they got back together to share their findings. Alicia went over the identifications with them on the board to make sure they all were in agreement.

Vignette No. 2, Oct 12th-- Jason Bond on Cladistics

I met with Alicia at her office several minutes before the 2:00 lab and she said we should go meet Jason, a doctoral student in taxonomy, to help allay his reservations about being taped. We went up to his office and I explained to him essentially what it was I was up to and that my presence is really a background kind of thing, over to the side and back of the classroom while filming is going on unobtrusively. Alicia told him that she had been a little nervous at the prospect of being filmed but got over it nearly as soon as she started, because she just focused on her instruction and I was not in the way of her interacting with her students. He agreed but still seemed a bit unsure.

Alicia introduced Jason in a short and fairly formal fashion, giving the impression that he was very much an authority on the subject of cladistics and that this would be an important discussion for them to understand for their project. Jason started by asking the lab a question- “Could someone describe to me the project you’ve been assigned?” Rick explains that their goal was to match the specimens they were studying to the various collection sites by using morphological, life history, and genetic data. Jason- “Why are they having you do this, is there a purpose behind this?” “Why does anybody look at these relationships?” Tom gives an answer by saying that it helps to understand the different environments the organisms inhabit. “What about the base entities?” “Species--Why bother with that?” As Jason goes on, he adds that the concept of what a species is boggles his mind, something that’s been argued over for a very long time. He asks some more questions, getting the students to think about their problem of studying these groups of species. Amy gives an answer: “It tells us a lot of different things--habitat, food, relationships, etc.” Jason says “Lets take a further step back.” Don says it helps to maybe better protect or prevent us from destroying habitats. Jason says “You win half the prize.” “What’s the other half?” John says “It helps us to understand evolution better.”

Jason continues:

We've got to be able to define what a species is. What are we trying to protect, what sorts of habitats are we trying to protect.   Newt Gingrich will get you on that every time, you've got to be able to define what a species is. Why should I bother to save something when I can't really define exactly what it is? What's the other real practical concern? What about malaria?.....so there's that practical/medical point of view. Organisms around us affect us, we need to know what those organisms are. The second is relationships. What we're getting at is phylogenetic systematics. Has anyone heard of this before? Rick mentions the phylogenetic species concept, showing that he's done a good bit of reading during his research for the species concept paper. Jason goes on to explain phylogeny. Two components here--history and classification. "What's a classification?" He goes on to classify humans with the help of the class--they pretty much know this. The final point being that the goal of systematics is to come up with some kind of classification.

Jason now mentions Lamarck. One female knows about acquired characteristics and uses the giraffe as an example. Jason talks about history for a few minutes.   He then goes on to three schools of systematics: classical taxonomy, phenetics, and cladistics. Classical taxonomy is based on similarities between observed characters. Phenetics employs a mathematical measure of overall similarity between organisms. Cladistics arranges organisms into branching diagrams (cladograms) according to shared, derived characters to show relationships.   He explains Ernst Haeckel's Tree of Life, showing an overhead of it. A cladogram of Chordata is drawn on the board. Jason asks for an example of analogous features. Sara mentions sharks & dolphins. Fern offers an answer showing that she is familiar with convergent evolution. Phenetics is downplayed because it would have sharks & dolphins more closely related.   Now, after about twenty-five minutes of introduction, cladistics is presented. He gives the definition on an overhead, which is covered with a piece of paper until he wants to show the information. The students quietly write this down.

Jason uses an example of spider characteristics with a diagrammed set of characters from different imaginary spiders to show them how a cladogram can be constructed, using the rules he has on the overhead. This was passed out to the students so they could work on their own cladogram. After a few minutes, he started getting them to help him construct cladograms on the blackboard. Two alternative cladograms resulted. He then offered for someone to come up and draw a cladogram for another character. Helen volunteered and successfully drew a third cladogram. Jason then combined the different characters into a single cladogram.

Rick asks how do you determine the outgroup and if you change the outgroup will it change the relationships on the tree. Jason responds by saying "That's kind of the million dollar question of systematics. If no one has done it before you have to guess, it's kind of a shot in the dark."

Nearly an hour had passed. Some complicated explanations about how many trees are possible ensue. Jason offered to show them a short slide show of the spiders that he is working on for his dissertation, including cladograms that he has constructed using software programs. After this, he handed the show back over to Alicia, who said that now is the time to direct questions about the project back to Jason

Fern asked whether you should separate the three groups of the same species into separate samples. Alicia said yes, that's a good question.

Mary wanted the cladogram to be explained in words. "What does it mean in words?" Jason diagrammed it as a lineage through time, trying to draw a parallel with a phylogeny. This alternate explanation was helpful, but it still used a diagram instead of just words, which is what Mary wanted. After this explanation, Amy asked, “How do we come up with an outgroup?” which is the question that Alicia had decided on for the Webchat. Alicia offered some suggestions on what kind of information they could find to help them. When Jason found out that the groups they were studying have such diverse and closely related groups, he said that this is getting really complicated. “Impossible questions to answer are kind of fun!”

Jason said you’re going to have to make some kind of educated guess. “What do you think is a related group? I would pick a number of different outgroups.” “Gosh, they’ve got different classes?!” He hypothesized how he would set up a study for different classes of spiders. He then showed how he might look at even larger samples--arthropods, by once again diagramming on the board.

Alicia gave more tips and advice saying that they could actually do a deep and shallow study with the one nested in the other. Jason said that if *Gammarus* is the species, then you can look at one species with multiple populations. Alicia told him “You can stop there”. He has given them a big tip. Jason said “Bye” and received an appreciative applause.

There were now questions about Webchat. They wanted to know if Alicia will be on the Webchat with them, would they be able to be open and/or criticize her. She explained her role by saying that she may be there and she may enter into the discussion with them, but she is open to criticism and she doesn’t really know the answers anyway. She hopes they won’t call her any names and they joke back and forth good naturedly about that. “Can you cut me down?” “Yeah, that’s part of the game!”

The students asked some more questions about Webchat and I talked some to let them know my role while they are on line. They wanted to know if

I'm "lurking" and I said I might be, but I'm more concerned about reading over the dialogues later.

Alicia showed them a paper that she wrote that her advisor had commented all over, as a way of letting them know that this is the way papers are critiqued and they shouldn't feel as if it's a personal attack when she comments on their papers. She told them she will leave it lying around so they can inspect it more closely later. A few more housekeeping kinds of things happen and then she mentioned sterile technique and how important it will be to their study. She then went back to answering more questions about how their papers should look. Many of the students asked questions along these lines. They wanted to know how long to make the introduction, whether to include the site description in the introduction, when things need to be turned in and how detailed to make their first hypotheses.

She introduced the microlitre pipettes to them and a session ensued on learning how to use them and the microcentrifuge, wearing surgical gloves.

Vignette No. 3, Oct 19th-- DNA Extraction

Alicia began this lab by making sure the students knew how much of their projects needed to be turned in the following week (intro and methods section), and then a few questions were asked by the students concerning the papers. For example, Amy asked how to include site descriptions and cite references.

Alicia emphasized the importance of the PCR procedure. (PCR stands for polymerase chain reaction and involves a set of doublings of extracted DNA so large quantities are obtained, large enough to use for analysis.) "PCR is the crucial step in what we do. After the PCR is finished the rest of that stuff is cake." "I won't say what you have is right or wrong." She then showed them a reference book. She also had material from last week, so they could continue their investigation. To efficiently manage the laboratory procedure, she told them that half the group could work on the extraction while the other half could continue the study of heir specimens.

A discussion was initiated to help the entire group share some of their findings. Alicia began this discussion by asking "What did you find out about *Gammarus*?" Troy mentioned habitat information by offering "Limestone and rocky substrates." Then Rick added some information about its habitat: "Oh yeah, it's native to the northeastern United States and its morphology is gonna be different from original populations of *Gammarus minus*." Alicia responded by saying "Okay, so I'll just say morphology variable." Then she asked "What does it eat?" Jane answered "It's is an omnivore and I'm not sure how to say this word." Alicia comes over and pronounces "detritovore" and says "that means it eats dead and decayed organic matter." Alicia then directs the discussion to the mayfly specimen. "What did ya'll find out about *Isonychia*?" Fern answered that it lives in "fast flowing water streams." "What does it eat?" There was a pause and Alicia drew a diagram of its filter feeding structure on the board. "I'm gonna give you a big help on this one. What do you think those big long hairs are for?" Several students correctly answer that they are for filter feeding. She then gives a detailed explanation about how it feeds. "What about *Caecidotea*?" Tom answered that "It lives in marshy, swampy areas, streams." Alicia told them that it used to be called "*Acellus*". This would help them in their literature search. Fern offered more information on where they live.

Now, with an assortment of habitat/life history information listed on the board, Alicia said "Based on what you have already, hypothesize where each specimen came from." Rick proposed a site for *Caecidotea* . Alicia responded "And why do you think that?" Rick said that this hypothesis fit with what Fern had said about preference for disturbed areas. He also placed specimen #6 based on dark areas in the stream under watercress. To encourage them to hypothesize, Alicia said "You guys don't have enough info yet to have a final answer, so don't worry. I'm going to write these up here, these are just different hypotheses." A pause in the discussion caused her to say "Okay let's hear from someone else. You guys talk about this in your groups, Fern, what did you guys come up with, you have an idea? Fern said "yeah" in a drawn out manner that caused sveral chuckles from the other students. Alicia then said "Tell us, come on, it doesn't matter if it's not right." Fern offered that "*Isonychia* would be found in site D (river)." Alicia replied "And what was your reasoning for that?" Fern said that "We thought it might have a current." Alicia said "Now Crab Creek and Stroubles Creek also have current flow through them. I'm not saying that what you have is right or wrong, I just want to make sure you're considering all the possibilities." The discussion continued in this manner with students offering ideas and Alicia adding them to the list on the blackboard. Amy used a quote from a source to guess the mayfly's site: "small river with rocky substrate" for the mayfly. Tom read aloud that *Gammarus minus* is associated with limestone, so it could be the cave species. Jane mentioned something about dead matter being used as food, which would be found in caves, to corroborate Tom. As a hint, Alicia told them to "find out what *Caecidotea* eats." Alicia explained how limestone streams come out of caves. More suggestions about what characteristics a cave dwelling organism might have were suggested by several of the students: heightened or exaggerated smell, touch, or lack of pigments.

Thad and Amy asked about how to put together information into the introduction. More explanations on writing the report followed. Alicia mentioned that the Pennak book (for identification) could be very helpful. She offered to help them gather more references and even do interlibrary loans if they wished.

At this point a description of PCR ensued, with two handout sheets, an overhead and the blackboard. For about ten minutes the explanation was technical and difficult to follow. This would be nearly impossible to follow unless a good understanding of DNA replication is known. Most of the students quietly took notes during this time. Her description started with a little review and then went on to the procedure itself. Amy finally asked "What exactly are these dNTPs doing?" This made it apparent that she had not grasped exactly what is needed for the reaction to occur. Later she finally said "I just don't understand." The amount of new terminology in the description made the description difficult to follow. If others did not fully understand, they did not let Alicia know. The lack of questions and talk, with only quiet note taking seemed uncharacteristic.

Vignette No.4, Nov 2nd-- Gel Day

Alicia began by handing them back the first draft of their introduction and methods sections of their project and started to explain to them how to make them better. She had marked on them but no grades were given at this point and she reminded them so. Better ways were mentioned to present information, especially how to clearly label their cladograms. She also gave them a few more references which she said will be useful. Mentioning the lab today, she said that "I'm going to pool all the data..." to get the best set of results and then let the whole class share that data for their reports. This is because it is unlikely that any particular primer chosen will give results. It is hoped that at least one of the several primers used will give a set of banding patterns that will help them see differences between the samples.

She then showed an example of an abstract which they could use to model after and left it out for them to see later at their convenience. She reminded them that their full report would be due in one week for peer review and that the second species paper would be due the week after Thanksgiving.

A step by step explanation of today's procedure followed as students read along from the handout. She showed them the equipment they would use and how to set up a casting tray and explained the purpose of the tracking dye. Several important tips were mentioned: making sure the tip of the micro pipette is inside the well, making sure the wells are positioned not too close to the end of the tray, and making sure that the electrical connections are not reversed. She also told them that the gels would not finish for a few hours and that she would finish them up later that night by taking photographs of them as they fluoresce in the ethydium bromide solution.

Alicia handed the class over to me for a few minutes to brief them on their Webchat progress. I had passed around the chart of Webchat use showing how many topic-related/Webchat/social entries were logged for each group. I explained to them that is just an initial look at the discussions, and no inferences can be made about the quality of their conversations. They seemed very interested with a bit of concern for comparisons being made between the groups, especially on group two, the one with the large number of social entries. I told them that group two, for example, increased its social entries by staying on line well past the half hour required. I also mentioned that their comments concerning the use of Webchat are taken seriously and that it is likely that this format in the future will be changed to work more efficiently.

At this point the students started with their lab. First, they prepared their gels by heating the solution and pouring into the casting trays and molding the individual wells for each sample. Using surgical gloves, they took their PCR samples from the previous week and pipetted ten micro liter aliquots into three micro liter aliquots of the tracking dye as droplets on parafilm. Next, they placed each sample into its respective well and with the tray filled with buffer, connected the electrical leads to start the electrophoresis. Because, each segment of DNA has a different overall charge, differential migration rates occur causing the segments to separate as they travel across the gel. Under fluorescent light, these segments are revealed as bands which are photographed and photocopied to become data that can be directly compared genetic differences/similarities. They are finished with lab activities for today.

Once all the students had their electrophoresis going, Alicia started a discussion concerning what they have been able to conclude so far. She began by listing the samples and the locations on the board and said “What do you guys think so far?” Based on life history and habitat info, the students conclude that *Isonychia* came from the Roanoke River. Using morphological data, they conclude that sample number six, *Caecidotea sp.* came from the cave. Using habitat and the process of elimination (because two samples came from the same location) they also determine the location of *Caecadotea recurvata*. This leaves them with the three *Gammarus* species. At this point, Alicia sketched the locations of the streams from which the *Gammarus* were taken along with the mountain range separating one of them from the other two. She essentially let them know that if there are differences between the *Gammarus* samples, then two of the samples ought to be more alike and the remaining one should be different. Finally, she diagrammed the gel tracks on the board, showing them that tracks one, three, and five are really the ones they need data from, since these are the ones from that represent *Gammarus*.

For drawing their final cladogram, she also gave them the hint that they need to look in an invertebrate textbook to discover the relationships between insects and crustaceans. This essentially gave them the information they needed to construct the major nodes in their cladogram.

Analysis

This analysis is initially framed around the model for concept learning (Figure 1, Chapter 1, page 23) and focuses first on the roles of the teacher(s) and second on the interactions of the students in both small groups and as a whole class. Instances during interviews that are directly related to the development of the species concept are discussed.

Teacher as Guide

The roles that the teacher may take on are many in a dynamic learning environment such as this one. Both Alicia, the GTA, and Jason, the guest speaker on cladistics, actively served as guides to learning and encouraged the students to assume responsibility for learning on their own.

As a "Problem Framer," Alicia took on the task of managing a longterm project which was complex, requiring several different approaches to looking at the overall problem. This management was tied directly to the roles of "Culture Bridger" and "Knowledge Bridger" because to effectively implement such a project, the students needed preparation. This occurred during previous labs. The students, by employing investigative labs that required them to problem solve and hypothesize as scientists do, were already encultured into the practices of scientists by the time the project began. Further, the particular labs they had already experienced prepared them for the individual labs during the project. Had they not already had experience with taxonomy and keying out aquatic arthropods, the identification of the specimens would have proven quite difficult, if not impossible to do in the time allotted. These previous labs were likewise bridged to prior knowledge, giving the students a chance to apply and extend their thinking skills in the process of active inquiry. This occurred in a context that linked them to later endeavors.

Alicia, the GTA, served as an effective role model during many occasions and this helped to bridge or connect the students' experiences to those of scientists. During the very first lab, for example, she related her experience at not being able to find one of the specimens her first time out and how she solved this by effectively researching life history data. This also fits in with her role as a "Problem Framer" because she introduced this experience with comments about how the students should expect problems during their research. During another time, when some of the students had expressed a concern about the number of "markings" on the papers they have turned in to her, she showed them one of her own papers that had been marked over by her own advisor. By letting them understand that this constructive type of criticism is an important and beneficial practice of scientists, she is revealing yet another part of the culture of scientists that they need to understand.

On another occasion Alicia showed them a graph of some of her own research and how her advisor had made her change it to more effectively convey information. These are indicative of many instances where the practices of scientists are revealed to help the students understand the culture of scientific endeavors. These can all be viewed as ways of bridging or connecting the students to the culture and practices of scientists

As a "Problem Framer", Alicia's task was essentially to get the students to understand that several very different sources of information could be synthesized to help solve the problem. This was initially framed by providing the students with the overview in the electronic reserve (Appendix B). During class discussions, she was careful to remind the students that they should consider all the sources of data in making their conclusions. She also helped them maintain their perspective on the overall project by engaging them in class discussions. These often resulted in sharing of findings on the blackboard as she guided the discussions. This way the students could pool their data and share their ideas. During these times she often gave suggestions and hints and encouraged them to hypothesize on their own. For example, during a discussion during the third lab she tells them "You don't have enough info yet, so don't worry" (about coming up with wrong answers), in the context of encouraging them to think out loud.

Jason, the guest lecturer on cladistics, also served as an effective "Problem Framer" for the relationships part of the project as well as serving as another effective role model. (The other guest lecturer turned out to be primarily a "Knowledge Resource", giving a highly technical lecture, but engaging the students to a minimal degree.) Jason's discussion on cladistics was very interactive and probing. By asking the students what it was they were trying to find out, and letting them understand the two main aspects he studies (species concept and relationships) he was essentially getting the students to frame the problem themselves. During this time he situated the topic with a historical aspect and related it to other schools of thought. By getting them to practice at cladograms with a simple model, he was encouraging them to take part in the practice of being a taxonomist. By showing them how his discussion relates to his own research, he is giving them yet another view on the culture and practices of scientists. During this time he served as a "Culture Bridger" and "Problem Framer", and was also an important "Knowledge Resource", considered by both the GTA and the students to be an authority on this topic.

Because of a high degree of technical knowledge required to carry out most of the lab activities that the project included, Alicia took on the role of

"Knowledge Resource" frequently. This most often occurred when she introduced a new technique or procedure. It is important to note that the amount of time she spent doing this was minimized by the use of handouts and her desire to give the students the time they needed to complete the labs. Typically, a lab might begin with a few "housekeeping" items (reminders about sections of the project that were due, answering questions both about ongoing findings and format of the works due) and then become either a short discussion about progress or become a lecture presentation which passed along facts or procedures necessary to let the students begin the investigations of the day. During their investigations, the students might ask Alicia for help or corroboration on findings. In these instances, her role would change to fit the situation. In all cases, the intention was to give the students enough direction to allow them to take on the responsibility for learning for themselves.

Learners in Small Groups

The learning environment in the lab was very interesting from the viewpoint of the freedom allowed for individuals to work together. Twenty students were originally divided into five groups of four and these groups remained together for the entire term. They were already familiar with each other when the lab project started. They often subdivided their groups and worked in pairs, subdividing the tasks as well. This occurred in the first lab, where two major tasks were required--finding collection sites on the topo maps and identifying the specimens. The task of identifying the specimens was even further subdivided, with one student using the identification key and the other making observations through the dissecting microscope. The individuals working on the topo maps freely interacted with members of other groups, learning features of the map while informally socializing with others.

Later, individuals of each group came together to share findings. This is an example of the students acting as "Cooperative Learners", where tasks are often subdivided for the sake of efficiency.

When problems arose with some of the pairs identifying the specimens which required individuals reasoning out the alternatives to positively identify the specimen, the students interacted as "Peer Collaborators". The greatest opportunity for peer collaboration during this project may well be the interactions of students as they tried to determine the best cladograms for their papers. Some of the questions asked during the whole class discussions hinted that this was perhaps the most challenging aspect of the lab project. These interactions occurred mostly outside the lab.

The greatest potential for "Peer Tutoring" occurred during peer review of student papers. This was an enterprise which the students took seriously and was emphasized on several occasions by the GTA. Peer tutoring also occurred often, whenever a single student offered new information to another. In an extended sense, such information transfers were evoked by the GTA during the many whole class discussions. With the GTA mediating, students offered information they had found during outside research and offered their own ideas and conclusions. This is another prime example of the teacher as guide allowing the students to take on the responsibility for learning.

<u>Relating the Lab Project to Learning About Species:</u>

<u>Student Interviews</u>

The last scheduled time for the lab was originally designated as possible make up time, considering that there may have been a need to repeat some of the procedures. This was not the case, and this time was utilized for administrative matters. Three interviews were also conducted during this extra time, consisting of members of some of the lab groups talking about their experiences during the project. Some of their statements were revealing with respect to their learning of the species concept.

The interviews were conducted in an informal manner, letting the students talk together and compare their experiences. It was interesting to note that all three groups initially compared this lab to their chemistry lab, sharply contrasting its approach and favoring the open endedness of the biology lab. The discussion eventually became directed to more specific aspects of the lab project. During this time, one of the questions that had been posed on the Webchat regarding comparisons of the three *Gammarus* populations was brought up. It concerned differences observed from the gel electrophoresis and led on to the question of whether or not gene flow occurred between all three populations. From this question, I directed them to the notion of whether a separate species exists if no gene flow occurs. This was an attempt to get them to talk about their definition of species.

> Interviewer: If there is no gene flow, are they separate species? When do you say one is a separate species?
>
> Helen: Like maybe you could do it, uh, not mathematically, but some kind of difference in their DNA, if you could like scan all three of them and some percentage of difference between them and they would be separate species.
>
> Interviewer: So there would be some cutoff point where there would be-
>
> Helen: Yeah, but that's arbitrary too, so I think the whole species thing is sort of arbitrary.

The idea of interbreeding was suggested by Helen and this helped her explain how she might differentiate species.

> Helen: But as soon as they reach the point that they can't do that (interbreed and produce fertile offspring), that they can no longer do that, then I would say that they are different species.

Helen's reference to comparing the DNA of the organisms to gain an idea of their relatedness most likely comes as a direct result of her experience with the lab project. It is also likely that the opportunity to observe the small genetic differences between the *Gammarus* populations helped her to understand that the "whole species thing is sort of arbitrary."

In another interview, when the discussion led up to the question of "What is your definition of a species?", Amy laughed and told me that I would have to wait and read her species paper. She did talk about hybrids and gene flow relating to the species concept:

> I don't think genes are necessarily a deciding factor when you're talking about species. That even you might have gene flow that doesn't mean that...they are the same species. I think that's something you can look at, but I don't think that just because there is a flow of genes there that means... there's hybrids all over the place but you still wouldn't call them the same species.

Amy goes on to say that just because dogs and wolves can mate, it does not mean they are the same species. She finally concludes that "So when you look at gene flow between *Gammarus minus*, it's just something you can look at." Amy's judgment has been tempered by understanding that determining species and the relatedness of populations requires a whole set of criteria. This is exactly what the lab project experience has shown her.

In a third interview, Rick is most willing to give his approach to deciding relatedness of populations and what might determine whether separate species exist.

> Well I would say, and this gets back to our own definition of a species, if we look at the three populations of *Gammarus* that we have, okay, their physical differences weren't that great, so you'd say 'No, those probably aren't different species.' But, if you had a *Gammarus* that developed a different sort of structure, like say its pereopod structure in general- changed. Okay, so its got, oh eight to ten pereopods. If they changed in structure, like instead of going from three segment structures, they all went to two segment structures, all of them, well you might say 'Hey, this is a completely different species.'

Rick's ideas here hinge around morphological characteristics. During the project, Rick spent lots of time studying the morphology of the organisms. At one point, he spent extra time in addition to the regular lab time observing them with the hope of finding distinct differences in the populations. These experiences helped shape his own definition of species.

In all the cases above the conversations center around concepts that were revealed during the lab project such as gene flow, morphology, and genetic/molecular data. The project situates the students with real organisms to study from a variety of ways. It is likely than none of the students were familiar with *Gammarus* before the study. Now they are able to articulate their ideas and restructure them into new conceptual frameworks after working together and sharing their ideas in a collaborative environment that challenged them (see Figure 1, Chapter 1, page 23). Their understandings of the nature of scientific knowledge are implicit in their statements. Science has become a complex reasoning and decision-making process which involves subjective interpretation.

Chapter 4

Computer Mediated Communication:

Webchat Discussions

This analysis focuses on the electronic discussion data gathered during the Isopod/Amphipod laboratory project. Implementation was unique from two different perspectives. First, the participation by the students was voluntary. Second, the Webchat software used (Leahy, 1993) shares characteristics of both synchronous and asynchronous systems of computer mediated communication (CMC), but is also uniquely different from those typically used.

The main purpose for implementing the Webchat was to pilot electronic discussions during the project to determine the usefulness of this form of communication. The professor was curious as to whether such discussions could substitute for one of the three hours of lecture required by the course. For this to happen, substantive dialogues would have to occur. By posing discussion questions for the dialogues based on the lab project, another "window" into students' thinking during the lab project was opened. Because these electronic discussions were implemented in addition to the regular course requirements, it was decided by the professor that they should be strictly voluntary. As encouragement for participating, the students were offered the possibility of up to three percentage points added to their course average for what might be deemed earnest effort. Additionally, the professor up front stated his purpose for this trial, letting the students know that one of the scheduled class meetings for the coming semester's course might be replaced by a weekly Webchat discussion. Knowing this, the students could possibly influence the structure of their course during the spring semester by actively participating in the pilot study now.

There were two important reasons for the professor to choose the Webchat software over other more common vehicles. First, because it works via World Wide Web browsers, access is not limited to a Local Area Network such as required by most CMC systems (i.e., Daedalus). Second, because the World Wide Web is not platform specific, students could access from PC-based or Macintosh-based computers. (Students were required to have PIDs as part of the course requirements and most of them had computers in their dorm rooms.)

Computer Mediated Communication

Computer mediated communication (CMC) shows great promise as an alternate means of communication, when face to face communication is not practical. Ruberg (1994) states:

> Student interactions in the computer-based interactive writing environment can lead to increased student participation, active learning during the class periods, and variable pacing. The interactive writing environment offers an alternative social environment for the class which is much more active and can be less inhibiting for students, which results in increased participation as well as an increased tendency for students to share their ideas (p.86).

Romiszowski (1989) views such conferencing systems as having potential as a "supplementary medium" for conventional courses (Romiszowski & de Haas, 1989, p. 12). It is in this context that the usefulness of Webchat is regarded.

Compared to other conferencing systems, Webchat displays some unique characteristics.

Typically, CMC can be categorized as being either synchronous or asynchronous with respect to timing of input. In e-mail conferencing systems, for example, input is asynchronous, allowing participants to reflect on each others' inputs before responding, or even allowing time for research of other information sources before responses are composed (Harasim, Hiltz, Teles, & Turoff, 1995). Synchronous systems occur when participants are simultaneously online. They are considered to be an extension of face-to-face communication and may lend themselves to forms of interactions not common in face-to-face classrooms (Ruberg, 1994, p.86). Examples of synchronous systems include the Daedalus interface used in writing courses and Internet Relay Chats used informally on the Internet. Both of these examples may represent "interactive written discourse" (Ferrara, Brunner, & Whittemore, 1991) which occurs more slowly than spoken discourse, but also much more in the present than e-mail discussions.

Webchat discussions are unique in that they can be posted as asynchronous or "nearly" synchronous. This is due to the nature of the interface. Because the interface is a homepage on the World Wide Web, each entry by a participant can only be seen by others if their page is updated or "reloaded". Entries become permanent additions to the page, complete with the initials or name of the poster along with the time/date of posting. This need for reloading the page to view subsequent responses can take anywhere from a few seconds to even minutes, depending on a variety of factors: modem speed, length of homepage (as the dialogue grows), and server use by others across the system all contribute to slowing down the rate at which the page is reloaded. Because these records are kept, they become valuable data. A sample Webchat homepage is shown as Figure 4.

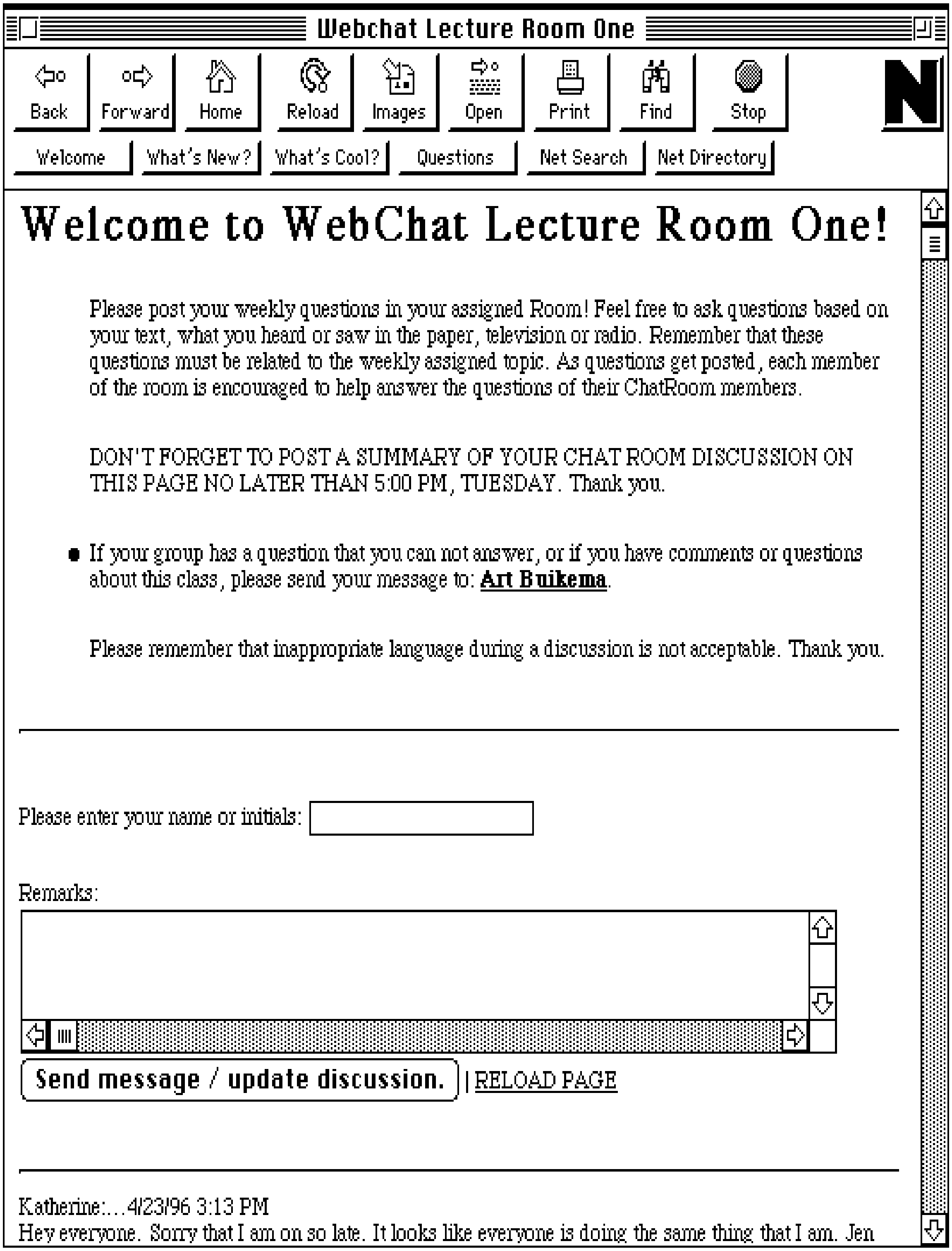

Figure 4
Sample Webchat Homepage

Method of Analysis for Electronic Discussions

The lab section being studied was composed of twenty individuals who were randomly assigned to five different discussion groups of four each and given a Webchat "room" and a password to access the room. Instructions for using the room were included on the professor's homepage. Students were told to arrange discussion times at their own convenience and that each discussion should last a minimum of one half hour. As topics for discussion, questions would be provided them either during their lab, posted as e-mail, or be posted directly on the Webchat homepage. Questions were formulated by the GTA and the researcher and were directly related to the on-going lab project. Students were also told to advise the professor and/or GTA of their scheduled times for being online. Discussion questions were posted for eight consecutive weeks, resulting in the possibility for up to eight discussions. Once the discussions had occurred, they were copied into text documents and stored for analysis.

Table 3
Webchat Discussion Questions

Week #1 1.) What would be a good outgroup(s) for the organisms you are using? 2.) How and/or when might molecular data be useful?
Week #2 1.) How (why) do you think the PCR procedure won the Nobel Prize? (Give examples of the impact of PCR on molecular biology.) 2.) For which organisms in lab is gene flow important?
Week #3 1.) In cladistics, shared derived characters are used to define relationships between taxa. Characters found in the outgroup are said to be ancestral. Knowing this, do you think *Isonychia* is a good outgroup for the organisms you are using in lab? 2.) Now that you understand the RAPD technique, give at least two reasons as to why some scientists do not regard it as a useful technique.
Week #4 1.) Why are ethidium bromide and ultraviolet light used to visualize bands on a gel? 2.) Assume data are reliable. Suppose data showed that the three samples of *Gammarus minus* Say were identical. What can be concluded? Give explanations.
Week #5 1.)What is ethidium bromide? Why is it used with UV light in gel electrophoresis, and what is the biochemical process involved?
Week #6 1.)What do the nodes on a cladogram represent? 2.) Many of you did not think the insect was a good outgroup because it was too advanced (it had wings). Could an insect with pleisiomorphic characteristics be found to use as an outgroup?
Week#7 1.) Recently, an isolated population of horses was discovered in western China. These horses closely resemble the prehistoric paintings found in caves. Could this be a different species of horse? 2.) Do you think a new species of *Gammarus* could arise from isolated populations even if the environments were identical?
Week #8 1.) Do you think a Great Dane could be considered a different species from a Pekinese? Explain. 2.) A navel orange has no seed. From your definition of a species, can a navel orange even be considered a species?

Data Analysis

Two separate approaches to examining the dialogues were taken to help determine whether this format could suffice as an alternative to lecture and to examine whether concept learning related to a definition of species was occurring. First, an attempt was made to characterize the dialogues by grouping inputs into separate categories. These included social responses, Webchat mechanics responses, and course-related responses. This was done by first arranging the dialogues into a hypermedia database allowing the researcher to access any dialogue quickly with a text field for tallying inputs and adding notes. This characterization was helpful in determining how the forum was being used and in comparing different groups. Once this was done, course-related responses were further divided to identify inputs that offered information and inputs that were engaging or thought-provoking. This characterization helped to identify discussions that were rich in thought. Length of each dialogue was also recorded.

Second, two discussions representative of those that were identified as rich in thought were analyzed for message type and flow. From this analysis, it was then possible to compare the discussions directly. Finally, the content of these discussions pertinent to learning about species was examined for evidence of concept learning.

It is possible to characterize each student input as to type of social interaction. (Bales, 1950/1976) devised a scale describing twelve separate types of interaction. For the purposes of this study, a similar but simpler approach was taken. As a pilot, the dialogues needed to be analyzed according to how much time was spent related to the topic of the discussion. Also, some feel for the interactive nature of the discussions was needed to help understand their effectiveness. While reading through the dialogues to classify the inputs, an idea of the individual group dynamics was developed. Each group displayed different personalities and dynamics, which became apparent from this characterization of inputs.

<u>Characterizing the Dialogues</u>

Each input was placed into one of three categories: Webchat mechanics, social, and course-related. Further, course-related inputs were additionally logged if they provided useful information or if they were deemed engaging. Duration for each chat was recorded so response per time could also be found.

Even with this simple classification system, there is room for lots of overlap. For example, a initial response of “Hi, is anybody out there?” would be judged as Webchat mechanics, because it is an attempt to log on and find out if anyone else has logged on, but it could also be considered a social response as well. An example of a typical social response might range from courteous and encouraging responses not related specifically to the course, to questions like “Are you going to the Marriott afterwards?”. Course-related responses fall into three categories: those dealing with course logistics (i.e., When is that paper due?), those offering information (i.e., *Gammarus* is in the class Crustacea.), and engaging or thought-provoking responses (i.e., Just because all three populations have the same DNA banding pattern doesn’t mean they are identical. After all, they live in different habitats, don’t they?). Once again, there is room for overlap. The last example offers information but also encourages others to think. Finally, some responses are really multiple responses, containing a sentence that is purely social added on to a question that is informative and engaging. Such responses are recorded as more than one response.

Dialogue Characterization Results

The following list of figures represents raw totals of Webchat responses according to the three main categories previously defined: Webchat mechanics, social responses, and course related responses. Each figure charts the number of responses each group had for the discussions they participated in. The amount and kind of participation each group exhibited is thus displayed. (For tables including data from which the charts were constructed, see Appendix D.) Following each chart is a description of the group that includes some of its personality and idiosyncrasies.

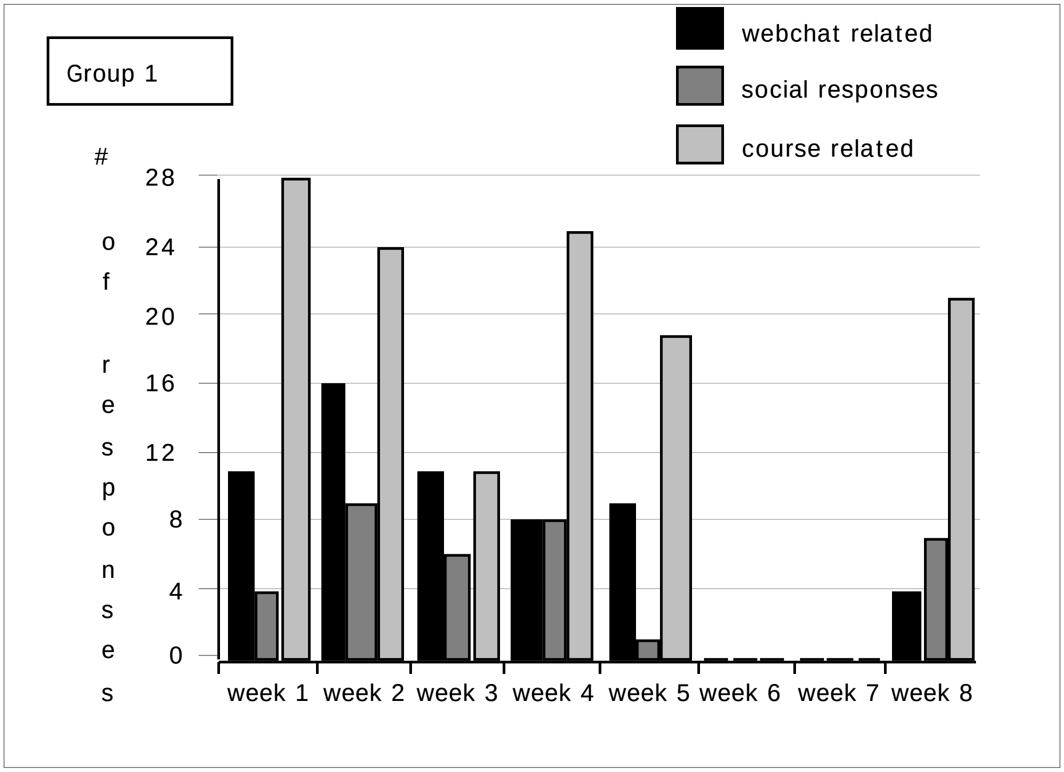

Figure 5
Response Totals for Group 1

Group One had the second highest amount of participation and displayed several characteristics that helped promote interactive discussions which shared ideas and encouraged thinking. Many of the responses were in the form of a question or a hypothesis. There was also a sense of purpose in reaching a conclusion that kept the discussions directed. For these reasons, a dialogue from Group One was chosen for detailed analysis. This secondary analysis occurs after the initial survey.

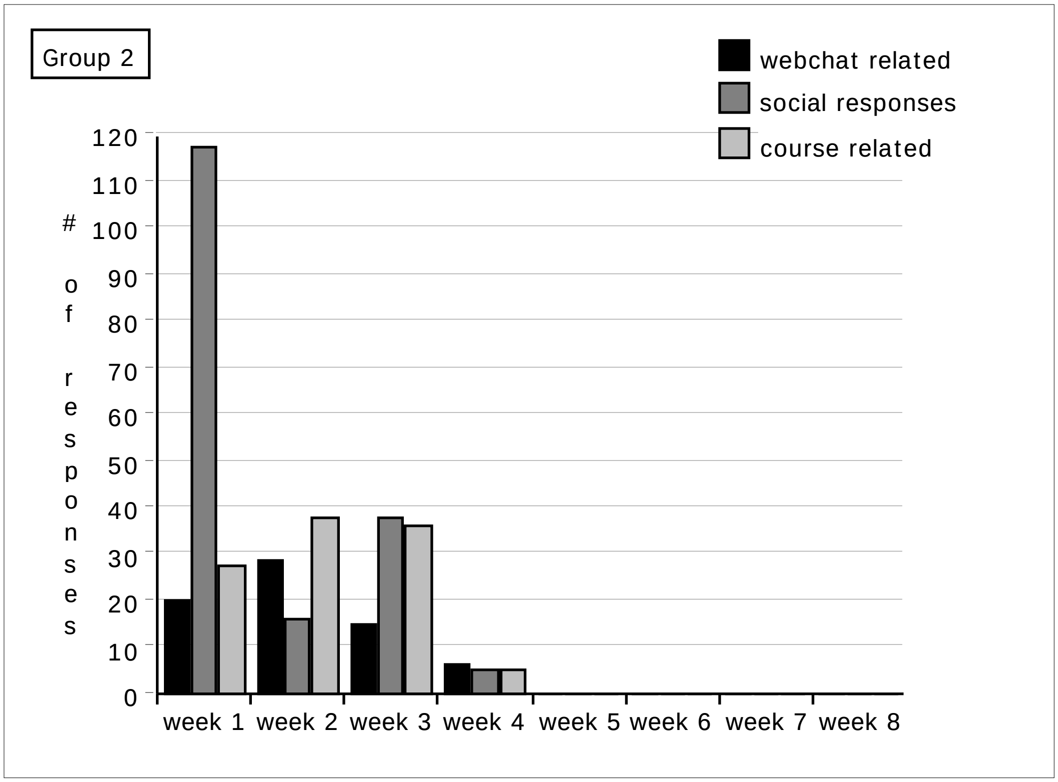

Figure 6
Response Totals for Group 2

Group Two started with a very long, late night dialogue that was predominantly social. Their discussion quickly developed into a series of flirtations and jokes that bordered on being unacceptable with respect to proper language according to university code. Apparently unaware that they were being recorded, their language could be compared to a private conversation. The next day, the professor warned them to refrain. (Later that week, they sheepishly apologized to the researcher for their behavior.) During the following week's discussion, social responses were minimized. By the third week, some of the same social interactions reappeared at a lower frequency. The fourth and final week's dialogue for this group was a minimal, perfunctory effort. These dialogues are a good example of how the dynamics of a small group discussion can be strongly affected by only one or two individuals, because each individual can play a significant role in the discussion.

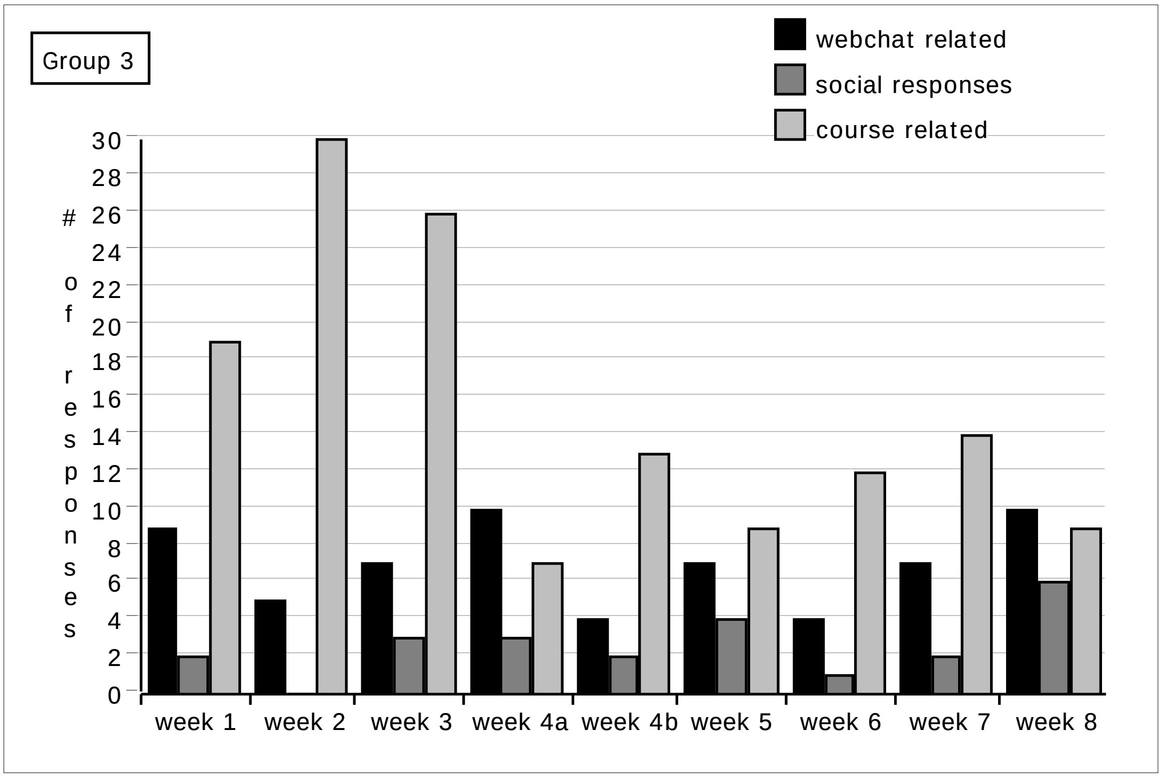

Figure 7
Response Totals for Group 3

Group Three was by far the most businesslike of the groups and had the highest participation. During week four, a scheduling error occurred and only two of the individuals in the group met. Later that same week, the other two came online with a separate discussion. This resulted in two discussions for the same week. Group Three's discussions were moderated and led by a very strong personality with an intellectual bent. For this reason, social responses were the lowest of all the groups. While participation was high, discussion length was always kept near the half hour length. A discussion from this group was chosen for detailed analysis and compared to a representative discussion from Group One. This secondary analysis follows the survey.

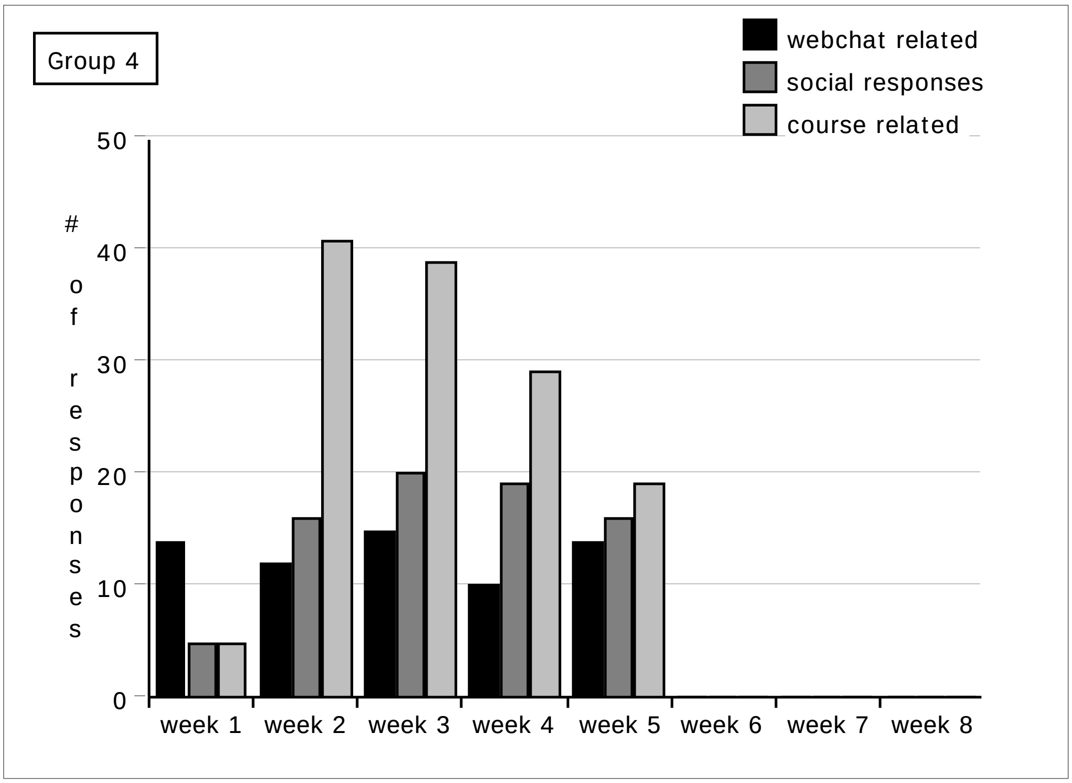

Figure 8
Response Totals for Group 4

Of all the discussions, Group Four contains more varied responses. These include both course-related topics and topics related to day-to-day activities of coeds. The individuals (all female) are apparently friends as well as peers, so they used Webchat to help them coordinate their lives in and out of the classroom. Because of its usefulness to them, Webchat is mentioned favorably several times during their dialogues: “Hi everybody! This is so neat! We'll have fun talking tonight.” and “This web chat is so awesome (even if I am a little fuzzy on the biological aspects)!”. Because of their mutual interests, the discussions of this group show multilevel threads common in larger groups. Much information sharing occurs as they ask questions and exchange their thoughts about the course, but other threads seem to keep the question-related dialogue open and unresolved.

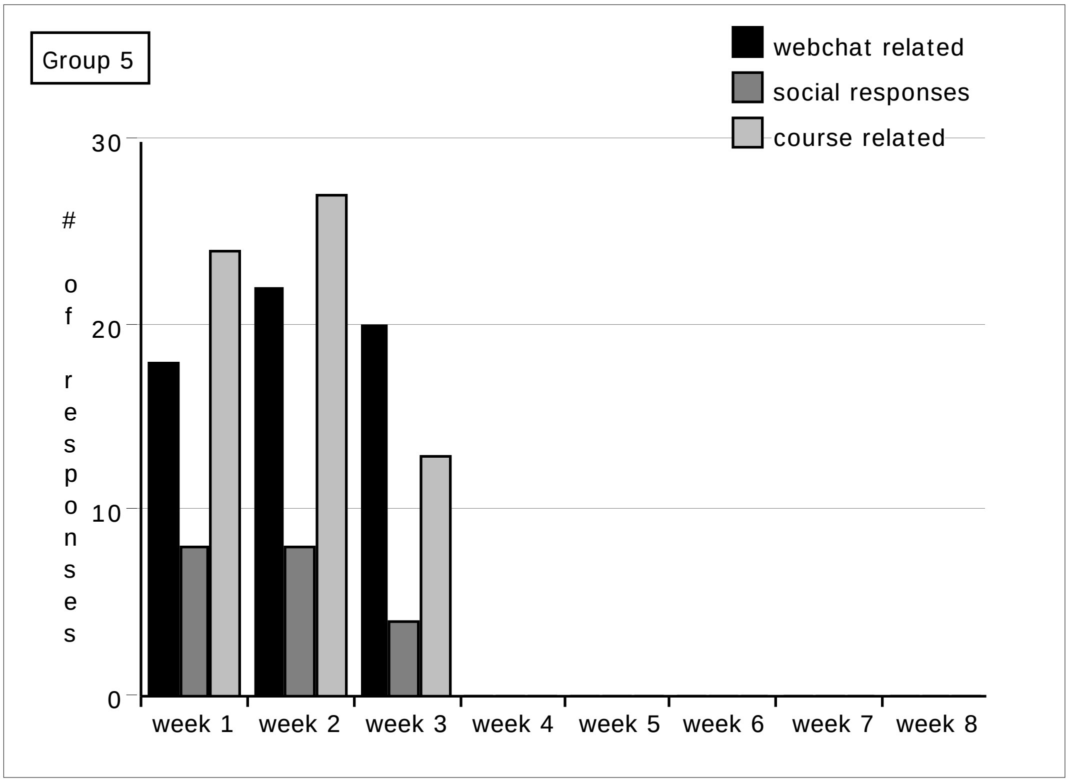

Figure 9
Response Totals for Group 5

Group Five found the Webchat format “obnoxious”, as one member described it, and posted only three dialogues. To gain a feel for why they disliked this format, the following excerpt is given. Pseudonyms are used. Also, the students use pseudonyms, making identification complicated. From this reading it is not apparent whether a fourth member joins as “zorn” or whether one of the participants has entered a new name. The entries have been reversed from their original “bottom first” order as entered on the

Webchat page. Notice the repetitive entry of Rita. This may very well be intentional.

Rita:...10/26/95 9:24 PM

What are the questions?

Rita:...10/26/95 9:25 PM

This is an obnoxious format

The DUKE:...10/26/95 9:25 PM

Hold on a sec and Ill get them

Brian:...10/26/95 9:27 PM

Finally I'm here...sorry, had trouble connecting, and originally I was watching the baseball game and

forgot to come on

The DUKE:...10/26/95 9:27 PM

hey brian, that's no excuse

Brian:...10/26/95 9:28 PM

So what are the two questions?

Rita:...10/26/95 9:28 PM

Oh I see, we always get dumped for some game or another

Brian...10/26/95 9:28 PM

The point it moot, DUKE :) You had to be called, too! Anyway, the ?s...

The DUKE:...10/26/95 9:29 PM

Ill write them as soon as they are done printing, PUNK!

:...10/26/95 9:29 PM

No prolem :) calm down

Rita:...10/26/95 9:29 PM

How am I supposed to read this?

Rita:...10/26/95 9:29 PM

How am I supposed to read this?

Rita:...10/26/95 9:30 PM

How am I supposed to read this?

Brian:...10/26/95 9:30 PM

Sorry...bad typing day :b

Brian:...10/26/95 9:30 PM

How are you supposed to read what?!?!

zorn:...10/26/95 9:31 PM

Boy. Good thing this is working so well(sarcastic tone)!

Rita:...10/26/95 9:31 PM

I don't understand how to follow the conversation

The DUKE:...10/26/95 9:31 PM

1) IN cladistics, shared derived charecters are used to define relationships between taxa. Characters

found in the outgroup are said to be plesiomorphic. Knowing this, do you think Isonychia is a good outgroup for the organisms you are using in lab?

Brian:...10/26/95 9:31 PM

If you're patient, it'll work...I should hook you all up on IRC and we'll try chatting there some time...I'll log it and then upload it to Dr. B

During other discussion times Brian was also monitoring Internet Relay Chat (IRC) and "the DUKE" watched football games. Although interest may have been low to begin with, the slow response time of the Webchat format did not help these particular students with their participation. In this case, previous experience with CMC caused the students to have expectations that did not match with this format. Group Five only participated for the first three discussions.

Participation of the Total Group

When all the groups responses are totaled, a general idea of the percentage of time devoted to each category can be obtained (Figure 9). Finally, grand totals and total time online are listed and compared to produce a response per minute value (Table 10). This is an indicator of how often students were responding.

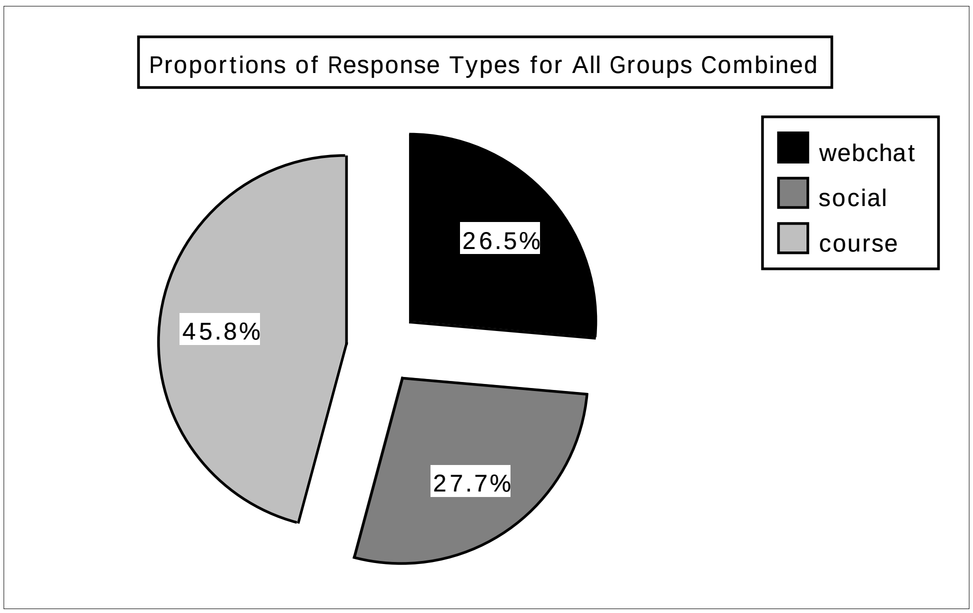

Figure 10
Proportions of Response Types for All Groups Combined

Table 4

Grand Totals for Responses and Time Logged Online

	# responses	% of total
webchat related	317	26.5
social responses	332	27.7
course related	549	45.8
offering info	164	13.7
engaging	196	16.4
total # of responses	1198	
length in minutes	1149	
length in hours	19.15	
# responses /min	1.04	

A Closer Look at Course Related Responses

The category of course related responses includes a range of inputs that include information that may be important to the students but is not considered rich in scientific thought. Comments about course logistics, assignments, grades and previous meetings make up a fair proportion of course related comments in some cases. Other responses which encourage interaction, sharing of ideas and active thought about the discussion questions have been designated "thought provoking", for lack of a better term. These responses have been divided into the two categories previously mentioned: "offering information" and "engaging". Responses that offer information helpful to the discussion sometimes promote responses that demonstrate active thought in other members of the discussion. They facilitate active thinking in others by providing new or missing information. Responses that are engaging are represented by queries or challenges to others' statements that help to cause rethinking or better explanations. Hypothesizing is also an example of an engaging response.

Figure 11 below charts the totals for thought provoking responses for each group. A simple comparison among the groups shows that Groups One and Three have the highest totals. These totals represent raw totals, however, so that groups with the highest amount of participation (Groups One and Three) should also have the highest numbers of thought provoking responses.

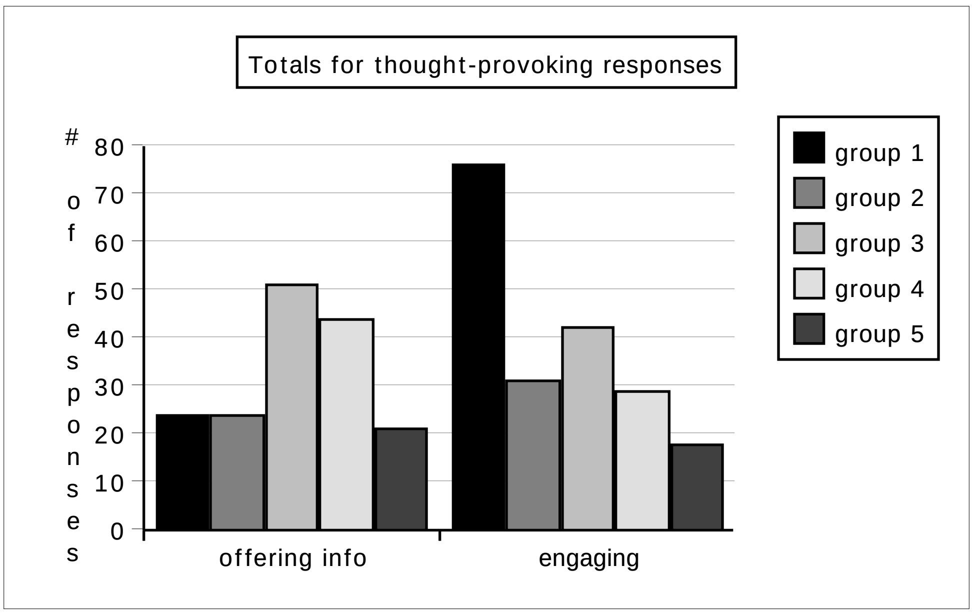

Figure 11
Totals for Thought Provoking Responses

When the response totals are converted to per cent of total for each group, the differences in length and amount of participation for each group's discussions are eliminated. This makes it possible to compare the performance of each group to other groups. The fact that participation varied greatly must not be forgotten, however. For example, the averages for group three are a result of nine separate dialogues while those of group five are the result of only three dialogues. Figure 12 charts these percentages and essentially compares the groups with respect to the quality of their discussions. Quality in this case refers to thoughtful, interactive discussion directly related to the questions posed.

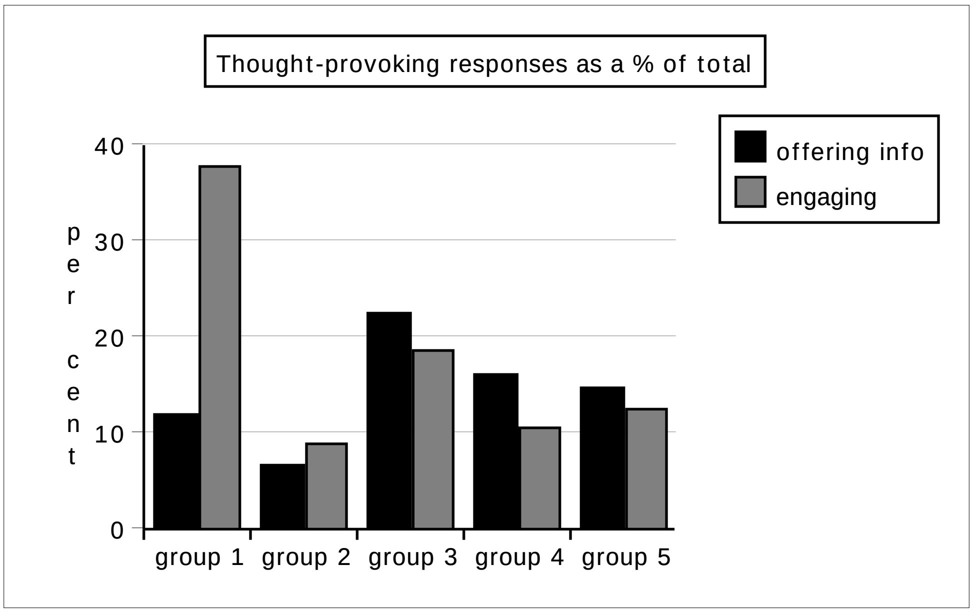

Figure 12

Responses as a Per Cent of Total for Each Group

Table 5 displays raw data used in Figure 12 above as well as total numbers of responses, percentages for other types of responses and another important figure for comparison-- the number of responses per minute.

Table 5

Raw Data: Responses as Per Cent of Total for Each Group

% of totals					
	group 1	group 2	group 3	group 4	group 5
webchat related	29.4	19.9	27.8	23.7	41.7
social responses	17.4	50	11	27.7	14
course related	53.2	30.1	61.2	48.5	44.4
offering information	11.9	6.8	22.5	16.1	14.6
engaging	37.8	8.8	18.5	10.6	12.5
total # of responses	201	352	227	274	144
# responses per min	0.59	1.42	0.77	1.61	1.47

Even though the nature of their dialogues differ, both Groups One and Three exhibit higher average values of engaging type responses than the other groups. Another very interesting comparison can be made between response time per minute and the per cent of engaging responses. The average for all groups combined is 1.04 responses per minute. Both Groups One and Three have much lower rates at O.59 and 0.77, respectively. The response per minute rate for Groups Two, Four, and Five are 1.42, 1.61, and 1.47, respectively. These data suggest that the more substantive the dialogue, the slower the input rate. From this point of view, the Webchat format, as a "marginally synchronous" mode, adequately serves the purposes of dialogues rich in thought, because such dialogues tend to take more time.

It should be reiterated at this point that all the previous comparisons are made on small groups that vary tremendously. Such comparisons therefore, should only be used as possible indicators of trends or qualities. The impact of a single individual in such a situation can determine the direction of the dialogue to a great extent. This has been especially apparent in Group Three, for example. Further, the tone or atmosphere is most definitely affected by prior interactions of these peers. This is evidenced in Group Four, where the social aspect was already in place.

Many different comparisons of each group's performance can be made by viewing the figures and tables above. Initially, the amount of participation is an indication of the success of the discussions. From a possible total of 40 discussions, 27 occurred. Several aspects of this survey point towards factors which may help determine the quality of the dialogues as a learning experience. These will be addressed in the discussion. For now, a closer, more qualitative examination of a few selected dialogues is necessary to understand some of the issues involved.

<u>An Examination of Individual Discussions</u>

Discussions from Groups One and Three were chosen for the following reasons. First, it was decided to look at groups that showed the most participation, had the highest proportion of course-related responses, and also had high values for either "information offering" or "engaging" types of responses. By reading through all the dialogues, it became apparent that some of the discussion questions were more appropriate for involving the students in dialogue. For example, such questions as "What is ethidium bromide? Why is it used with UV light in gel electrophoresis, and what is the biochemical process involved?" or "What do the nodes on a cladogram represent?" require only factual knowledge and do not lend themselves to discussion. (Though a few students actively speculated about the mechanism for ethidium bromide in the procedure.) Because the students already perceived the choice of outgroup as important for progressing through their project, the question "What would be a good outgroup(s) for the organisms you are using?" inspired much active discussion. Students were interested in sharing ideas and many had researched the question prior to getting online with their group.

Because the discussion groups are small, it is possible to describe these particular dialogue interactions as an essentially linear flow through time, though there is some "overlapping" of individual responses. Contrasted to what is seen in larger discussion groups, most of the discussions focused on a single topic at a time, with only an occasional response referring back to an input before the one immediately preceding. For the following dialogue analyses, each response has been classified to indicate its role in the discussion. The following response types were used:

A-- agrees/affirms

H-- hypothesizes

I-- offers information

M-- moderates discussion

O-- states opinion

Q-- questions

R-- reasons

S-- social

W-- logs on/off, mechanics of webchat

The actual dialogues that were analyzed appear in the appendix.

Table 6

Response Classification for “Outgroup Discussion”

Group 1

	Rick	Ann	Thad
9:29	**WIO**		
9:33		**WI**	
9:35	**QI**		
9:37		**RM**	
9:42	**IH**		
9:44		**A**	
9:49	**AQ**		
9:53			**W**
9:56	**WAI**		
9:57			**Q**
9:58	**I**		
9:58			**R**
9:59			**Q**
10:00	**W**		
10:01			**AI**
10:03			**SW**
10:05		**SM**	
10:05	**IR**		
10:06			**Q**
10:09			**RQ**
10:09	**AHR**		
10:11			**Q**
10:11		**AI**	
10:12		**I**	
10:13	**WRQ**		
10:16	**AR**		
10:17			**WM**
10:22	**MW**		
10:23			**QH**
10:24			**W**
10:26	**HR**		
10:27		**RAW**	
10:31			**SW**
10:33		**M**	
10:35			**W**

Group 3

	Penny	Fern	Helen
9:58	**W**		
9:58		**WM**	
10:00	**Q**		
10:01		**O**	
10:02			**WM**
10:02	**M**		
10:03	**M**		
10:04		**IQ**	
10:09			**AQ**
10:10	**I**		
10:11		**I**	
10:12		**R**	
10:17			**Q**
10:18	**O**		
10:19		**R**	
10:20	**M**		
10:21		**R**	
10:23	**Q**		
10:25	**AQ**		
10:25	**AR**		
10:28	**Q**		
10:28		**OQ**	
10:29	**AR**		
10:31	**Q**		
10:32	**M**		
10:35		**Q**	
10:37	**O/M**		
10:38			**A**
10:38			**M**
10:39		**AW**	
10:39	**O**		
10:40	**W**		
10:41			**W**

A-- agrees/affirms **H**-- hypothesizes **I**-- offers information
M-- moderates discussion **O**-- states opinion Q-- questions **R**-- reasons
S-- social **W**-- logs on/off, mechanics of webchat

Referring to Table 6, some interesting comparisons between these two groups can initially be made. First of all, notice the duration. Group One's discussion is half again as long as Group Three's discussion, even though the number of responses is similar. Also, Group One logs twice as many responses that are coded as multiple, while Group Three logs twice as many responses that are single. From this perspective, the ratio of total number of coded responses to duration is roughly equal. This means that Group One enters less often but with more multiple responses, while Group Three tends to enter more frequently with singular responses. Both groups ask questions frequently and facilitate the discussions by using responses that moderate. (Moderating responses were <u>not</u> as common in the other group discussions. This is an important factor that will be attended to later.) Also, Group One was more likely to offer hypotheses while Group Two was more likely to state opinions.

There is a qualitative difference that can be observed by reading through excerpts of the Group One and Group Three discussions. Excerpts that follow were chosen as representative segments that can be correlated directly to Table 6 above. The complete dialogues are listed in Appendix C . The order of entry has been reversed from the "bottom first" format recorded in the Webchat page.

Group One's excerpt begins when Ann responds to a query by Thad because there has been a lull in the discussion. She senses a need to direct the discussion toward the second question and by so doing performs an important step in facilitating or moderating the flow of the dialogue. The idiosyncrasies of this mode are apparent from the first, where Ann and Rick input responses at about the same time without knowing it. Ann is responding to Thad and moderating while Rick is summing up the first part of the dialogue and reasoning. Later, at 10:13, Rick responds to Thad's 10:09 and 10:11 inputs where he forgets to enter his name.

Ann:...10/15/95 10:05 PM

Hey Thad! What do you all think about the second question? Wasn't it about when molecular data would be useful

Rick:...10/15/95 10:05 PM

Ok, so we're using G lacustris and we want to get some samples but we have to look in to that. The second question dealt with the importance of the molecular date we're going to start collecting next week. First this might be important in determining if the G. minus are of different variation and if so to
what extent.

Thad:...10/15/95 10:06 PM

wouldn't the molecular data be useful when the organisms are closely related. like the three species of G. minus

:...10/15/95 10:09 PM

i think it is almost certain that the G. minus are of a different variations, how else would be we be able to distinguish where they are from? the molecular data will be good for determining what the variations are, right?

Rick:...10/15/95 10:09 PM

Exactly Thad. I have a hunch that two of the three G.minus either came both from site A or one from A and one from B. If so, using morphological data wouln'd be much help in determining which G. minus was which.

:...10/15/95 10:11 PM

we have six organisms, how many sites are there? (i don't have that data near me)

Ann:...10/15/95 10:11 PM

That's true. We could also use the molecular data to find the similarities the other species - to find which are more closely related, etc.

Ann:...10/15/95 10:12 PM

there are 5 sites

Rick:...10/15/95 10:13 PM

Who just came on? Once we get our data and determine the molecular relationships between our organisms how do we apply that to determining location of the organism. The data really won't tell us which G. minus is suited for shaded water or fast current etc...

Rick:...10/15/95 10:16 PM

Good point Ann, I didn't even think of it. The data from the insect and isopods could give us a clue to which developed first and how much of the original molecular make-up did each one retain.

From this short excerpt, it is obvious that these students are actively engaged in dialogue that is thoughtful and purposeful. They show each other that they value each others ideas by affirming/agreeing when they recognize good points and they are also able to take others ideas and extend them by adding followup questions or adding their own ideas to them. This was a productive discussion because an outgroup was decided upon through sharing both resources (Rick used a reference book with a map of distributions) and ideas and reaching a consensus. After the decision on which outgroup to use, the group went on to the second question and actively speculated on how they would use molecular data. While they reached no definite conclusion, the discussion did help them focus on this particular aspect of the project.

Group Three also actively engaged in dialogue, but the nature of the dialogue is very different. The following excerpt is typical. Notice how many of the responses represent one thought. It begins when Penny answers a question from Helen about how many outgroups the GTA said they would need for their project.

Penny:...10/16/95 10:10 PM

I think (the GTA) said we would need at least 2.

Fern:...10/16/95 10:11 PM

(looking on pg. A4 in back of book) We could use trilobites,
but they're extinct. I'm afraid we're stuck with those choices.

Fern:...10/16/95 10:12 PM

We do need 2: one to compare the two classes, and one to compare the isopods and amphipods.

Helen:...10/16/95 10:17 PM

How can we compare isopods and amphipods?

Penny:...10/16/95 10:18 PM

Well, I guess we should go with the first suggestions.

Fern:...10/16/95 10:19 PM

We need to find another Order of crustacean.

Penny:...10/16/95 10:20 PM

Anyone have any suggestions?

Fern:...10/16/95 10:21 PM

Let's figure out what the best class would be to compare the insect with the crustaceans.

Penny:...10/16/95 10:23 PM

Couldn't we compare using the subphylums?

Fern:...10/16/95 10:25 PM

We could do that. Do you want to use Trilobitomorpha or Cheliceriformes(arachnids and other stuff)?

Helen:...10/16/95 10:25 PM

Ithink that's what we're going to have to do. Because insecta is a class and crusteacea is a subphylum.

Of all the groups, Group Three was the most business-like and least social. Group Three was also aware of the time involved and tended to log off soon after the required thirty minutes. This discussion came to a consensus on the choice of an outgroup, but the amount of idea sharing and open speculation was lower than that exhibited in Group One's discussion. The second question about molecular data was not broached. During the fourth week, this group broke apart and had two separate discussions. After that, the remaining discussions consisted of only two members, including Fern, the businesslike discussion leader.

Discussions Involving Species Concepts

The first six sets of discussion questions were drawn directly from the individual lab experiences each week. For the last two weeks, data for the project had already been gathered and no new topics were introduced. It was at this time that questions about the definition of species were posed. Only two groups participated in discussions the last two weeks. Group 1 had a discussion concerning whether very different breeds of dogs should be considered different species. Group 3 discussed this question very briefly and also addressed the question concerning the discovery of a population of primitive horses in an isolated valley in Asia.

All three discussions were brief and more social than usual. Overall, they could be described as examples of casual speculation. This may be due to the fact that first of all, the students had no prior knowledge of the topics and the topics were not directly related to their project. Group 3 found the horse question interesting. The following excerpt represents most of the discussion related to this question.

Fern:...11/28/95 10:06 PM

We can be interviewed if we want to be. How about those horses?

Helen:...11/28/95 10:08 PM

I think it is very interesting. Do you know where we could get the article to read? It makes sense that the horses could be "unchanged" since they have been isolated from everything for who knows how many years.

Fern:...11/28/95 10:11 PM

I would like to see that article. I do think those horses could be unchanged, especially if their environment hasn't changed. I don't know if they are a separate species. None of the extinct modern wild horses were a separate species.

Helen:...11/28/95 10:13 PM

I don't know. It is possible that they are the groundwork of the modern day species of horse. Or they could be almost completely different, more like cousins removed a couple of times instead of parents or siblings.

Fern:...11/28/95 10:16 PM

That's a possibility. If the horses had been isolated since before some of the other horse species went extinct, they could be a primitive species of horse that existed before the modern
species.

In this exchange, Fern and Helen mention geographic isolation and relatedness, which indicate that they are able to relate concepts they have learned to new situations. It also shows that Fern is knowledgeable about horses and seems to have her own well-developed definition of species. In their discussion of whether a Great Dane and a Pekinese are different species, Group Three quickly resolves this question by explaining that gene flow occurs through intermediate-sized breeds, therefore, all dogs are one species. Again, a concept essential to understanding what constitutes a species (gene flow) is used to help resolve a different question.

Group 1's handling of the Great Dane/Pekinese question is very different from Group 3's analysis. The following excerpt reveals a chatty, social dialogue that enlightens Rick by making him realize that all dogs really are the same species. Several concepts are mentioned which display these student's understanding of what concepts need to be considered when one is looking at differences between species: behavior, interbreeding, geographic isolation, and morphology are all mentioned.

> Rick:...12/5/95 9:38 PM
>
> Hello Ann. I guess you got my message. So let's talk about this whole thing. First, do you really think a mating between a great dane and a pekingese is a viable consideration?
>
> Rick:...12/5/95 9:40 PM
>
> Oh, and then there is the consideration of behavior. Did you ever see a pekingese rescue dog?
>
> Thad:...12/5/95 9:42 PM
>
> i think mating a pekingnese and a great dane is possible, because i once saw some minature beagle/black lab pups. (it would have been halarious to catch those two in the act.)

Thad:...12/5/95 9:43 PM

and what about great dane rescue dogs? are you thinking of saint bernard's?

Ann:...12/5/95 9:44 PM

I'm sorry, I got a phone call, and didn't know if you all were coming on and kind of forgot to update. I don't really think they should be considered different species. IF they were, we'd have to classify all different dogs into different species.

Rick:...12/5/95 9:44 PM

I think they should be considered two separate species. First off, I don't think they are native to the same regions of the world (geographical isolation). Therefore, they can't mate. They display different types of behavior. They've been bred so long to have different characters that they're characters are

probably no longer compatible.

Rick:...12/5/95 9:46 PM

damn Thad! my mind is just going into a gazillion different directions, thanks for clarifying that point for me. You know I hate to be wrong. I feel so foolish, i must repudiate. The point I'm trying to make I think remains the same. The two dogs just seem to incompatible to me.

Thad:...12/5/95 9:48 PM

i agree with Ann. (yeah Ann. we'll have a party later and won't ask Rick to come because he doesn't see things in the exact same way we do.) they are both dogs, so the are very similar in areas like sturucture and placement of bones, muscles, and internal organs.

This discussion is a good example of how one individual can be enlightened by others in the group but still hold on to prior convictions. From the help of

Thad and Ann, Rick realizes that all dogs must be one species even though they exhibit extremely different size and appearance (morphology). Even though he "repudiates" he still makes his point about the seeming incompatibility between the two dogs.

Conclusions and Implications

Depending on small groups to engage in thoughtful discussion entails assigning a large responsibility to each member for the enterprise to be successful. The very act of coordinating a meeting time was difficult for many of the groups and resulted in many discussions where only three members attended, sometimes only two. Further, the responsibility of facilitating or moderating the dialogue was never assigned or even mentioned, so many of the dialogues lacked direction or took unproductive tangents. Considering the unstructured format and the voluntary nature of this project, it is impressive that so much thoughtful participation did occur.

Within the special set of conditions framed by this pilot study, the Webchat electronic discussion format demonstrated a range of results that included rich and thoughtful dialogue indicating that students were actively involved in learning through this special mode of collaboration. Several conditions were noted that affected the quality of the dialogue. Initially, the questions posed for discussion were most effective when they were open-ended and connected to the goals of the laboratory project. Further, the nature of the interactions during the dialogues was observed to be linked in some cases to previous online experience and prior social/peer relationships. Small group discussions were shown to vary considerably, with a single individual having potential to have a determining effect on the course of the discussion.

Dialogues that were considered to be the most productive included those that had high amounts of participation and included the highest percentages of responses classified as engaging or thought-provoking. These dialogues are rich with responses that include reasoning, questioning and hypothesizing. Further, these dialogues are also characterized by responses that facilitate or moderate the discussion, keeping it purposeful (Harasim, et al., 1995; Johanek & Rickly, 1995; Kimball, 1995). This particular mode of computer mediated communication was considered to be “marginally synchronous,” meaning that update time for each input varied from several seconds to a few minutes. This property annoyed several students but compared favorably to the richest dialogues, indicating that the Webchat mode of CMC is quite suitable for use as an extension to regular face-to-face classroom discussions.

Recommendations

Using Webchat successfully as an alternative or extension to lecture-based discussions should take into account the major conclusions from above as well as consider possible avenues for connecting the small groups so divided to their larger classroom community. Considering the importance of the type of discussion question, the prior experience of the individual student, and existing social relationships, high quality dialogues can occur when students facilitate or moderate the discussion, keeping it purposeful. The Webchat format has been shown to effective in accommodating such discussions because their thoughtfulness may require more time between responses than synchronous modes of CMC display. These major conclusions lead to the following recommendations.

First, questions should be chosen carefully. They should connect to the larger goals of the course as well as the immediate goals of the students, be engaging and raise the curiosity of the students. Questions requiring a synthesis of ideas, such as experimental design or questions that pose open-ended problems can help to engage students.

Second, groups should be slightly larger, perhaps five or six individuals and a set time for the weekly meeting should be encouraged. This would help the students remember their meeting times and avoid the difficulties of scheduling a new time every week. During the pilot study, the groups often met with only three or even two individuals. Having five or six individuals might help the discussion to be productive even when all can not attend.

Third, a moderator should be assigned for each discussion. Romiszowski (1989) states :

> To assure input of the participants, an active group leadership is necessary. This leader or moderator must be the host, setting a congenial, nonthreatening climate, thanking people for their contributions, and stimulating them to react (again). But next to this he or she has to be a "chairperson": summarize this discussion, ask for clarifications, create unity, and watch the theme from drifting off track. And last but not least, the leader has to maintain the bunch of participants as a group. Group maintenance includes such duties as mediating differences that become obstructive and making comments that pertain to the group's progress (p.9).

By having each group assign a different moderator for every week’s discussion and having that moderator summarize their findings and report to the class, several goals could be accomplished. First, responsibility for focusing the discussions is assumed with the discussions being more likely to reach some definite findings. Harasim, Hiltz, Teles and Turoff (1995) say that it is the "...opportunity to lead a seminar, while the most difficult and even intimidating, that students typically rate as the most enjoyable and best learning opportunity (p.84)." Second, the professor can obtain a concise summary for evaluation/assessment. Thirdly, and perhaps even most importantly, this summary can be shared with other groups so they can learn from each other. This could be accomplished as an additional Webchat room where all could have access or it could also be posted on an e-mail discussion group. Many of the students were curious of how the different Webchat groups were doing during the pilot study. In fact, one student reported sitting on some other discussions as an observer for his own interest sake. The possibilities of such a "meta-group" discussion would be quite interesting to explore.

Chapter 5

Analysis of the Species Papers

The first question posed for this research (How did students' concept of species develop through the implementation of this project-based curriculum?) hinges on the analysis of the two species definition papers assigned at the beginning and at the end of the term. This question must be further delineated and focused through the limitations of studying "before/after" works. Careful analysis of the content of the papers can then expose specific cases which reveal possible insight into learning. Finally, examples of student writing provide an opportunity to examine the possible connection of their development of the species concept to their experiences with the lab project.

Limitations

First of all, it is important to consider the conditions under which each paper was written. The first paper was part of the very first laboratory exercise, a library research activity. Only two references were required. With no information other than their own prior knowledge and their ability to research and synthesize a definition of species from references, it might be expected that their efforts would be condensations from literature sources. For their second paper, they would have had a rich set of experiences from which to build a more individualized and personal definition. Such experiences would include actively engaging in inquiry, writing and collaborating on the lab project, and participating in online discussions and interactive lecture discussions. However, from another point of view, the second paper could be seen as another assignment due near the end of the term (a busy time) which did not need to be different from the first writing. In fact, in lab, the GTA had reiterated that their second paper may be identical to their first, if their ideas hadn't changed. The species papers grades were to be averaged together and then account for ten per cent of the lab grade. Considering that just handing in an identical paper would have an almost negligible effect on their grade, any changes made would most likely be self-motivated.

Method of Analysis for Species Papers

Knowing that a range of responses all the way from simply citing authorities to formulating individualized definitions by incorporating personal experiences was possible, more refined questions needed to be addressed to better understand how this complex concept was approached by these students:

1.) What kinds of authorities are cited?

2.) What kinds of examples were used?

3.) What defining concepts were used?, and

4.) Was the lab project used to help formulate the definition?.

The last two questions help to address the second part of the major question- the link of the project-based curriculum to the species concept development. They are also more difficult to ascertain. For example, the lab project uses molecular data as an important tool for demonstrating relatedness of species. If a student alludes to "molecular data" in the second paper, is this a direct result of the lab project? If the only difference between a student's first and second paper is the statement that she now has a better understanding of the species concept- is that necessarily so? Can this be attributed to the experience of the lab project? While the students are part of a very select group and similar to each other in some ways, it is also quite apparent that are all very different individuals. Because of this, comparisons between individuals must be cautious. Each individual also deserves a separate analysis.

All the papers were first read as a set. From reflection on this initial reading, the different aspects or themes emerged which are addressed in the four questions alluded in the beginning of this chapter. Further review confirmed that these themes could serve as a basis for closer comparison and analysis (Ely, et al., 1991). After this, each pair of papers was carefully analyzed with respect to those four aspects: references used, illustrating examples, related concepts mentioned, and whether there was specific reference to the lab project in the second paper.

There are several definitions of species found in the literature. These often go under a specific title such as folk species, morphospecies, biological species, phylogenetic species, etc. Folk species, the simplest definition, relies on the recognition of individual species due to easily observed similarities between individuals of the same species. At the other end of the spectrum, a definition of phylogenetic species includes evolutionary lineages that require close examination of evidence of relatedness. It was first thought that students would embrace a given definition and defend it. Campbell (1993), the course text, devotes a chapter called *The Origin of the Species* to speciation and begins with a discussion of anatomically defined species (morphospecies). Later, Campbell introduces Ernst Mayr's biological concept of species: "A biological species is a population or group of populations whose members have the potential to interbreed with one another in nature to produce fertile offspring, but who cannot successfully interbreed with members of other species (Campbell, 1993b, p.458)." Campbell goes on to discuss barriers to reproduction, biogeography of speciation, and genetic mechanisms of speciation. These are additional concepts that help in understanding the multidimensional species concept.

Each species definition encompasses a set of ideas or concepts that help delineate it. For example, the biological species concept emphasizes interbreeding populations of individuals, but does not adequately address species that reproduce asexually. The concept of species is necessarily complex and any single definition is inadequate to fit the diversity of life. Because species is a multidimensional concept, it became necessary to look more specifically at the sets of ideas or concepts each student presented. After further review of both sets of papers, categories were constructed to accommodate the students' ideas. These are listed in the following table.

Table 7
Categories of Student Ideas

morphology	physical appearance; often refers to specific structures, as in type and number of appendages in crustaceans
interbreeding	ability to successfully produce viable offspring between individuals of different genetic stock
hybridization	the crossing of individuals from different genetic stock to produce a viable hybrid
reproductive isolation	inability to successfully interbreed due to a variety of reasons including physical isolation, behavioral mechanisms, and hybrid sterility
habitat/ geography	preference for specific environmental conditions or occurrence in different geographic regions that result in reproductive isolation
genetics	broad category that refers to differences in genetic makeup of different groups of organisms
DNA/ molecular	specific reference to genetic evidence of differences using DNA or protein sequencing technology, as in the PCR and gel electrophoresis techniques used in the laboratory
gene flow	exchange of genetic material between populations of individuals through interbreeding
convergent evolution	superficial morphological similarities of different organisms due to similar selective pressures, as in the overall body shape of shark and dolphin
behavior	inherited tendencies that result in reproductive isolation, e.g. bird songs and mating dances

There is overlap in the categories. If, for example, a student uses the course text and gives a definition from Campbell's discussion of morphospecies and the biological species concept, then the categories of morphology, interbreeding, and reproductive isolation would be covered. Hybridization is listed only if it is referred to specifically and used as an example to illustrate reproductive isolation. Hybridization implies genetics, but genetics is not listed unless it is mentioned specifically. Likewise, the category of DNA/molecular also is directly related to genetics, but once again, this category encompasses only specific references to this kind of evidence. For example, a student might discuss the gel electrophoresis data from the lab project as one kind of evidence to help explain how species are differentiated. Convergent evolution may seem peripheral to a definition of species, but is a helpful concept to illustrate anatomical similarities in unrelated species and was used effectively in some definitions.

Observing an increase in the number of categories used to define species in the second paper tends to support the argument that, during the course of the term, the students have gained a more sophisticated concept of species. The categories of habitat/geography, DNA/molecular, gene flow, and genetics are all closely related to the lab project. The occurrence of these categories in the second paper, when they were not already in the first paper, may be considered to be a result of the lab project experience.

Question 4 above (Was the lab project used to help formulate the definition?) is perhaps the most difficult to address. Consider, for example, that the only difference between two papers is the inclusion of the phrase "molecular data" added to the final definition. Because the lab project used molecular data, is this a result of that student's experience with the lab project? A subjective evaluation of each student's writing is in order. From an analysis of students' ideas in writing and in lab, a feel for the overall impact of the lab project can be attained. Representative excerpts demonstrating this impact are woven into a narrative that displays the how effective this mode of instruction has been on learning in these students.

Results and Discussion

A total of 19 pairs of papers were analyzed for references, use of examples, ideas/concepts about speciation, and references to the lab project. (One of the 20 papers was not available to the researcher.)

<u>References</u>

A rich variety of references were used, including various books, journals, and in some cases even a relevant internet source. Of 53 references used for the first papers, Campbell (1993a) (course text) was cited nine times. Darwin and Mayr (possibly because they were mentioned in Campbell) were used five times each. Interestingly, a single internet source was also used for five of the papers (Boxhorn, 1995). References for the second papers were similar to the first, but fewer- 37 total. Typical references included those mentioned above as well as other texts, encyclopedias, and a variety of sources that would likely show up during online library searches for “species”. The decrease in number of references for the second paper reflects a general trend of less dependence upon outside authority along with an increased ability to express ideas and concepts that had been learned during the term. This trend will be further revealed when excerpts of student writing are presented.

<u>Examples</u>

Referring to particular organisms as examples was a common way for the students to explain different defining ideas. While fewer references were used in the second paper, an increase in the number of examples was observed- 29/36 (first paper/second paper). In both cases, the most common use of examples were in explaining hybridization. Several students used the same examples. Crossing lion and tigers to produce “ligers” was used by 8/7 students and 9/4 students used plant hybrids as examples. The mule was used as a case of hybrid sterility by 4/4 students. Ligers and mules were not mentioned in the course text chapter on speciation. The common occurrence of these examples suggests that this topic may have surfaced during lecture discussions.

Only three of the examples used in the first papers illustrate ideas other than hybridization. They dealt with gene flow, variation across a cline, and DNA sequencing. This is the main difference between the use of examples in the first paper and the second paper. In addition to using more examples in the second paper, the students also used examples to illustrate concepts other than hybridization. Significantly, *Gammarus* from the lab project was used by seven students to help explain gene flow, genetic differences between populations, molecular data, and geographic isolation. The *Gammarus* examples will be discussed later.

Ideas/concepts about speciation

Each paper was carefully analyzed to determine whether the ten categories listed earlier were presented. The following summary table (Figure 13) lists the ideas/concepts that each student presented in both their papers. This table only reflects whether a particular idea was presented. In some cases an idea may only be mentioned while in other cases it may be explained in detail. Comparisons made must take this into consideration. The depth of understanding can only be judged by an individual analysis.

	morphology		interbreeding		hybridization		reproductive isolation		habitat/ geography		genetics		DNA/ molecular		gene flow		convergent evolution		behavior	
Amy		●	●	●		●	●	●		●						●				●
Ann	●	●	●	●	●	●	●	●						●				●		
Barry	●	●	●	●	●	●				●		●		●						
Betty			●	●	●	●	●	●												
Bonnie	●	●	●	●	●	●	●		●	●	●	●								●
Dawn			●	●	●	●	●	●			●	●								
Don			●	●			●	●	●	●		●								
Fern	●	●	●	●	●	●	●	●	●	●	●	●			●	●			●	●
Helen			●	●	●	●	●	●				●								
Jane	●	●	●	●	●	●								●						
John	●	●	●	●			●	●						●						
Kate		●	●	●	●	●	●	●		●		●		●						
Mary	●	●			●	●				●	●	●		●	●	●				
May	●	●	●	●	●	●								●	●	●				
Reba	●	●	●	●					●	●		●								
Rick	●	●	●	●	●	●	●	●		●						●		●		●
Tammy	●	●	●	●	●	●								●						
Thad	●	●			●	●						●				●				
Tom	●	●	●	●	●	●	●	●						●						●
Paper #	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**

Figure 13
Students' ideas represented in two species papers

Differences Between the First and Second Papers

Much can be determined about the differences between the first and second species papers and between the individual students through a careful examination of the preceding table. The categories listed along the top of the table are grouped so that the first 4 categories were those that were most often found in both papers. Considering that three of them are directly related to the species definitions commonly discussed (morphospecies and biological species) in biology texts, it is reasonable to expect that most of the students would use these ideas in definitions for both papers. The next four categories list concepts that were integral to the lab project. The last two categories list concepts that were the least frequently occurring, but are included to represent all the ideas reported.

The major observation that one can make from an inspection of this table is that the second species papers were richer in ideas and concepts about speciation. Further, the first group of four categories shows essentially no difference between the first and second papers (57/59 total), while the second group of four categories shows a large difference between the first and second papers (11/35). From these observations, it can be concluded that these students developed a more sophisticated concept of species during the time between the two papers and that it is likely that this concept development is due at least in part to their lab project experience.

By examining the performance of individual students, this table can be used as a tool to reveal both typical and unexpected cases (Erickson, 1986). For the most part, students discussed three or four concepts in their first paper and increased the number of concepts by one or two for their second paper. Three cases show a larger increase (Amy, 3/7, Kate, 3/7 and Rick, 4/8). Three cases exhibited no change (Betty, 3/3, Fern, 8/8 and Bonnie, 6/6). These cases require individual analysis.

Examination of Individual Cases: Narrative

Initial Examination

During my first reading of these papers I was immediately struck with the overall competence of these students' writing abilities. From the beginning it was apparent that their first effort at defining species was probably much better than what a typical incoming freshman would be capable of. As I tried to uncover any patterns or themes, I realized that while most of the first papers were quite good attempts at synthesizing the work of others, some of these papers actually included examples of independent reasoning by the student. I began to realize that these instances were windows of insight into what these students might be thinking. This happened while reading May's first paper:

> For example in three similar organisms, groups A, B, and C; group A will mate with group B and group C will mate with group B, but group A and C will not mate. It is then possible that traits from group A will be passed onto group C even though the two groups cannot interbreed directly. It is then unclear as to whether or not groups A and C should be placed in the same species.

In this case, May explains gene flow in her words by her own reasoning without ever mentioning the term! Though her grasp of the concept may not allow her to clearly define species, her reasoning demonstrates an ability to understand its difficulties. She finally concludes by saying that she is

"...doubtful that there will ever be a method in which every organism can be clearly defined into a species with no overlapping simply because under the theory of evolution every organism can eventually be linked back to one organism." Though she leaves the issue unresolved, she has still demonstrated a thoughtful approach.

Some students not only demonstrated an ability for independent reasoning in their papers, but were bold enough to suggest hypothetical cases or even suggest new ways of defining species. For example, Rick hypothesized the consequences of a "human with wings"--whether it might be able to interbreed and the fate of possible offspring--not as a real example, but more to let him express some of his own ideas. Likewise, Tom, in his second paper, recognizing the difficulties of an all-encompassing species definition proposes a solution by extending the concept of species with an "extra step":

> Many people have different beliefs on where the border is between different species whether it be morphological, molecular, behavioral, etc. A possible solution to this could be to add yet another step in the classification of beings. The "species" step could separate beings by breeding capability and then a more specific step in classification could separate members of the same species into more categories based on behavior, detailed morphological analysis, and molecular data. There would have to be a line drawn as to how detailed the molecular data is used to separate organisms. If every deviation in the DNA of species was used, then every organism would be its own group. No two people would be members of the same "extra step". With this type of classification, a Golden Retriever would be a member of the same species as a German Shepherd because they are not isolated reproductively, but they would not be members of the same "extra

> step"....Although this form of classification is somewhat different than the method known today, it could be very useful in studying evolution. It would also result in less argument over what separates species. The "extra step" would be an extra step toward understanding evolution.

In this case, Tom has gone beyond just trying to develop a concept of species by trying to resolve some of the differing distinctions that people use to define species. This shows a maturity of thought even though he may harbor conflicting conceptions--he is unsure as to whether different breeds of dogs are also different species (This was evidenced in his first paper.). Also, this finer distinction that Tom promotes shows he is aware of the many distinctions that are used in taxonomy. In fact, from the excerpt above, Tom would be considered a "splitter" by taxonomists. This level of thought is more representative of upperclass or even graduate students.

Analysis of the Second Papers

When I realized that the students could essentially return their first species paper at the end of the term in lieu of revising their definitions, I expected that many of them would tend to do just that. All the students seemed to be very busy with school and from some of their comments on the Webchat, a few of them were feeling "burned out". Surprisingly, there were only three second papers that showed no increase in the number of concepts covered. Most of the papers were very similar to the first, but they took their first definition and refined and expanded it. Two of the three papers showing no increase in the number of concepts added revisions.

Betty's papers were identical, with a comparison of Darwin's and Campbell's definitions and a discussion involving morphospecies and the biological concept species, presumably from Campbell. Because her papers are identical, there is no way to tell whether her own definition of species had developed. Bonnie's papers, while both showing the same number of concepts, were different. She uses Campbell, the internet source, and a book entitled Concepts of Species to initially compose her own definition. Stating that she is a biology major, she also believes that each researcher should have their own definition. Her second paper cites a different book on species concepts and speciation. She does mention the lab project as an example of differentiating between species, but does not really emphasize it. Her second paper emphasizes genetics more and her final definition ends up as a single sentence: "In conclusion, I believe that a species can be accurately defined as a group of organisms occupying a specific habitat that share basic physical characteristics and mannerisms, that have the ability to interbreed and produce viable offspring, and that share similar genetic compositions." Mention of the word "mannerisms" is interpreted as the "behavior" category in the table of student ideas. It is worth noting that Bonnie's first paper contained a higher number of concepts than all but one other first paper. With an already sophisticated concept developed, she may have been less likely to add more ideas than her peers.

Superficially, Fern's papers are an example of a discrepant case analysis (Erickson, 1986). The number of concepts covered in the first and second papers remain the same and this is not unexpected, however, the high number of concepts covered is unexpected. Her definition of species is perhaps more sophisticated than many upperclass biology majors. In her first paper she writes:

> Classification of species will always cause some difficulties, because any one set of rules for classifying will not fit every case. Therefore, no one definition of a species can be used exclusively. After all, the classification of organisms was created to make easier any attempts to

> understand the natural world, and is not a rule by which the natural world must run.

This conclusion comes after a discussion that weaves the concepts from her references into a logical synthesis using pertinent examples. She brings up problems with speciation related to gene flow using the example of variations in deer populations from the Key deer in Florida to deer in the north. Behavioral barriers to gene flow are discussed using the wolf/dog example. Questions are posed that bring up the crux of each issue. Because her own species concept is extremely well-formed at the beginning of the term, it becomes no surprise that her second paper is essentially the same. However, her treatment of the lab project in the context of the second species paper is enlightening. In this case, she has had the opportunity to apply her already competent understanding of species and speciation to a real world situation (the lab project) and she has used the evidence given to again address the subjective issues by posing appropriate questions.

> The isopod/amphipod lab has not helped me to choose any particular definition as correct. Instead, it has reinforced my idea that no particular definition is absolute. For example, although genetic composition is used to differentiate between species, what degree of genetic variation is needed for two organisms to be considered a separate species? In the case of the three gammarids, how much more will the *Gammarus* population at site C have to diverge before it is considered a separate species, if there is no gene flow between it and the other gammarid populations? If this population diverged farther from the other two so that it was more genetically unique than it is now, but could it still interbreed with them in a laboratory situation, would it be a different species?

She extends her argument with examples of the gray wolf (a single species but with no gene flow between continents) and plant hybrids which may form new species in one generation. Her content and conceptual knowledge is impressive. Finally, she concludes with:

> And new species are being formed all the time, making it difficult to classify the transitional forms that are not yet a separate species. These unusual situations demonstrate that one definition of species will not fit every case. Therefore, I still believe that these methods of classification should be applied with some flexibility. After all, the taxonomic system was created to make an understanding of the natural world easier to obtain, and is not a rule by which the natural world must run.

With this level of knowledge, having students like Fern in a class brings up the issue of how others may benefit from their presence. It also brings up the issue of creating a challenging environment for these types of students.

On the other end of the spectrum were two students who increased in the number of concepts addressed in their second papers more than any others. These were Rick (4/8) and Kate 3/7).

Rick was one of the more active participants in the lab, always quick to offer answers to questions and willing to think out loud. He spent lots of time studying the morphology of the gammarids during the labs and at one point thought he had actually found anatomical differences between the populations. (Members of his group convinced him otherwise.) During the outside research done on the project for determining the outgroup for the cladogram, he helped his group decide on another species of *Gammarus* found in a different part of the country to use as an outgroup. His second paper contains plenty of references to the lab project and is a well-developed composition that brings in specific references to the lab project concerning gene flow, habitat and geographical distribution, and the idea that the relationships between populations may be more important than a particular definition of species: “I think that the definition of species is less important than the relationships between populations and organisms, whether we consider them separate species or not.” For all these reasons, Rick’s second paper is convincing evidence for the effect of the lab project on his concept of species.

Of all the second papers, Kate’s most directly addresses the influence of the lab project on the development of her species definition. The following excerpt is the conclusion to her paper:

> After completing the six week lab, in which we studied different species of aquatic organisms, I now have some insight as to the definition of a species. This lab has taught me that a species is more than organisms that have similar traits. Our studies of *Gammarus minus* helped me to learn that two organisms that come from different collection sites may not look alike. As two groups of the same species become geographically isolated, they evolve in different ways to adjust to their individual environments.
>
> Although morphological characteristics are very important in determining a species, they are not the only way in which to determine that a species is either largely of less intensely related to other organisms, and a group of organisms is determined to be a certain species by its relatedness to others.
>
> The testing we did with DNA, showed that genetic data is very important in determining this relatedness. The *Gammarus minus* were obviously closely related by the amount of genes that they had in

> common in the gel electrophoresis. It was then possible to determine which of the *Gammarus* were more related, thus determining which of the three was the first to split away from the group. Geographical data can then help to determine where each organism is located.
>
> This lab was very helpful in my understanding of the definition of a species. A species is not only a group or population that shares strict genetically transferred traits, but it is also flexible in those traits as related organisms become geographically isolated. This lab did confirm my understanding that a species is constantly adapting, and being reclassified. I had no idea, how changing the world of taxonomy really is.

From these statements, Kate has added the concepts of morphology, habitat/geography, genetics, and DNA/molecular evidence to her understanding of the species concept. It is also apparent that her realization of species as a dynamic concept changing through time has been enhanced as a result of her experience with the lab project. This is powerful evidence in support of the connection of the lab project to her development of the species concept.

Fern, Rick, and Kate were three of the seven students that specifically mentioned the lab project in their second paper. One of the four remaining students used the lab project as an example of why molecular data is not helpful in sorting out species. This was Don. While he did use the lab project in writing his second paper, he felt that the molecular data could not be used effectively. His reason was because the molecular data did not reveal genetic traits. By making these statements, Don shows a more sophisticated understanding of genetics, but may also be reacting to the tenuous nature of the data and the complexity of the problem. His argument in this case is different from most of the other students. His statements are more philosophical: "What difference does it make if two organisms can interbreed even though they can never coexist in the same environment?" Being one of the more social members of this lab and also the only second year student (He had already taken the second semester honors biology course the previous year.), Don was the only student of this group to point out the limitations of the method for collecting molecular data in his paper. It is impossible to know from his writing whether this more critical treatment of the lab project in his paper is because of his different background or whether his reaction would have been similar had he not had prior university course experience.

Three other students used *Gammarus* from the lab project as an example in their second papers. Amy uses *Gammarus* in an explanation of gene flow and geographic isolation. Jane uses *Gammarus* in an explanation of molecular data. Barry's use of *Gammarus* and the lab project provides some useful insight into his learning:

> The most defining way to determine a species is to look at the genetic makeup of the organisms believed to be within that species. In order for a group of organisms to be called a species, they must share in common a certain number of genes, a number greater than that which the species shares in common with any other. This is difficult to determine because different populations of the same species will often have different gene pools due to geographical or some other form of isolation. This was observed from the molecular data obtained in lab of the three specimens of *Gammarus minus*. Although they were the same species, they each had somewhat different genes and sequences.

In his first paper, Barry did not mention genetics. From the above excerpt it appears that his emphasis on genetics is due in large part to the lab project. Even more insight into his understanding is revealed by the following excerpt:

> The problem is that the results of the gel electrophoresis also showed that some organisms of different species also share genes in common. It is extremely difficult to decide which genes and what number of genes which are similar between organisms determines the two as the same species. In order to determine a species, one must look at physical characteristics, genetics, and the ability or inability to interbreed.

From this excerpt it appears that Barry may be equating the banding sequences from the gel electrophoresis to actual genes. He does understand the difficulty in determining how different species should be genetically, but viewing shared genes between species as a “problem” shows that his grasp of the species concept is still limited by his understanding of genetics.

All told, many instances of student reasoning show a progression of development of the species concept from the first writing to the second writing. The fact that 7 of the 19 students used *Gammarus* as an example in their second papers to effectively expand their definition of species is proof of a direct connection of the lab project to their learning of the species concept.

Conclusions

Both the species ideas/concepts analysis and the individual case analyses make a strong argument for a more sophisticated species definition being developed by these students during their enrollment in the honors biology course. This was observed in all but one of the nineteen cases analyzed. The connection of this development to the lab project is also evidenced by these analyses. In the species ideas/concepts analysis, categories of species ideas/concepts relating directly to the lab project increased more than threefold with the writing of the second paper, after the lab project. Further, specific mention of the lab project occurred in seven of the final papers. From this evidence the conclusion is made that the lab project had an important role in learning for these students and their experiences during this lab project resulted in a more sophisticated species definition.

Chapter 7

Summary of Findings, Significance and Implications

There is a clear need to investigate learning where science education reform is being implemented for two major reasons. First, learning theory needs to be better understood in the context of practice; and second, innovative efforts at reform that are effective need to be documented and substantiated according to this theory. This study focused on a project-based laboratory curriculum in a freshman honors biology course. This investigative curriculum incorporated the research practices that scientists use in approaching real-world problems. In order to obtain a more defined focus for this study, the students' development of their concept of a biological species was studied. Qualitative research methods which incorporated a variety of data were used to address the following questions:

1. How did the students' concept of species develop through the implementation of this project-based curriculum?
2. How did the project-based approach influence learning?
3. How does learning documented through the project-based approach mesh with the goals for the curriculum?

To address these questions, a theoretical perspective based on a socio-cultural approach to teaching and learning was used. A model for learning that connected the tenets of this theoretical perspective to conceptual change theory was developed to provide a framework for study. Three very different sets of data were analyzed separately and offered as different "windows" into student learning. These include videotaped laboratories and interviews of the project-based curriculum, electronic dialogues via the World Wide Web, and student papers defining their concepts of biological species.

Although an entire chapter has been devoted to each of these three sets of data, these findings were viewed as separate units of analyses. Pertinent findings were drawn from each data set to answer the questions posed. Each set of findings contributes to answering the research questions in different ways, some more than others. The following section summarizes findings pertinent to the questions, but does not specifically attempt to link these three chapters because the laboratory experiences and most of the electronic dialogues do not directly address the concept of species. When appropriate, pertinent links with the concept of species from each data set were discussed in relation to the research questions.

Collectively, these research findings help to provide a necessary framework for understanding how this approach to learning a complex scientific concept can occur from a socio-cultural perspective. For example, the laboratories provided vital experential learning that is necessary and prerequisite to building more complex frameworks of knowledge which relate directly to the students' understanding of biological species. The electronic dialogues offered an important avenue for the active exchange of ideas which encourage restructuring conceptual knowledge. Direct evidence of learning the species concept came from student interviews and student writing. Without providing a broader context however, appreciation for this approach to learning would be greatly limited.

Summary of Findings in Context of Research Questions

This section will summarize the data and interpretations of each set of findings as they relate to the major questions posed.

1. How did the students' concept of species develop through the implementation of this project-based curriculum?

The strongest evidence for demonstrating species concept development during the implementation of this curriculum was found in an analysis of the species definition papers that were written prior to and after the laboratory project (Chapter 5). This analysis looked at differences between the first and second paper by focusing on four aspects of the students' work. The major findings from this analysis were:

1.) Students cited fewer references in their second paper, relying more on knowledge gained from their lab experiences.

2.) Students used more examples of organisms in their second papers, in several cases citing a specific organism studied during the laboratory project.

3.) Students' second papers displayed richer, more complex definitions, using more ideas and concepts about speciation.

4.) Significantly, a threefold increase was observed in the number of defining concepts that directly related to the laboratory project.

In addition to demonstrating competent writing abilities, all of the papers offered coherent species definitions. Significantly, seven of the nineteen students specifically referred to the laboratory project in their second papers. This is strong evidence for experiential learning through the laboratory project. An increase in the number of concepts or ideas helpful in defining species was observed in all but three cases. Of the three cases exhibiting no change, two initially displayed an already sophisticated definition. Both of these students referred to the laboratory project in their second paper. Only one of the nineteen students submitted a second paper that was identical to the first.

Important evidence relating student learning from the laboratory project to the development of a definition of species can also be found in interview data (Chapter 3, p. 64). When the students were prompted to discuss their ideas about their definition of species and speciation, they offered explanations and examples that directly related to their project. These included gene flow, morphology, DNA evidence, and the organism *Gammarus minus.* Further, they made statements relating their understanding of a species from the viewpoint of a related population of individuals, where delineations are arbitrary. This shows a level of sophistication not found in most of their initial species definition papers.

Evidence for development of the species concept is minimal from the electronic discussion data (Chapter 4, p. 97). During one dialogue, students engaged in a discussion involving the defining concepts of gene flow and geographic isolation; however, no direct link can be made to the laboratory project. Substantive electronic discussions did occur when thoughtful or engaging questions were posed that related directly to the laboratory project. The few questions posed about the concept of species occurred when interest and participation in the electronic discussion format was low.

2. How did the project-based approach influence learning?

This project-based approach is fundamentally different from typical laboratories in several respects. Because it models a real research problem, it is complex, requiring several different (and possibly contrasting) data sources to be synthesized into one report (see Appendix C: ISOPOD / AMPHIPOD LAB INTRODUCTION AND SCHEDULE). With the responsibility for learning being shifted primarily to the students, and with students working in small groups, the opportunities for learning through collaborative efforts are enhanced (see Figure 1, Chapter 1, page 21). The requirement for peer review of work (see Appendix B) and the opportunity for engaging in electronic dialogue also encourage active exchange of ideas. Finally, the ambiguities of the data and the open-endedness of the problem posed stimulate and challenge the students to learn both from themselves and each other.

The limitations to addressing this question are directly related to the types of data collected. Each of the three sets of findings from these data offer insight into learning. They are addressed separately and follow below.

The analysis of the vignettes in Chapter 3 (p.41) offer a description of the learning environment in the laboratory that meshes well with the model for learning from Chapter 1 (Figure 1, page 21). The learning environment during the laboratory project often required collaborative interactions among the students. Specifically, examples were documented that demonstrated each of the types of Learners in Small Groups as displayed in the model for learning: Peer Tutors, Cooperative Learners, and Peer Collaborators (Chapter 3, page 56).

Evidence of learning in small groups as a result of this project-based curriculum is also documented through the analysis of the electronic Webchat discussions (Chapter 4). The dialogues recorded showed a range of social interactions and interactivity. While discussions pertaining to development of the species concept were minimal, other discussions which directly related to solving problems associated with the laboratory project were found to be rich in scientific thought, engaging discussants by offering information, questioning, and actively hypothesizing. This written record of active sharing of ideas offered a unique window into how these students interact and learn from each other. Once again, the ability of students to learn by interacting in small groups has been evidenced.

Convincing evidence of the effect of the laboratory project on student learning about the species concept is demonstrated through the analysis of the defining concepts in student species definition papers in Chapter 5 (Figure 13, page 109). Not only did students offer richer and more sophisticated definitions of species in their second attempt after the laboratory project, but the occurrence of specific concepts that were inherent in the laboratory project increased from eleven in their first papers to thirty-five in their second papers. Further, in seven of the nineteen second papers the lab project was used to help articulate a more sophisticated definition. In these cases, students were able to use knowledge gained from the lab project to directly help them with their reasoning to formulate new understandings. This evidence demonstrates the important connection of experiential learning from the project to understanding the species concept.

<u>3. How does learning documented through the project-based approach mesh with the goals for the curriculum?</u>

The goals for the laboratory across the entire term are listed in the electronic course syllabus and are included in Chapter 2, page 34, along with a description of how they fit with the specific labs scheduled. In general, they describe the practices of biologists who study populations of organisms, including the analysis, synthesis and communication through the writing of findings. The general goal for the laboratory project is stated as follows:

> Students will be given organisms collected from various sites throughout the New River Valley and will be asked to identify them. Then, using morphological, geographical and molecular data, the students will assign the organisms to the site at which they were most likely collected.

The guidelines and schedule, which give more specific requirements, are listed in Appendix C.

Because this study focused specifically on the development of the species concept, the data sets did not include student reports on the lab project. However, findings from all three major data sources do point toward fulfillment of the goals for this curriculum.

The most convincing evidence for learning documented during this project that corresponds to the goals of the curriculum come from the analysis of Chapter 3, page 56. The most striking characteristic of the labs during the project was the ability of the students to work together in small groups toward the major goal listed above. It could be concluded that because all the students completed a final report according to the required guidelines, that the major goals for this project had been attained, but this would be too simplistic. A whole range of dynamic interactions with students actively investigating problems and sharing both their findings and thoughts during this time occurred, essentially modeling the authentic practices of scientists. Peer tutoring, cooperative learning, and perhaps most importantly, peer collaboration was observed when students grappled with difficult problems for which there was no single right answer. In this respect, this curriculum not only fulfilled its goals, but also succeeded at attaining the goals of the larger science education reform movement by encouraging students to model the authentic practices of scientists. This significant point is discussed in the following section.

Significance

Findings that address the research questions have been summarized in the previous section. This section addresses the significance of this study from a broader perspective. Three important aspects of this study help to extend understanding about learning. First, a unique and important connection has been made between the socio-cultural approach to learning and conceptual change theory. Second, there is documentation that this innovative curriculum, which is connected to this theory, is successful. This important theory-into-practice link helps to further the efforts of the larger science education reform movement. Finally, findings from the piloting of the electronic discussion format, some of which did not relate directly to the questions posed, offer valuable insights into understanding the usefulness of this form of communication.

Linking Social Constructivism to Conceptual Change Theory

Lumpe and Staver (1995) concluded that students working as peer collaborators developed more scientifically correct conceptions about plant nutrition than did students working alone. In this study, they favorably compared Piagetian and Vygotskian theoretical perspectives with respect to the idea that cognitive conflict can be caused by the social interactions of problem solving during peer interactions. Piaget's (1970) and Vygotsky's (1978) theories both attend to the importance of peer interactions, their emphasis on either the individual mind or the initial social interaction being the main difference. The importance of Lumpe and Staver's study here is the idea that conceptual learning is indeed enhanced with peer interaction, specifically peer collaboration, where the active exchange of thoughts is required to attain new knowledge (Damon & Phelps, 1989). In this specific case, then, the social constructivist viewpoint is needed to help understand how students acquire scientific concepts.

Researchers studying Strike and Posner's (1985) conceptual change theory have tended to focus more on the individual's thinking as opposed to the "extramental" social interactions that socio-cultural researchers examine. To approach the conceptual knowledge of the individual, one must of course try to find out the individual's conceptual frameworks. However, if one wishes to better understand how that individual acquired those frameworks, then the study of social interactions is a necessity. And these social interactions are dependent upon a complex host of factors. The study of a socio-cultural approach is therefore prerequisite in this respect. Both perspectives are necessary. It is the difference in emphasis that distinguishes most researchers.

This difference in emphasis has led many researchers to focus either on the individual mind (cognitivists) or social interactions (social constructivists). The model for learning synthesized for this research effectively links these two realms by showing how small group interactions as extramental, socially constructed thought processes promote intramental restructuring of conceptual frameworks. The model is offered again below as a matter of convenience. A more detailed description of it can be found in Chapter 1, page 18.

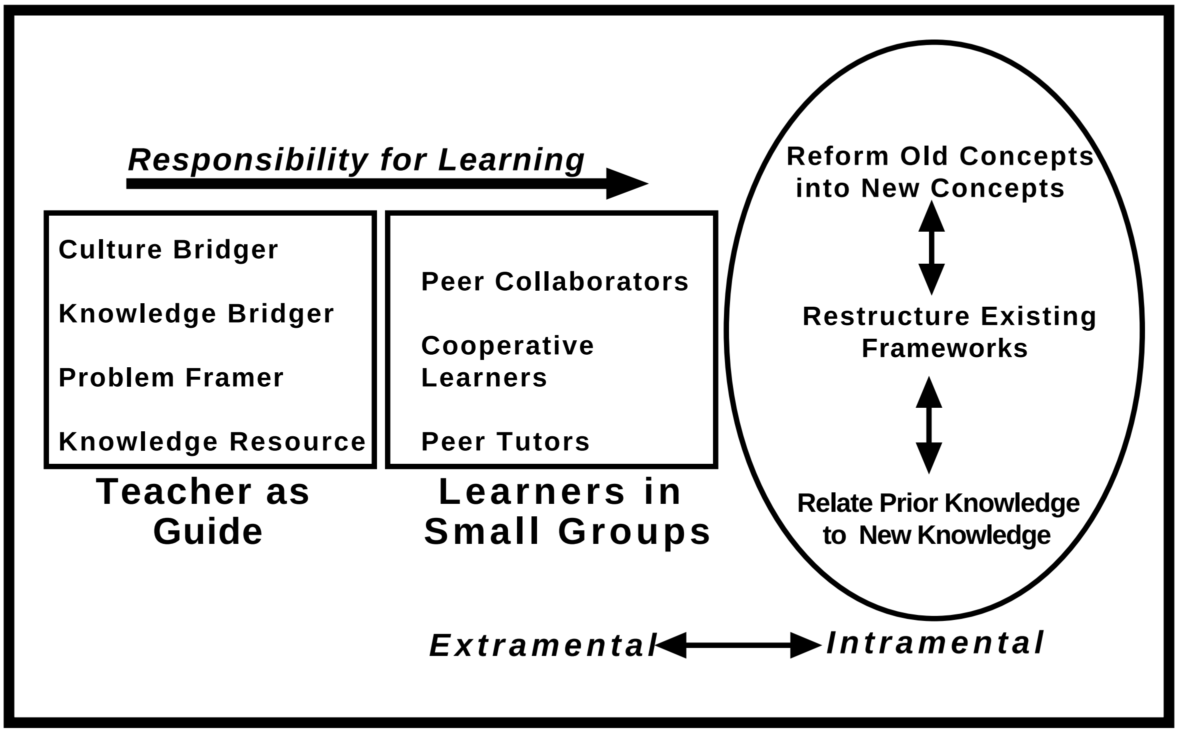

Figure 1 Revisited

A model for concept learning through peer interactions.

This model effectively links the tenets of a socio-cultural approach to teaching and learning (O'Loughlin, 1992) to the conceptual change theory of learning (Strike & Posner, 1985). Significantly, this helps different researchers understand learning theory as a developmental process that encompasses many perspectives. And these perspectives need not be mutually exclusive. This model also highlights the importance of learners as small groups, particularly working to solve challenging problems as peer collaborators. This is an extremely important aspect with respect to learning concepts in science education. Its significance has implications far beyond this study.

Reform Into Practice

In order to understand the research conducted, ample description of the course curriculum was necessary. Both the theoretical perspective of a socio-cultural approach to teaching and learning and the concordance of authentic practices and assessment with research methodology mesh nicely with this curriculum. As well as examining concept learning during a project-based laboratory, this study also documents an exemplary effort at reform in undergraduate science education. From this perspective, this study represents one avenue for dissemination of these innovative practices.

The National Science Education Standards (1996) view science as a way of knowing, not just content or even process knowledge, but a way of gaining knowledge through inquiry.

> Inquiry is central to science learning. When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others (p. 2).

These statements match the learning efforts of the students engaged in the laboratory project quite well. Beyond meeting the specific goals for the curriculum, this effort corresponds to the recommendations of the national science education community. In this case, the theoretical framework is exemplified in practice which is in line with national trends and recommendations. This research has confirmed this important reform effort and in so doing helps to further the process of science education reform.

Electronic Discussions: Significant Findings

While the electronic discussions that were voluntarily conducted during the laboratory project did not yield significant data relevant to species concept development, some very interesting and important findings resulted from the examination of this novel format. Because these discussions were conducted as a pilot, it was necessary to examine their general characteristics. This section summarizes the findings from Chapter 4 and discusses their significance.

These discussions used a software (Webchat) that enabled student responses to be updated to a World Wide Web page (Leahy, 1993). Importantly, this allowed access from any computer connected to the Internet, which gave students the ability to carry on discussions at convenient times and locations (e.g.. dorm rooms). Compared to asynchronous modes of computer mediated communication, such as electronic mail, and synchronous modes of CMC, such as the *Daedalus* interactive writing environment, Webchat discussions were found to be “marginally synchronous”, with a response time limited by the speed at which the page could update after each entry. This is due to several factors, including the nature of the interface and access speeds of the computers and server.

Five groups of four students each participated in the discussions. Voluntary discussions were generated around questions provided by the graduate teaching assistant and the researcher during the eight weeks corresponding to the laboratory project. Out of a possible 40 discussions, 27 occurred. A wide range of variability with respect to participation and quality of discussion was found. More than 1100 individual responses were categorized to gain an understanding of types of responses. For all the discussions, approximately one-half of the responses related directly to the course, one-fourth of the responses were social in nature, with the remaining one-fourth concerned with the mechanics of the interface (logging on/off, etc.). Average length of all the discussions was 42 minutes. (Refer to Figure 10, page 81 and Table 4, page 82 for more details on total values.)

A closer look at course related responses was made by determining which ones offered relevant information or posed engaging or thought-provoking responses. Individual discussions that displayed the highest amounts of these types of responses were regarded as being the most productive or highest quality (Figures 11 and 12, pages 83 and 84, and Table 5, page 85). From these, two different discussions were chosen for a specific response classification to examine the attributes of high quality discussions (Table 6, page 88).

Important characteristics found to be shared in the discussions that were examined included frequent offering of information along with questioning and hypothesizing. The ability of the discussion flow to be actively facilitated or moderated was considered an important characteristic of these high quality discussions (Harasim, et al., 1995; Johanek & Rickly, 1995; Kimball, 1995). Groups exhibiting high quality discussions also had a lower response time per minute than other groups, indicating that more substantive dialogues which are rich in thought proceed at a slower pace (Table 5, page 85). In this respect, the “marginally synchronous” Webchat format served as an effective mode of communication.

Several other factors were observed to cause differences in discussions among the groups studied. The dynamics of small group interactions were affected by prior experience with electronic dialogues, social relations that were already in place, the effect of single strong personalities, and participation within the group. A major factor that influenced quality of discussions was the nature of the questions posed. Challenging questions that were directly related to understanding the project resulted in more thoughtful discussions.

Implications

Several conclusions can be drawn from this study that deserve consideration with respect to undergraduate science education and the larger science education community in general. As with any first look at a curriculum, this study also raises questions that deserve further investigation. This section addresses conclusions that have been made after reflection on the completed research and poses directions for further study.

The Importance of GTAs as Teachers

The important role of graduate teaching assistants in undergraduate science education has been noted as well as the inadequacies of educational institutions to provide needed support for their development as teachers (Abbott, Wulff, & Sego, 1989; Moore, 1991; Nyquist, Abbott, & Wulff, 1989; Sprague & Nyquist, 1989). Effectively implementing the laboratory project required the GTA to assume the roles of Culture Bridger, Knowledge Bridger, Problem Framer, and Knowledge Resource as described in the model for learning used in this study. Graduate teaching assistants must not only be competent in their discipline, but must also be adept at interpersonal skills and be willing to assume the multiple roles that an effective guide to learning must take on. Above all, they must be concerned for their students' learning. Educational institutions need to foster these skills and attitudes in these important educators. When innovative reform efforts modeling the complex, authentic practices of scientists are initiated, then valuing and promoting graduate teaching assistants as important educators is necessary if such efforts are to succeed.

Undergraduate Science and Pedagogy

A very interesting observation can be made concerning how this curriculum came to be implemented. The professor was willing to take risks and initiate change to improve his own teaching practices (Glasson & McKenzie, in press). As a scientist, this meant trying to make his course encompass aspects of his discipline that modeled the authentic practices of scientists. Because traditional methods of assessment were not appropriate for evaluating learning in this mode, more alternative or authentic forms of assessment resulted. The important implication for science educators here is that a first step at reform can come from the scientist. Authentic practices necessarily make learning a messy and time-consuming process, but the first step in science education reform can be made through respect for the scientist (or GTA) as an educator that mentors students into the discipline. Content knowledge becomes de-emphasized and acquired through the process of learning science as a method. With this approach, the scientist as educator is liberated from traditional text-bound curriculum approaches and science educators are not seen as prescribers of curricula, but rather as consultants that facilitate the process. The major implication here is that other scientists will recognize their unique potentials as educators capable of engaging students in learning through the very practices that are a part of their lives.

Research as a Portfolio

Originally, data for this study were collected from five separate sources. Later, these were combined into three major categories : videotapes of the labs and interviews along with researcher notes, electronic discussions as computer text files, and student species definition papers. Because each data set was different, its analysis was different also. In each case, the data was examined to reveal categories or themes that would allow interpretation. In the case of the videotape records of laboratories, vignettes describing selected laboratories allowed the researcher to portray the teacher in the roles proposed in the model for learning. An analysis of the electronic discussions was made possible by categorizing specific responses so that high quality discussions could be identified and more closely examined. Species definition papers required yet another method for demonstrating student learning. This entailed analyzing each paper for numbers and types references, organism examples, and defining concepts used. Once this knowledge was gained, specific papers could be more closely examined using this framework.

This qualitative research approach is directly tied to the authentic practices of assessment in science education reform. From this point of view, data should be collected as a rich variety of evidence of learning, reflecting the actions that the students take as they learn. In this sense, this varied collection of data becomes a “research portfolio”, with each set of data requiring its own particular method of analysis and also offering its own unique perspective on learning. Taken as a whole, these different findings give a richer overall view of the learning environment than any single view could alone. Each window has its own view. This view, however detailed and specific, is limited. The more windows, the better.

The Need for Further Study

The concept of a research portfolio using a variety of evidence is a double-edged sword. As more different data sets are used, less time is available for detailed and exhaustive analysis of any one set. This is an important limitation to this study. In this case, access to students was limited to the kinds of data collected, which included very limited time for interview and no time outside the actual scheduled laboratory times. The question of how individual students learned about the biological species concept could only be approached by the data gathered. For example, many questions could have been answered in follow-up interviews to the species concept papers. These did not occur. This study therefore represents an important first step in demonstrating how learning takes place in this kind of environment by looking more at the students as a group. It “paints with a broad brush”. The need now exists for a “finer brush” where a smaller group of individuals is studied in a detailed case analysis to more clearly define the process of how science concepts are acquired or restructured.

There are many avenues for further research which could extend from this study. An important one is the idea of learners in small groups working through peer collaboration to learn science concepts. Effective use of a project based curriculum was demonstrated in this study. An even more powerful vehicle would be student-created projects that are challenging. If concept acquisition could be effectively assessed, then the emphasis on learning science as a way of knowing as opposed to a body of knowledge could be advanced.

Because this curriculum was implemented in a special case (honors biology course), the next logical step for this approach is a more general course where students are not normally as highly motivated. Corresponding research needs to be conducted to validate this approach and these research findings in these different settings.

The Webchat electronic discussion format was researched during this study as a pilot. Initial findings and recommendations from this pilot need verification. Further study is needed as this technology becomes more widespread.

Using the model for learning to link a socio-cultural approach to teaching and learning to conceptual change theory worked well in this circumstance and represents a synthesis that should interest other educational researchers. Attempts to describe other settings using this model need to be made to demonstrate its efficacy and offer an alternate view of how concept learning occurs.

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Appendix A

Consent Form

and

E-Mail Survey Form

Consent Form

Consent Form for Undergraduate/Graduate Students
Interdisciplinary Science and Mathematics Education Project
Virginia Quality Education in Sciences and Technology (V-QUEST)

As part of the statewide V-QUEST Project, we invite you to participate in a study that will help us improve science and mathematics teaching.

The information collected may include your participation in one or two interviews that focus on your perceptions of science and mathematics teaching. These interviews will take about one hour and will be scheduled at your convenience. The interviews will be audio taped and transcribed.

As a participant in this project, we may also collect samples of your work and ask you to keep a journal or log of your activities. In addition, you may be surveyed to assess curriculum and instructional programs and ongoing activities of the project.

Your identity will remain anonymous in all reports that include information from your interviews, journals, logs, or classroom work.

Occasionally, we may video tape classroom interactions in your classes. Video tapes of your participation in science or mathematics classes may be shown at professional meetings or in university classes. While we will not use your name in videotapes, your face, actions and voice may appear so you will not be an anonymous participant.

From this project, we hope to learn how the science and mathematics curriculum and instructional practices are changed at your school. You are free to withdraw from this study at any time without penalty or prejudice, by contacting (local contact person at your university or community college and phone).

This study has been approved by the Human Subject Committee and the Institutional Review Board. If you have any further questions, please contact Dr. George Glasson, Division of Curriculum & Instruction, War Memorial Hall, Virginia Tech (703-231-5269) or Dr. Ernest R. Stout, Chair of the Institutional Review Board at Virginia Tech (703-231-9359).

Your signature below indicates that you have read the information above and have agreed to participate in the research project.

______________________________ ______________________

Signature of Participant Date

E-mail Survey

Dear Afternoon Honors Bio Lab Student:

I hope you will have the time to answer the following questions. They will give me an idea of who you are as a student and how you are progressing in the Honors Biology Lab. Remember that your cooperation with me is totally separate from evaluation in the lab. Also, when this data is used later as evidence in written reports, your name will be changed to a pseudonym to protect your individual identity. Thanks for all your help!

1.) Give a brief background on who you are--for example,

Where are you from and why did you come to VA Tech?

Are you a Freshman/Sophomore/Junior?

What is your major?

Why did you choose to take this course?

2.) How do you feel about the Isopod/Amphipod lab project so far?

Comment on both good and bad aspects of learning.

3.) Earlier, you were required to write a short paper on the definition of a species. Has your definition changed any? If so, why?

4.) Comment on your experience with Webchat. Try to include both positive and negative aspects of usability and the possibility for learning using this on-line communication software.

Appendix B

Materials on Electronic Reserve

for

Honors Biology Course

SYLLABUS - HONORS BIOLOGY H2984 (H1205) - FALL 1995

INSTRUCTOR: Arthur L. Buikema OFFICE: 1000 Derring Hall OFFICE HOURS: by appointment --

Honors Biology is offered under the Honors System at Virginia Tech and all violations will be reported. ------------------------------------- Week of Topic/ Campbell

Aug 21 What holds this stuff all together? 2-39

Aug 28 Unique properties of water and the 40-63 organic garden

Sep 4 The organic garden continued 64-90 Introduction to metabolism 91-111

Sep 11 What are cells made of? 116-150 Can a membrane be fluid and still do its job? 151-172

Sep 18 How is energy released? 173-198

Sep 25 How is energy trapped? 199-220

Oct 2 How DNA is inherited? 300-315 Making proteins from DNA 316-343

Oct 9 How do cells reproduce? 221-239 The true meaning of sex! 244-257

Oct 16 Did Mendel cheat on his data? 258-279

Oct 23 Chromosomes and inheritance 280-299

Oct 30 Genetics of viruses and bacteria 344-371 POSITION PAPER DUE

Nov 6 How are genes expressed? 372-389 Is DNA Technology a good idea? 390-415

Nov 13 How does evolution occur? 420-455

Nov 20 THANKSGIVING BREAK

Nov 27 Are we really related to monkeys? 456-499

Dec 4 Alternate hypotheses on the origin of life 504-514 Evaluations

Dec 14 Final Examination due Thursday Dec 14 by 12:05 pm

Text: Campbell; Biology, Edition 3. Other Course Requirements: 1) Pechenik, A Short Guide to Writing about Biology 2) Adobe Acrobat 3) Active PID

CLASS ATTENDANCE: Students are expected to attend class. Students who miss more than 15% of the “lectures” or more than 1 laboratory session without a valid medical excuse will have their class participation grade reduced 50%. If absences in “lecture” exceed 25% or you miss more than 2 labs without a valid excuse, a course grade of F will be given.

CLASS PARTICIPATION: Students are expected to be prepared before class and to participate in class discussions. Students must provide at least two (2) questions per week that are relevant to the topic. These are to be handed in at the beginning of class each week. Questions handed in after class on Monday will not be accepted. Twice each week, you will be asked to respond briefly in writing to the topic being discussed or the speaker. These papers will be used to partially evaluate class participation.

SPEAKERS: During the semester invited speakers will present different perspectives on biological/environmental/ethical issues. In the past these speakers have included engineers, family systems theorists, poets, economists, sociologists, etc. You are expected to attend at least 10 presentations. Once a final program exists you will receive a copy.

REACTION PAPER: At the end of each speaker presentation, you must turn in a 1/2 page paper summarizing your reaction to the speaker’s presentation.

EXAMINATIONS. There will be two take-home, open-book essay examinations that will require integration and application of information. Creativity is expected. Students may use any source necessary to answer the questions, including the aid of another person such as a faculty member. Students will be given about one week for each examination.

POSITION PAPER. See separate file for description of paper.

PEER CRITIQUE: All written assignments must be reviewed by another person before they are turned in for a grade. Papers can be sent to the peer reviewer electronically. To do this, you must purchase a copy of Adobe Acrobat.

The instructor will provide you with the name of the person who will peer critique each of your papers. You must allow 24 hrs for a peer critique to be completed. As the person conducting the peer critique, you must return your critique within 24 hrs of receipt and give the author at least 24 hrs to respond before the assignment is due.

When you turn in your paper, you must identify the person who critiqued your paper (or should have critiqued it) and also provide a copy of their critique. There are penalities for not participating in the peer critique. If you don't do the peer critiques required in this course, your final course grade will be reduced by one letter grade.

As a peer reviewer, you will be graded on the thoroughness of the critique. The grade given to the author of the paper will based on the topic, its coverage and response to the peer who critiqued the paper.

PRINTED PAPERS: All assignments must be typewritten or printed. Papers not printed or typewritten will not be graded.

REGRADES: If an examination answer or paper does not meet expectations, you will be given an opportunity to rewrite the assignment (one time/exam or paper). Your grade for this assignment will be the average grade for the original score and the rewrite.

COURSE GRADE. The final course grade will be determined as follows:

Examination Number 1 20% Examination Number 2 20% Position Paper 10% Peer Critiques 10% Reaction Papers 10% Lecture Discussions 10% Laboratory 20%

ELECTRONIC RESERVE: All assignments will be placed on electronic reserve. Xeroxing will be held to a minimum.

HONORS BIOLOGY LABORATORY: An Honors Biology Lab is required as part of this course. Separate instructions will be given in the laboratory by the Graduate Teaching Assistant.

SIGNIFICANT DATES: Monday, August 28: no class Monday, October 30: position paper due Thanksgiving Week: no class

PORTFOLIOS: Students are encouraged to keep copies of all written work, including the peer critiques that you conduct, for this class and place them into a portfolio. When you apply for a job, this portfolio may be useful to demonstrate the types of critical reading and writing experiences that you have had.

USE OF COMMERCIAL NOTES

The use of commercially purchased notes (selling and buying) will not be permitted in this class. Any violation of this policy will be considered an Honor Code violation.

CLASS CONTRACT - FALL 1995

IF YOUR NAME IS ON THE CLASS ROLE AND YOU ELECT TO STAY IN THE CLASS, THIS MUST BE SIGNED AND HANDED IN NO LATER THAN THE THIRD CLASS PERIOD.

By taking Honors Biology, I:

1. am expected to be prepared before class and to participate in class discussions.
2. know that if I miss more than 15% of the “lectures” or more than 1 laboratory session without a valid medical excuse I will have my class participation grade reduced 50%. If my absences in “lecture” exceed 25% or I miss more than two laboratory sessions without a valid excuse, I will be given a course grade of F.
3. must provide at least 2 questions per week that are relevant to the topic and these are due at first class of each week. Questions handed late will not be accepted.
4. will attend at least 10 speaker presentations and prepare a 1/2 page paper summarizing my reaction to the speaker.
5. may use any source necessary to answer the questions on the take-home, open-book essay exams.
6. must write a position paper.
7. have my written work reviewed by a class member. I must allow 24 hrs for a peer critique to be completed. As the person conducting the peer critique, I must return my critique within 24 hrs of receipt and give the author at least 24 hrs to respond before the assignment is due.If I do not comply, my final course grade will be reduced by one letter grade.

8. may rewrite an assignment and receive credit for the revision. My grade for a rewritten assignment will be the average grade of the original score and the rewrite.

9. agree to inform the professor by voice mail if I will be absent from class.

10. understand that all assignments must be typed or printed or they will not be graded.

11. understand that the requirements for laboratory will be provided by the graduate teaching assistant.

SIGNED: __________________________ DATE ____________

August 1995

TO: Students in Honors Biology

FROM: Dr. Arthur L. Buikema, Jr.

Welcome! Thank you for choosing my class as part of you college curriculum. You have worked hard both to be successful at Va Tech and to pay for your education. In response to your efforts, it is my job to ensure that you truly feel that you have received quality instruction.

You are important to me. Thank you for the opportunity for allowing me to teach this course to you. My responsibility is to make this educational experience as stimulating and rewarding as possible.

To do this, I must create an environment conducive to facilitating your learning experience. But, I cannot do this alone. I need your assistance. I depend on you as an equal and active participant in this teaching opportunity. My responsibility is to come to class prepared and your responsibility is to come to class prepared as well. To do this, you will have to read the assigned materials prior to coming to class and to actively participate in class discussions. To do this, I also will need your undivided attention in class. I will come to class with an open mind and enthusiasm and I expect you to do the same. I cannot teach you anything unless you are willing to learn.

If at any time you feel that you are not getting what you expected from this course, please feel free to communicate this to me. If there are problems, we need to resolve them as quickly as possible. I look forward to making this a unique and valuable learning experience for you.

Thank you.

POSITION PAPER

A position paper is required during the semester. The position paper will be an exercise in writing a unbiased review of an issue. Imagine that you work for a senator who has to vote on hundreds of bills each year. The senator cannot be informed on every subject. Your job is to identify the issue, present the pros and cons of the issue and summarize the ramifications of what an yea or nay vote means, so your employer can make an intelligent decision. The position paper must not reflect your personal bias. Remember, you are not a lobbyist and it is not your job to decide how your employer will vote.

TOPIC. You will need to identify a specific problem or issue that you feel strongly about. The topic can be any issue related to biology, medicine or environment. THE ONLY REQUIREMENT IS THAT THE TOPIC MUST BE APPROVED BY THE INSTRUCTOR BEFORE YOU BEGIN. A common mistake among students is to select an issue that is too broad and which cannot be completed in the required format.

PAPER. Once the topic has been approved, collect the information and begin to write the paper. You must have at least 6 references.

The total length of the paper must not exceed five (5) typed pages. The main body of the paper must not be more than three (3) typed pages. The main body must have the following sections:

1. Brief statement of the problem or issue (about three sentences).
2. Concise listing of the pros and cons (usually about one-half page). Best if pros/cons are presented side by side with bullets for emphasis.
3. Narrative discussing the significance of the problem or issue and the ramifications of voting yea or nay on the issue (usually one and one-half pages).

4. Brief summary statement that includes a statement of the issue and the pros and cons (usually less than one-half page).

On page four list your references. On page five provide a statement of your personal views on the issue.

CRITIQUE. Don't forget to have this paper critiqued by a classmate.

CHECK SHEET FOR WRITING AND REVIEWING THE POSITION PAPER (This check sheet must be attached to the position paper; must be marked and signed by the writer and the person conducting the critique.)

Author ______________________________ Id Number _____-___-________ Peer Reviewer ________________________ Id Number _____-___-________ -- Author-Peer (please check each item when you have completed the critique.)

_____|_____ This paper is not plagiarized. While it draws on the work of others, the paper is the original effort of the author.

This paper has been proof-read for: _____|_____ spelling errors. _____|_____ grammatical errors. _____|_____ verbose and non-scientific writing.

_____|_____ This paper is typewritten.

_____|_____ The paper uses an appropriate number and kinds of references.

_____|_____ The references conform to the scientific style described in Pechenik (1987).

_____|_____ This paper uses a voice appropriate for scientific writing.

_____|_____ The paper is well organized such that the reader can easily construct an outline of the paper.

_____|_____ There are no major omissions, interpretations or misstated facts.

Each subthesis of this paper is: _____|_____ comprehensive. _____|_____ well documented. _____|_____ coherent. _____|_____ substantively linked to other subtheses. _____|_____ makes a good contribution to the main thesis.

_____|_____ This paper is based on solid research and interpretation, not simply hearsay.

_____|_____ This paper is appropriately paragraphed .

_____|_____ The writer has a clear grasp of the topic.

_____|_____ In the introduction, the author clearly states the premise or hypothesis.

_____|_____ The conclusion is thoughtful and cogent; it is more than a mere summary.

_____|_____ The paper makes an original contribution and is not a mere literature review.

_____|_____ The author is persuasive and the paper is well conceived and written.

_____|_____ I was given 24 hrs to conduct the critique and I returned it so the author could respond in a timely fashion.

CHECK SHEET FOR WRITING AND REVIEWING EXAMINATION 1 (This check sheet must be attached to examination 1; marked and signed by the writer and the person conducting the critique.)

Author ______________________________ Id Number _____-___-________ Peer Reviewer ________________________ Id Number _____-___-________ ------------- -- Author-Peer (please check each item when you have completed the critique.)

_____|_____ This paper is not plagiarized. While it draws on the work of others, the paper is the original effort of the author.

This paper has been proof-read for: _____|_____ spelling errors. _____|_____ grammatical errors. _____|_____ verbose and non-scientific writing.

_____|_____ This paper is typewritten.

_____|_____ The references conform to the scientific style described in Pechenik (1987).

_____|_____ The paper uses an appropriate number and kind of references.

_____|_____ This paper uses a voice appropriate for scientific writing.

_____|_____ The paper is well organized such that the reader can easily construct an outline of the paper.

_____|_____ There are no major omissions, interpretations or misstated facts.

Each subthesis of this paper is: _____|_____ comprehensive. _____|_____ well documented. _____|_____ coherent. _____|_____ substantively linked to other subtheses. _____|_____ makes a good contribution to the main thesis.

_____|_____ This paper is based on solid research and interpretation, not simply hearsay.

_____|_____ This paper is appropriately paragraphed .

_____|_____ The writer has a clear grasp of the topic.

_____|_____ In the introduction, the author clearly states the premise or hypothesis.

_____|_____ The conclusion is thoughtful and cogent; it is more than a mere summary.

_____|_____ The paper makes an original contribution and is not a mere literature review.

_____|_____ The author is persuasive and the paper is well conceived and written.

_____|_____ I was given 24 hrs to conduct the critique and I returned it so the author could respond in a timely fashion.

DISCUSSION QUESTIONS FOR HONORS BIOLOGY

(These questions are compiled from a variety of sources including several Biology textbooks.)

QUESTION SET NUMBER 1 - ATOMS AND OTHER GOOD THINGS

Discuss this statement: "There is no pollution. Chemicals used by farmers and industry are made up of the same atoms that are in our environment."

How can radioisotopes incorporated in cells compound the threat of pollution in air, water and soil?

Why is it difficult to give meaning to life?

If you have ever been a witness in court, you have had to say this phase: " Do you swear to tell the truth, the whole truth, and nothing but the truth...." What are some of the problems inherent in this statement? Can you think of an alternative wording for this statement?

When I was raised on the farm, most of our chickens were keep in a coop. A few roamed the farm yard. The egg yolk from chickens that roamed the yard was a very intense yellow-orange color. Those kept in the coop were a pale yellow. What is going on here? State a testable hypothesis. Design an experiment to test your hypothesis.

Homeostasis has been defined various ways; for example, homeostasis is the dynamic maintenance of steady states. Persons interested in cybernetics (homeostasis or control theory) have had to deal with many dilemmas in the application of this concept to describe systems at levels higher than the person or organism. Negative feedback (deviation diminution) can explain the regulation of blood sugar, but may not be useful in trying to describe succession of different ecosystems (increases in diversity and complexity), evolution of different species (change in gene pools as organisms interact with their environment), or how people get well during individual or family therapy even though they come from different backgrounds or cultures (choices or options increase as well as communication skills); obviously changes occur that are beneficial and ensure survival. Maybe the "second cybernetics" (positive feedback or deviation amplification) may be more important than we realized. Maybe our concept of the steady state is too rigid. Maybe ..... So what are the questions? 1) Does the definition above limit our ability to broadly apply the concept of homeostasis? How would you restate the definition so that it can be more broadly used? Are there any examples from your readings that will support your answer? 2) Could the problem be in our definition of the "steady state"? How Would you define the "steady state"? Why?

What is vitalism? Can it exist? What do you feel about this "Biologists have been unable to discover a physical or chemical
basis for human thoughts or ideas because such abstract aspects of being human have no basis fin natural processes."

Appendix C

Materials on Electronic Reserve

for

Honors Biology Lab

HONORS BIOLOGY LABORATORY SYLLABUS Fall 1995

Course #: H2984 Index #'s: 4876 and 4877

Teaching Assistant: Alicia Slater (Schultheis)

Office: 1082 Derring Hall

Office hours: By appointment

Phone: 231-9053 (ofc) 951-4116 (hm)

Text: Pechenik J.A. 1993. A Short Guide to Writing About Biology. 2nd edition. Harper Collins College Publishers. New York, NY.

Attendance Policy: Students are required to attend every lab. Work missed due to unexcused absences cannot be made up. Also, your laboratory attendance affects your course grade. Check your syllabus from lecture for details.

Purpose: This laboratory was designed with several objectives in mind. Specific objectives will be laid out with each exercise. In general, it is expected that, by the end of the semester, the student will:

1) be adept at writing in a concise, scientific manner (this includes familiarity with library resources, proper format and tone for scientific journals)

2) be able to collect, record, analyze and successfully communicate results and conclusions of field, laboratory, and observational data

3) be able to use and construct dichotomous keys for the purpose of taxonomic identification

4) be able to distinguish discrete populations of animals on the basis of morphological data, geographic barriers and molecular data

5) know how to critically review the work of their peers as well as offer constructive criticisms

Written Reports: All written papers must be typed, double-spaced, and on time. Papers not meeting these requirements will not be accepted. You will have at least one chance to rewrite each paper after I have reviewed it. You may accept the first grade given or rewrite the paper to try for a better grade. You will also review other students' papers in a peer review process.

Grading: Library Report 10 A: ≥ 90% Fish Report 15 B: 80-89 % Tree Key 15 C: 70-79% Fermentation Report 20 D: 60-69% Isopod Report 40 F: <60% 100

Please note changes to revised syllabus

Lab # /Date/ Topic --1 Aug. 24 The VT Library-- How to find what you're looking for...

2 Aug. 31 What is the mean height of the students in your Honors Biology Lab? Library Paper Due

3 Sept. 7 Aggressive Displays in Siamese Fighting Fish **Do not wear bright colors to lab**

4 Sept. 14 Yuk! What kind of bug is that?

5 Sept. 21 How to tell a Bradford Pear Tree from a Maple Tree... **no formal lab Meeting** Fish Lab Write-up Due

6 Sept. 28 Why do naturally aged wines have only 12 - 14% alcohol even though there may be sugar remaining? (aka Fermentation Lab)

7 Oct. 5 Isopod/Amphipod ecology, molecular biology and geographic barriers to gene flow. Fermentation Lab Write-up Due

8 Oct. 12 " " Isopod/Amphipod Intro. and Methods Due

9 Oct. 19 " "

10 Oct. 26 " "

11 Nov. 2 " "

12 Nov. 9 TBA Full report Due

13 Nov. 16 TBA Isopod/Amphipod Peer Review Due

14 Nov. 23 **Thanksgiving Holiday**

15 Nov. 30 Final lab meeting Wrap-up: student evaluations and comments

I know this sounds like a lot of work and it will be. The motto for the lab section of this course is "Expect a lot and the students will rise to the occasion, expect very little, and they will do the same". Just remember we have a whole semester to accomplish the aforementioned objectives and that I am here to help you.

GUIDELINES FOR WRITTEN REPORTS

All reports must be typed, double-spaced, and on time. Number all pages except: title page, the first page of text, and the literature cited section. Margin sizes from 1-1.5' are acceptable. Papers not meeting these requirements will not be accepted. Note: The use of typewriters is strongly discouraged.

Please write all reports in the following format:

Title page: Title of your paper, your name, course #, my name and date submitted should be included.

Abstract: The abstract is placed at the beginning of the report following the title page. Your abstract should be about 200 words long and should include the main conclusions from the studies well as some background information and information on the methods used. In "real life" abstracts are often the only part of the paper some readers ever see and it is important that it accurately reflects the paper's contents and be completely self-contained. For more information: see pg. 104 in Pechenik.

Introduction: The introduction is limited to the scope, purpose, and rationale of the study. What is the question you are investigating? Give any pertinent background information. Explicitly state your hypothesis. For more information: see pgs. 94-102 in Pechenik.

Methods: Give your methods in enough detail for someone else to conduct the experiment again using only your methods section for direction. Keep this section short and clear. For more information: see pgs. 54-58 in Pechenik.

Results: Report your findings (such as major trends observed, etc.) in the results section, but do not interpret them. Use tables and figures for your data. The text should briefly cover the results, referring the reader to the appropriate tables and figures. Always label tables and figures. For more information: see pgs. 60-81 in Pechenik.

Discussion: Interpret your data here. What conclusions can you draw from your results? Make sure you address the hypothesis stated in the introduction. For more information: see pgs. 85-94 in Pechenik.

Literature Cited: This section contains references for the authors you cited in your paper. If you didn't cite a source, do not include it in your literature cited section. Do not number pages in this section. Follow instructions in the pages from Scientific Style and Format you copied as part of the library assignment. All citations in the text should be in this form:(author date).

Each section (except the title page) should begin with the words in bold above. The title page, abstract and literature cited section are pages separate from the body of the paper.

Questions??? See Pechenik, if you can't find the answer there, then ask me.

Guidelines for Amphipod Lab Report

As with previous reports, the write-up should include a title page, an abstract, an introduction, and methods, result, and discussion sections. See the handout "Guidelines for written reports" if you have questions.

This lab will be peer reviewed. I will assign peer reviewers the day the full report is handed in.

In order to help you start early, the introduction and methods sections are due Oct. 19.

Your results section will include the slides of the gels run by all groups.

Your introduction should contain your cladograms, as they embody your hypotheses.

In your discussion section, assign each group of organisms to the site you think it was collected in.

The experiment will be performed in groups. However, each individual is responsible for turning in a lab report.

A minimum of three references must be included.

Finally, some details are subject to change, but this should give you an idea of what is required of you.

ISOPOD / AMPHIPOD LAB INTRODUCTION AND SCHEDULE

Goal: Students will be given organisms collected from various sites throughout the New River Valley and will be asked to identify them. Then, using morphological, geographical and molecular data the students will assign the organisms to the site at which they were most likely collected.

Life History and Morphology

The students will be asked to identify the organisms and to obtain life history information about the organisms. Students will be informed of the location of all the collection sites, but will not be told which organisms were collected from each site. The students will be asked to hypothesize about the relatedness of the organisms based on morphology. Students will draw a cladogram that embodies their hypothesis based on morphology.

Geography

Students will be given topographic maps with the collection sites labeled on them and will be asked to hypothesize about the probability of gene flow between populations based on geography (i.e. are there geographic barriers to gene flow?).

Molecular Data

Students will use molecular data obtained by extracting genomic DNA and using RAPD's (Random Amplification of Polymorphic DNA) to formulate a hypothesis of relatedness. A cladogram that embodies this hypothesis will also be drawn. Finally, the students will use all the above information, life history, morphology, geography and molecular data to assign each organism to a collection site.

At the beginning of the semester, students were asked to write a short paper defining what they thought a species is. At the end of this lab students will be asked to rewrite the paper and incorporate what they learned from this lab into their definitions.

Tentative Schedule

Week 1: Introduction and basic outline. Oct 5 Identification of organisms. Formulate hypotheses based on morphological and geographic data.

Week 2: Discussion of life history information. In what Oct. 12 type of habitat are the organisms identified last week found? Based on this information, what are the possible collection sites for the organisms? Based on morphology, how do you think the organisms are related? Guest Lecturer: Jason Bond (Intro to Cladistics) Introduction to Molecular Data Practice DNA Extraction

Week 3: Based on morphology and geographic data, how Oct. 19 genetically similar do you think the organisms are? What is your hypothesis about the results of the molecular data? Introduction to PCR DNA Extraction Hypotheses Due (including cladograms)

Week 4: PCR (Polymerase Chain Reaction) of DNA extracted last Oct. 26 week Introduction to RAPD procedure collect additional morphological data

Week 5: Run Gels, redo PCR if necessary Nov. 2

Week 6: Go over results, Run Gels again if necessary Nov. 9 *Full Report Due*

Week 7: Discussion, go over results, redo gels if necessary Nov. 16 *Peer Review/Final Report Due*

Week 8: THANKSGIVING HOLIDAY Nov. 23

Week 9: Final Lab Meeting, Wrap up and discussion Nov. 30 Species Definition #2 Due

Appendix D

Tables of Raw Data

for

Webchat Discussions

Raw Data for Group 1

	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	total	average
webchat related	11	16	11	8	9			4	59	9.8
social responses	4	9	6	8	1			7	35	5.8
course related	28	24	11	25	19			21	107	17.8
offering information	8	4	3	4	4			1	24	4
engaging	14	12	5	14	15			16	76	12.7
total # of responses	43	49	28	41	29			32	190	31.7
length in minutes	64	78	26	64	64			44	340	56.7

Raw Data for Group 2

group 2										
	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	total	average
webchat related	20	29	15	6					70	17.5
social responses	117	16	38	5					176	44
course related	27	38	36	5					106	26.5
offering information	3	9	10	2					24	6
engaging	4	7	19	1					31	7.8
total # of responses	164	83	89	16					352	88
length in minutes	127	52	49	20					248	62

Raw Data for Group 3

group 3											
	week 1	week 2	week 3	week 4a	week 4b	week 5	week 6	week 7	week 8	total	average
webchat related	9	5	7	10	4	7	4	7	10	63	7
social responses	2	0	3	3	2	4	1	2	6	25	2.8
course related	19	30	26	7	13	9	12	14	9	139	15.4
offering information	7	11	13	5	5	3	3	1	3	51	5.7
engaging	2	14	7	1	7	3	3	4	1	42	4.7
total # of responses	30	35	36	20	19	20	17	23	25	225	25
length in minutes	40	43	39	39	34	30	34	36	37	293	32.5

Raw Data for Group 4

group 4										
	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	total	average
webchat related	14	12	15	10	14				65	13
social responses	5	16	20	19	16				76	15.2
course related	5	41	39	29	19				133	26.6
offering information	0	15	18	6	5				44	8.8
engaging	0	10	9	5	5				29	5.8
total # of responses	24	69	74	58	49				274	54.8
length in minutes	26	37	37	33	37				170	34

Raw Data for Group 5

group 5										
	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	total	average
webchat related	18	22	20						60	20
social responses	8	8	4						20	6.7
course related	24	27	13						64	21.3
offering information	4	14	3						21	7
engaging	6	8	4						18	6
total # of responses	50	57	37						144	48
length in minutes	30	31	37						98	32.6

Raw Data: Totals for All Groups

totals					
	group 1	group 2	group 3	group 4	group 5
webchat related	59	70	63	65	60
social responses	35	176	25	76	20
course related	107	106	139	133	64
offering information	24	24	51	44	21
engaging	76	31	42	29	18
total # of responses	201	352	227	274	144
length in minutes	340	248	293	170	98

Raw Data: Averages for Each Group

averages					
	group 1	group 2	group 3	group 4	group 5
webchat related	9.8	17.5	7	13	20
social responses	5.8	44	2.8	15.2	6.7
course related	17.8	26.5	15.4	26.6	21.3
offering information	4	6	5.7	8.8	7
engaging	12.7	7.8	4.7	5.8	6
total # of responses	31.7	88	25	54.8	48
length in minutes	56.7	62	32.5	34	32.6

Appendix E

Webchat Dialogues

The actual Webchat discussions for the table above follow below in the format that the participants view it, last entry first. One must scroll to the bottom of the field on the Webchat page to view the first entry. (In this case, read from the bottom up.) Pseudonyms have been used in place of real names, otherwise all entries appear exactly as they were posted, including typos, actual phrasing, etc.

Webchat Discussion, Group 1, Week 1

:...10/15/95 10:35 PM

good bye. "happy painting and God bless" -- Bob Ross

Ann:...10/15/95 10:33 PM

good idea. I guess we'll just have to figure out the specifics as we go along. Are you all about ready to call it quits?

:...10/15/95 10:31 PM

that sounds good, rick. i know you all are going to want to kill me because i haven't been on as long as you all, but i have a laundry date (i haven't done any since i have been down here) and an outrageous amount of calculus work to do because i've been sick and missed the last two classes. so i'm going to go. are we going to do this again next week, same bat time, same bat chanel

Ann:...10/15/95 10:27 PM

Also, if we know how much molecular makeup each organism retained, it help us establish an outgroup. We can see what species might have some of the characteristics that we think the other organisms retained. Do you understand what I'm trying to say? Bye Rick. I think I'll log out too.

Rick:...10/15/95 10:26 PM

By comparing the similarities between the fingerprints (this is all just speculation on my part) and seeing how much alike they are, I think we might be able to guess how closely related the organisms are. It could be speculated that when part of the fingerprint matches from one organism to another, the that particular piece came from a shared ancestor.

Thad:...10/15/95 10:24 PM

(sorry guys, i keep forgetting to put my name.)

:...10/15/95 10:23 PM

how will it help us if we determine how much of the original molecular makeup each organism retained? i guess the ones taht are more closely related will live geographically closer to each other.?.?.?

Rick:...10/15/95 10:22 PM

I guess we'll just have to wait and see what the data look like and then decide what, if anything, we can do with it. I'm pretty much fresh out of ideas on the subject. So if it's Ok with every one I'm cutting out.

Thad:...10/15/95 10:17 PM

(no one else came on. my name just wasn't going up) i guess we will have to compare the molecular data with our other data to determine where the species came from? and i don't really expect it to be that easy.

Rick:...10/15/95 10:16 PM

Good point Ann, I didn't even think of it. The data from the insect and isopods could give us a clue to which developed first and how much of the original molecular make-up did each one retain.

Rick:...10/15/95 10:13 PM

Who just came on? Once we get our data and determine the molecular relationships between our organisms how do we apply that to determining location of the organism. The data really won't tell us which G. minus is suited for shaded water or fast current etc...

Ann:...10/15/95 10:12 PM

there are 5 sites

Ann:...10/15/95 10:11 PM

That's true. We could also use the molecular data to find the similarities the other species - to find which are more closely related, etc.

:...10/15/95 10:11 PM

we have six organisms, how many sites are there? (i don't have that data near me)

Rick:...10/15/95 10:09 PM

Exactly Thad. I have a hunch that two of the three G.minus either came both from site A or one from A and one from B. If so, using morphological data wouln'd be much help in determining which G. minus was which.

:...10/15/95 10:09 PM

i think it is almost certain that the G. minus are of a different variations, how else would be we be able to distinguish where they are from? the molecular data will be good for determining what the variations are, right?

Thad:...10/15/95 10:06 PM

wouldn't the molecular data be useful when the organisms are closely related. like the three species of G. minus

Rick:...10/15/95 10:05 PM

Ok, so we're using G lacustris and we want to get some samples but we have to look in to that. The second question dealt with the importance of the molecular date we're going to start collecting next week. First this might be important in determining if the G. minus are of different variation and if so to what extent.

Ann:...10/15/95 10:05 PM

Hey Thad! What do you all think about the second question? Wasn't it about when molecular data would be useful

Thad:...10/15/95 10:03 PM

i'm just checking, but is anybody else out there? i'm starting to feel all alone.

Thad:...10/15/95 10:01 PM

that sounds like a good pln to me. we'd have to check with (the GTA) as to whether we could get some.

Rick:...10/15/95 10:00 PM

If you scroll down the page to the message I sent at 9:42 it explains the madness behind my madness.

Thad:...10/15/95 9:59 PM

why G. lacustris? is it just a guess?

Thad:...10/15/95 9:58 PM

i also think it would be easier to focus on just a few major characteristics. there is no sense in doing something more complicated than it needs to be.

Rick:...10/15/95 9:58 PM

We thought G. lacustris and now we're wondering if we can actually get some.

Thad:...10/15/95 9:57 PM

alright, sorry it took my so long to get on. if it wasn't for rick i wouldn't have made it here at all. (thanks rick) so, what are you guys thinking so far about an outgroup?

Rick:...10/15/95 9:56 PM

I see we just picked up Thad. So if he has any ideas on an outgroup, we're ready and waiting. I would have to agree with Ann that we only should pick a few characteristics, unless we can get a hold of one of those cladogram programs mentioned Thursday. If we had one of those, we could get a tree for 20 or 30 characters in half an hour.

Ann:...10/15/95 9:53 PM

I would think that we would just have to use the keys and pick a a few characteristics and then compare them to the three G. minus. One possibility would be to focus on the eyes and antenna length, etc.

Thad:...10/15/95 9:53 PM

heowdy rick and ann

Rick:...10/15/95 9:49 PM

I think we could try it, but where are we going to get G. lacustris samples, or do we just use keys to make some physiological comparisons?

Ann:...10/15/95 9:44 PM

That could definitely be a possiblity.

Rick:...10/15/95 9:42 PM

I'm looking at a distribution map of Gammarus over North America (from The freshwater amphipod crustaceans of North America, USEPA 1972) and it looks like G. lacustris is the most widely distributed species, whereas G. minus is found only in Appalachia and some parts of the Mississpi valley. The extent of G. lacustris compared to G. minus could mean that G, minus developed from G. lacustris. So it might be a good outgroup.

Ann:...10/15/95 9:37 PM

This might help in finding out which site they are from, but I still don't know what kind of outgroup we should use for distinguishing the three G. minus.

Rick:...10/15/95 9:35 PM

That's a type of character that we need to examine, like in the spider model with different abdomens and such.

Ann:...10/15/95 9:33 PM

Hey y'all! I found that there are morphological differences in G. minus that live in caves and in surface streams. This includes reductions and absence of eyes, antenna and pigmentation.

Rick:...10/15/95 9:29 PM

OK, this is the first time we're getting together at once so I hope it works. First off, Tammy, the serial number for the Acrobat is WVW200R3101660-848. The first question is what might make a good outgroup. I don't think we really need an outgroup for the cladogram betwwen the insect, isopod, and amphipod. The real problem is determining the relationships between the three examples of G. minus.

Webchat Discussion, Group 3, Week 2

Helen:...10/16/95 10:41 PM

I have an 8:00 too, bye.

Penny:...10/16/95 10:40 PM

I need to go too, so I will see ya'll sometime.

Penny:...10/16/95 10:39 PM

I don't know.

Fern:...10/16/95 10:39 PM

I agree with the decapods idea. I have an 8:00 class tomorrow, so I really have to get to bed. Bye everybody!

Fern:...10/16/95 10:39 PM

I agree with the decapods idea. I have an 8:00 class tomorrow, so I really have to get to bed. Bye everybody!

Helen:...10/16/95 10:38 PM

Where do we go from here?

Helen:...10/16/95 10:38 PM

Maybe decapods?

Penny:...10/16/95 10:37 PM

I say use Decapods.

Fern:...10/16/95 10:35 PM

Decapods(lobsters,crayfish)? or maybe copepods(in plankton)?

Penny:...10/16/95 10:32 PM

I really do not know. Any ideas?

Fern:...10/16/95 10:31 PM

Okay, what crustacean can we use to compare the isopods and amphipods?

Penny:...10/16/95 10:29 PM

I guess so since that is all that is left.

Fern:...10/16/95 10:28 PM

I don't think using an extinct subphylum would be wise. Does that mean that we should use Cheliceriformes?

Penny:...10/16/95 10:27 PM

Would it make sense to use something that is extinct?

Helen:...10/16/95 10:25 PM

Ithink that's what we're going to have to do. Because insecta is a class and crusteacea is a subphylum.

Fern:...10/16/95 10:25 PM

We could do that. Do you want to use Trilobitomorpha or Cheliceriformes(arachnids and other stuff)?

Penny:...10/16/95 10:23 PM

Couldn't we compare using the subphylums?

Fern:...10/16/95 10:21 PM

Let's figure out what the best class would be to compare the insect with the crustaceans.

Penny:...10/16/95 10:20 PM

Anyone have any suggestions?

Fern:...10/16/95 10:19 PM

We need to find another Order of crustacean.

Penny:...10/16/95 10:18 PM

Well, I guess we should go with the first suggestions.

Helen:...10/16/95 10:17 PM

How can we compare isopods and amphipods?

Fern:...10/16/95 10:12 PM

We do need 2: one to compare the two classes, and one to compare the isopods and amphipods.

Fern:...10/16/95 10:11 PM

(looking on pg. A4 in back of book) We could use trilobites, but they're extinct. I'm afraid we're stuck with those choices.

Penny:...10/16/95 10:10 PM

I think (the GTA) said we would need at least 2.

Helen:...10/16/95 10:09 PM

I agree about insects and crustaceans--I think that might be a good place to start. But what about using 2
different outgroups? Won't we need 2?

Helen:...10/16/95 10:09 PM

I agree about insects and crustaceans--I think that might be a good place to start. But what about using 2
different outgroups? Won't we need 2?

Penny:...10/16/95 10:07 PM

do we have to use arachnids, centipedes, and millipedes?

Fern:...10/16/95 10:04 PM

I was looking at classes that could be used to compare crustaceans and insects. What about arachnids, or centipedes, or millipedes. Also, any other suggestions?

Penny:...10/16/95 10:03 PM

It looks like a tie so someone else has to vote.

Penny:...10/16/95 10:02 PM

I have not really had a chance to do any research, so why don't we start with the molecular data.

Helen:...10/16/95 10:02 PM

Hi! This is HElen. I made it. I guess we should try to tackle outgroups first...maybe we can come up with some ideas?

Fern:...10/16/95 10:01 PM

No.

Penny:...10/16/95 10:00 PM

It does not really matter to me. Do you care?

Fern:...10/16/95 9:58 PM

Hello. Do you want to talk about possible outgroups first or about molecular data?

Penny:...10/16/95 9:58 PM

Hello, anyone here yet?