The Effects of Inter-School Collaboration on Student Written Product Scores in a Problem-Based, Constructivist Environment

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THE EFFECTS OF INTER-SCHOOL COLLABORATION ON STUDENT WRITTEN PRODUCT SCORES IN A PROBLEM-BASED, CONSTRUCTIVIST ENVIRONMENT

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(ABSTRACT)

Recent studies indicate that American high school students are not performing adequately on standardized tests in the area of science. In response, there has been a call to reform science education in the United States. These reform efforts coincide with advances in electronic communication and information technology that have revolutionized knowledge sharing. This study describes an effort to assess the effects of inter-school electronic collaboration on the quality of student final written products. In this study, students ranging in grade levels from 9-12 completed a problem-based earth science module delivered via the Internet.

The module presented students with an ill-structured problem, problem-solving model, resources, and recommendations for further inquiry, all related to an authentic environmental issue. Students were also given a set of guidelines for a final written product and a minimum of 4 weeks to complete the project. While all students worked in cooperative groups within their classrooms, selected cooperative groups worked with cooperative groups of students in other schools via e-mail. These groups were collectively referred to as parallel groups. Cooperative groups of students who did not work via e-mail with other groups were collectively referred to as nonparallel groups.

A team of evaluators scored the written products of parallel and nonparallel groups. The results were unexpected: The nonparallel groups scored significantly higher than the parallel groups on the final written product.

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CHAPTER I

INTRODUCTION

Description of the Study

This study was conducted as part of an Alpha test for the NASA Classroom of the Future's Exploring the Environment (ETE) project. For this project, ETE developed Internet-based earth science modules for high school students. "Science teaching that attempts solely to impart to students the accumulated knowledge of a field leads to very little understanding and certainly not to the development of intellectual independence and facility," (American Association for the Advancement of Science [AAAS], 1990, p. 203). The ETE modules teach students to solve real-world science problems using real-world tools.

"Tropical Poison," the ETE module used in this study, was designed based on principles of constructivism and problem-based learning. It required students to identify problem(s) presented by the module, to conduct research surrounding the identified problem(s), and to develop a final written product. Student participants in the study worked on the module in cooperative groups within their classrooms. Some of these classroom groups were paired to work on the project via electronic mail (e-mail) with remote groups of students. All groups of students were to complete a final written product that was scored by a team of evaluators. The study focused on assessing the effects of electronic inter-school collaboration on the quality of student written products.

Need for the Study

According to an excerpt from Science for All Americans, the future of life on Earth will be determined by the human species. We depend upon scientific explorations and scientific discoveries for our very existence (AAAS, 1990). However, studies indicate that high school students in general have not achieved a satisfactory level of scientific understanding from traditional classroom experiences.

A study conducted by Miller in 1989 concluded that only 20% of the United States population were scientifically literate. Miller places responsibility squarely on the shoulders of secondary education: "whatever science learning does take place in the pre-college classroom has almost no sustained impact on...scientific literacy" (Miller, 1989, p. 2). A 1990 report in Science for All Americans concurs, indicating that U.S. students rank near the bottom in science and mathematics on international studies of educational performance (AAAS, 1990, p. xv).

In response to these studies, there has been a call to reform science education in the U.S. These reform efforts coincide with relatively new computer technologies such as the Internet and electronic communication. These technologies have redefined collaboration, allowing students to interact outside the boundaries of their classrooms. Because "technologies have become more interactive, distributed, and collaborative [, these] technological advances merge nicely with innovations in instructional strategies for collaboration, mentoring, and project-based learning. Through this marriage of technology and instruction, global networks have connected learners across time and space, resulting in a myriad of new learning communities" (Harasim, 1993; Quarterman, 1993; Riel, 1993; as cited in Bonk & King, 1998, p. 5). By participating in these remote learning communities, students become powerful and active advocates for their own education.

The ETE modules present students with authentic science problems and challenge them to solve those problems in a collaborative context. This unique approach encourages students not only to investigate issues in depth by constructing, critiquing, and revising ideas through collaboration with others, but it also expands the scope of collaboration in exciting ways.

Though many on-line educational projects have been undertaken, relatively little research has been conducted to assess electronic collaboration's effects on the quality of student written products. This study intends to investigate on-line collaboration and add to the growing body of knowledge concerning its effects on learning.

This remainder of this chapter reviews the current literature in the areas of constructivism, problem-based learning, cooperative learning, and computer-mediated communication. These areas are related to the study in the following ways:

- *Constructivism* - The ETE module used in this study was designed to reflect principles of constructivism, a learning theory that emphasizes how students construct meaning and knowledge.
- *Problem-Based Learning* - Students in this study followed a problem-based learning model to address the scenario presented by the ETE module.
- *Cooperative Learning* - All students worked on the module within in-class cooperative groups.
- *Computer-Mediated Communication* - Particular cooperative groups were assigned to work with remote cooperative groups. The groups communicated via the computer using e-mail.

REVIEW OF THE LITERATURE

Constructivism

According to Jonassen, Davidson, Collins, Campbell, and Haag (1995), the current dominant teaching paradigm assumes that knowledge is external to the learner and is therefore transferable from instructor to student. The learner must in turn remember and reproduce reality as perceived by the instructor. Schank and Jona (1991) refer to these assumptions as the "sponge method" of instruction; the teacher imparts knowledge to the learners who absorb it. During the assessment phase, the knowledge that learners have absorbed is "wrung out" of them. Achievement is then measured by how accurately students reproduce information as perceived by the instructor.

Constructivist educators strive to create environments where learners "are required to examine thinking and learning processes; collect, record, and analyze data; formulate and test hypotheses; reflect on previous understandings; and construct their own meanings" (Crotty, 1994, p. 31). Wiggins (1993) suggests that understanding is more akin to judgment or disposition than the possession of information. The constructivist sense of "active" learning, according to Jonassen et al. (1995), involves applying knowledge to new situations and emphasizes creating over conforming.

System Attributes of the Constructivist Environment

Jonassen et al. (1995) maintain that instructional design in a constructivist environment focuses less on creating prescriptive learning situations and more on creating environments in which learners construct their own knowledge. Constructivist learning environments, then, are built on four general system attributes: context, construction, collaboration, and conversation.

Context

Context, according to Jonassen et al. (1995), "includes features of the 'real world' setting in which the task to be learned might naturally be accomplished. The features may include the physical, organizational, cultural, social, political, and power issues related to the application of the knowledge being learned" (p. 13). Attention to context creates exciting learning environments as opposed to the boredom of instructional sequences (Brown, Collins, & Duguid, 1989).

Brown et al. (1989) suggest engaging students in authentic activities, defined as the ordinary practices of the culture. They contend that "when activities are not those of practitioners and do not make sense or would not be endorsed by the cultures to which they are attributed, students' access to important structuring and supporting cues that arise from the context is limited" (p. 34).

Jean Lave's (1988) ethnographic studies of learning and everyday activity reveal the differences between school learning and learning in the 'real world' (cited in Brown et al., 1989). As shown in Table 1, Lave focuses on the behavior of JPFs (just plain folks), students, and practitioners, and records the ways each learns.

Table 1
JPF, Student, and Practitioner Activity

	JPFs	Students	Practitioners
reasoning with:	causal stories	laws	causal models
acting on:	situations	symbols	conceptual situations
resolving:	emergent problems & dilemmas	well-defined problems	ill-defined problems
producing:	negotiable meaning and socially constructed understanding	fixed meaning & immutable concepts	negotiable meaning & socially constructed understanding

Note. From Cognition in Practice, by J. Lave, 1988, New York: Cambridge.

Table 1 illustrates the similar activities of JPF’s and practitioners. According to Brown et al. (1989), "Both have their activities situated in the cultures in which they work and within which they negotiate meanings and construct understanding. The issues and problems that they face arise out of, are defined by, and are resolved within the constraints of the activity they are pursuing” (p. 34).

Authentic activity is important for learners because "it is the only way they gain access to the standpoint that enables practitioners to act meaningfully and purposefully . . . Knowledge comes coded by and connected to the activity and environment in which it is developed, is spread across its component parts, some of which are in the mind and some in the world much as the final picture on a jigsaw is spread across its component pieces" (Brown et al., 1989, p. 36).

The AAAS (1990) recommends that "teaching should be consistent with the nature of scientific inquiry" (p. 200). Specific recommendations include the following: starting with questions about nature, engaging students actively, concentrating on the collection and use of evidence, providing historical perspectives, insisting on clear expression, using a team approach, combining knowledge and discovery, and de-emphasizing the memorization of technical vocabulary.

Construction

For constructivists, the goal of learning processes is knowledge construction. In a constructivist environment, knowledge is a product of thought and results from the individual's experiences and interpretations of the context (Jonassen, 1991). Learning environments are constructivist only if they allow individuals or groups of individuals to make their own meaning from their experience (Jonassen et al., 1995).

Meaning, according to Norman (1993), is the understanding we derive from our experiences. It is a reflective form of knowledge, or "knowing what." Experiential knowledge, or "knowing how," is the application of reflective knowledge in real-world practice. Both types of knowledge are required for performing real-world tasks. Traditional forms of instruction and assessment tend to generate reflective knowledge rather than experiential knowledge (Brown et al., 1989). This is similar to, and is about as useful as, evaluating doctors exclusively on the basis of their recall of biochemistry (Wiggins, 1993).

Knowledge construction involves processes both internal and external to the learner. In other words, we analyze and reflect on what we know, then negotiate over the meaning of ideas or events with others (Jonassen et al., 1995). Therefore, constructivists emphasize collaborative learning in real-world situations in order to teach collaborative, real-world problem solving (Lave & Wenger, 1991).

Collaboration and Conversation

A crucial element of constructivism as described by Jonassen et al. (1995) is the need to test and evaluate individually constructed knowledge by collaborating and conversing with others. Collaboration, according to Jonassen et al., occurs throughout the learning process and aids in developing, testing, and evaluating beliefs and hypotheses within learning contexts.

Through conversation, “individuals and groups negotiate plans for solving situated problems before initiating those plans. This planning involves reflecting on what is known, what needs to be known, the viability of various plans, and their potential effectiveness. Conversation is an essential part of the meaning-making process because knowledge, for most of us, is language mediated” (Jonassen et. al, 1995, p. 13).

Knowledge acquisition, according to Chee (1996) requires both individual and social construction. “Things that individuals perceive and experience are mediated by their own interpretation of surrounding phenomena. These interpretations are constrained by the interactions of individuals with other people as well as by their personal goals" (p. 138).

Based on what constructivists believe about knowledge construction, it would seem that truth and reality exist only in the individual mind as completely subjective concepts. Jonassen (1994) responds to this misconception by pointing out that human perception is somewhat constrained to physical laws of our world that everyone interprets in the same general way. He goes on to say that regardless of these universal physical laws, individual experiences, beliefs, and biases cause individuals to interpret the physical world somewhat differently.

Constructivists believe that learning is a social process and that knowledge is socially negotiated. The meanings that learners construct are validated or invalidated in comparison to those of others. Individual understandings must be tested in order to determine how adequately they allow us to interpret and function in our world. The social aspect of knowledge construction safeguards the human race from straying in as many cognitive directions as there are people. (Savery & Duffy, 1995).

Society once accepted as fact the notion that the earth was flat. As is the case with all facts, this perception was based on general agreement, not on some ultimate truth (Savery & Duffy, 1995). Much of the knowledge we accept as truth in our every day lives is also based on general agreement. Savery and Duffy describe the evolution of knowledge as social negotiation and social viability of individual understandings.

The Constructivist Learning Environment

If learning is indeed the result of individual construction arrived at in an embedded context and tested by collaboration and conversation, then instructional designers must modify traditional learning models to foster the evolution of knowledge. Simply assessing the student's ability to 'regurgitate' information is not enough. Savery and Duffy (1995) recommend the following for designing instruction in constructivist environments:

- Anchor all learning activities to a larger task or problem.
- Support the learner in developing ownership for the overall problem or task.
- Design an authentic task.
- Design the task and the learning environment to reflect the complexity of the environment students should be able to function in at the end of learning.
- Give the learner ownership of the solution process.
- Design the learning environment to support and challenge learners' thinking.
- Encourage testing ideas against alternative views and alternative contexts.
- Provide opportunity for support and reflection on both the content learned and the learning process (pp. 32 - 34).

Savery and Duffy’s specifications for instructional design are applicable and well-suited to technology-supported learning environments. Relatively recent advances in communication technology such as e-mail and information tools such as the Internet make it possible to create learning environments in ways never before imagined.

Constructivism and Computer-Mediated Communication

Computer-mediated communication (CMC) utilizes "technologies including electronic mail (e-mail), computer conferencing, and on-line databases to facilitate interaction between spatially separated learners through networks of computers" (Jonassen et al., 1995, p.16). By definition, CMC supports learners in their attempts to converse and collaborate with others. While conferencing, Jonassen et al. recommend that “learners engage in knowledge construction by exploring issues, taking positions, discussing those positions in an argumentative format, and reflecting on and re-evaluating their positions" (p. 16). Such electronic discourse engages learners in the iterative process of constructing and negotiating meaning through contact with peers, groups of individuals, and experts.

Communication tools such as e-mail also support the development of discourse communities, defined as "groups of individuals who share and discuss common interests and goals" (Jonassen et al., 1995, p. 17). According to Brown and Campione (1990), when instructional goals take learners beyond simple sharing and discussing, these discourse communities become purposive "communities of learners and thinkers" (cited in Jonassen et al., 1995), or "knowledge building communities" that focus on problem-solving and deep understanding (Scardamalia & Bereiter, 1993/94, cited in Jonassen et al., 1995).

According to Harasim (1990), students engaged in collaborative activity, as in a CMC environment, are not only afforded the opportunity to collaborate, but also enhance their collaboration efforts through interaction. Group collaboration in a CMC environment is asynchronous; therefore, learners initiate and respond to communications at a time and pace that best suits their needs. Through CMC, learners are afforded the time to compose thoughtful communications and responses. Meaningful communication with others exposes learners to different views and perspectives thereby contributing to higher order learning through cognitive restructuring or conflict resolution (Harasim, 1990).

To illustrate the compatibility of constructivist learning environments and technology, Table 2 shows the effect of technology on knowledge domains as viewed by Trent Batson. The 'Emerging' domain clearly illustrates constructivist principles and further legitimizes the use of constructivism as a theoretical basis for on-line environments.

Table 2
Insurgent Technologies: Re-Framing Knowledge Domains

Traditional	Emerging
1. Knowledge as an object (printed, storable; closure is possible) *Books have a beginning and an end.*	1. Knowledge as conversation (consensus, process; closure is difficult) *Electronic text does not seem to have a beginning and an end.*
2. Knowledge identified with individual (Darwinian, Copernican, Jeffersonian) *Books seem to have only one "voice."*	2. Knowledge identified with community *There are many voices in electronic conferencing; it is harder to believe one person should be identified with a set of ideas.*
3. Teaching: conveying knowledge *Knowledge domains are hierarchical.*	3. Teaching: getting students engaged in knowledge-development process *The Internet seems to open knowledge domains to all comers.*
4. Professional collaboration: acceptable? *If knowledge is an object, the creator must be an individual, and collaboration is suspect.*	4. Collaborative development of knowledge more visible; therefore, it seems legitimate *If knowledge emerges from conversation, the participants are the creators of the knowledge.*
5. Publications are refereed *In a hierarchy, access to power is controlled*	5. Publications may co-evolve electronically and in print *Access to power seems to have increased.*
6. Logical preferred to associational *Print tended to be linear; thus thinking must be linear, too.*	6. Associational thinking gains credence *Electronic text can be hypertextual.*
7. Classroom as ivory tower *Hegemonic structure of knowledge domains isolates them; universities seen as depositories, conservatories; funding depends on controlling access to knowledge.*	7. Classroom more connected to world *Knowledge domain boundaries become blurred.*
8. Visualization tools expensive *Training in visual representation of knowledge not as common as training in textual representation.*	8. Awareness of visualization as a knowledge path may increase *Knowledge is being re-framed by increased use of multi-media tools.*
9. Knowledge work highly abstracted *Knowledge representation and creativity necessarily is text-based.*	9. "Authentic materials" and simulations reducing abstraction of knowledge-making *Knowledge representation and creativity finding new paths in rich computer environments.*

Used with permission from Trent Batson, Ph.D., Director, Academic Technology, Gallaudet University

For the most part, instructors use current technology to support traditional teaching styles in traditional learning contexts. Instructional designers must break out of existing instructional paradigms by using technology to create unique learning environments that will enrich students' performance in the real world.

PROBLEM-BASED AND COOPERATIVE LEARNING

Problem-based learning (PBL) is a model of instruction with a constructivist orientation. PBL, like constructivism, emphasizes the importance of students' taking ownership of problems, taking an active role in the learning process, cooperating with others, and acquiring transferable knowledge.

History of Problem-Based Learning

Problem-based learning was formally developed in the medical education community in the mid-1960's. Medical students beginning their clerkships did not display the skills required of them. Observations such as, "Everything that the students had learned in freshman neuroanatomy they had forgotten by their neurological clerkship," and, "the skill of problem solving is the crucial skill of the physician . . . our conventional methods of teaching probably inhibit if not destroy their (students') ability," led medical professionals at McMaster University to initiate the use of a problem-based curriculum (H.S. Barrows, personal communication, November, 1995).

The PBL model developed by Howard Barrows, one of the forerunners in PBL, is currently used in more than 60 other medical schools, usually in the first two years of the science curriculum in lieu of the traditional lecture-based courses (Savery & Duffy, 1995). Upon entrance, students are divided into groups of five, and each group is assigned a tutor. The students are presented with a simulated, symptomatic patient. The students must work cooperatively in small groups to diagnose and 'treat' the patient. The groups are also responsible for defending their course of treatment.

An adapted description of Savery and Duffy's (1995) PBL process follows:

> The students do not know what the problem will be until it is presented. As a group, students discuss the problem, generate hypotheses based on their prior experiences or knowledge, identify relevant facts in the case and identify learning issues. The learning issues are topics the group members feel are relevant to their problem and which the group feels they do not understand as well as they should. At the conclusion of each session, each student verbally commits to a temporary position and assumes responsibility for particular learning issues that were identified. After the initial session, students engage in self-directed learning. They are responsible for gathering information pertinent to their learning issues from any available resources, much the same as any real-world physician. Assessment at the end of the process is achieved through peer and self-evaluation. These evaluations include suggestions for improvement in three areas: self-directed leanring, problem solving, and skills as a group member. There are no tests (pp. 34-35).

Group collaboration, use of ill-structured problems, hypothesis formation, information gathering, metacognition, and facilitator role are critical to the PBL process. Combined, these elements make possible what is perhaps the most important aspect of PBL - students who are no longer bound to a single instructor or textbook. Instead, students are encouraged to utilize all resources at their disposal—fellow students, libraries, electronic databases, professionals and experts, as well as instructors and textbooks -- to formulate their own hypotheses and solve problems.

The Problem-Based Learning Environment

Problem-based learning is designed to "simultaneously develop both problem solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem-solvers confronted with an ill-structured problem that mirrors real-world problems"

(Finkle & Torp, 1995, p.1). PBL models may be implemented using a variety of strategies but are generally characterized by the following steps: 1) presentation of a problem in a small group, 2) discussion of the problem, and 3) an attempt to solve the problem.

Problem Presentation and Ill-Structured Problems

In this model, students begin with an ill-structured problem that has personal relevance to them. Barrows (1990) defines ill-structured problems as follows: a) lacking necessary preliminary information, b) a variable definition, c) differing perspectives on the problem, and d) no existing absolute answer. Well-structured problems, problems most commonly presented to students in the school setting, provide students with all necessary information, including the appropriate algorithm needed to arrive at the single correct answer. Student motivation revolves around finding the correct answer. This approach generally leads to inert, unusable knowledge. When students work to solve ill-structured problems, they learn generalized problem-solving procedures that transfer to new situations (Simon, 1980; cited in Frederiksen, 1984).

When presenting ill-structured problems to students, the problems must reflect real-world situations. Student interest is enhanced when the problem is authentic and has perceived value (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palinscar, 1991). This does not mean that high school students studying the rain forest need to reside in the tropics to conduct investigations. Rather, instructional designers should seek to place students in situations that approximate the challenges confronted by real scientists (Savery & Duffy, 1995). According to Honebein, Duffy, and Fishman (1993), an authentic learning environment is one in which the cognitive demands, i.e., the thinking required, are consistent with the cognitive demands in the environment for which the learner is being prepared (cited in Savery & Duffy, 1995).

Authentic problems motivate students because they help students recognize the relevance of a particular problem to their own lives. By solving such problems, students develop a sense of ownership of the problem-solving process. Presenting a problem that designers see as authentic does not guarantee that students will recognize relevance in the problem. Savery and Duffy (1995) suggest two possible ways to support learners in developing ownership for the problem. First, the problems may be solicited directly from the learners. Second, the problem may be established so that the learners will readily adopt the problem as their own. Many simulation environments utilize this second strategy.

According to Simon (1978), the processes for solving well- and ill-structured problems are basically the same, but for ill-structured problems, as new information is evoked from long-term memory or from outside sources, students' perception of the problem changes. The student must have insufficient prior knowledge to understand the problem in depth (Norman & Schmidt, 1992). As the students work toward a solution using the PBL process, they engage in an iterative process of assessing what they know, identifying what they need to know, gathering supplementary information, and collaboratively evaluating the hypotheses in light of the data they have collected (Stepien & Gallagher, 1993).

Traditional problem-solving approaches involve providing students with a body of information and then presenting them with problems to solve based on their newfound knowledge. PBL is a more realistic approach to problem-solving in that learners are first presented with a problem, then they set about the task of defining and analyzing that problem (Stepien & Gallagher, 1993). One model of PBL, the Stepien, Gallagher, and Workman Model, offers a simple and effective structure for students to follow in their problem-solving process.

The Stepien, Gallagher, and Workman Model

The discussion of a problem among students involves the iterative process of defining and detailing issues, creating hypotheses, searching for and scanning data, refining hypotheses based on collected data, and conducting empirical experiments or research (Stepien, Gallagher, & Workman, 1993). Stepien et al. present a simple design for this stage of the problem-solving process. Figure 1 illustrates an organizer for student questions, ideas, statements, plans of action, and any other information pertaining to the problem.

What do we know?	**What do we need to know?**	**What should we do?**

<u>Figure 1.</u> Problem-based learning model; Stepien, Gallagher, and Workman (1993).

In this model, students first assess their collective prior or existing knowledge about the problem and list such facts under a heading entitled, "What do we know?" This analysis leads to a problem statement. Students then list a series of questions that relate directly to the solving of the problem under a heading, "What do we need to know?" A third list entitled, "What should we do?" directs students in the information-gathering process. What sources--the classroom, the library, experts, electronic sources--should be consulted?

An attempt to solve the problem requires that students develop solutions that fit the conditions of the problem and justify or evaluate their solutions. There is reason to expect that conditions specified by the problem will improve (Stepien et al, 1993). Since there are no right or wrong answers when engaging in PBL, a problem's solution is determined by group consensus, or sometimes, simply by the group's submitting the best, though perhaps incomplete, information they have. Both of these options reflect real-world problem-solving situations and constraints.

Facilitator Role and Metacognition

Teachers familiar with didactic forms of teaching are often wary of 'letting go' of the classroom. PBL requires that teachers act as tutors and facilitators rather than dispensers of knowledge. Barrows (1992) sees the use of facilitory teaching skills as central to education intended to develop thinking or reasoning skills, and to help students become independent, self-directed learners.

Savery and Duffy (1995) insist that facilitators should model higher order thinking by posing questions to students that require them to explain, clarify, and validate their positions. Their role is not to express opinions or to provide students with information, but rather to challenge the learner's thinking through questioning. In a PBL environment, metacognition should take place throughout the entire learning process. Students should constantly think about, monitor, and adjust their ideas as they solve the problem at hand. As students become efficient problem-solvers, the role of the facilitator should fade, giving way to the students' own metacognitive processes.

Metacognitive strategies of learning, as described by Chiquito (1995), "involve thinking about or planning a learning process before the actual learning activity, monitoring the acquisition of new knowledge, or carrying out a critical self-evaluation of the results obtained after a learning process" (p. 211). These strategies are geared toward arousing learners' awareness of possible relationships between existing knowledge and new information.

Research on Problem-Based Learning

Norman and Schmidt (1992) summarize the advantages and disadvantages of PBL:

- There is no evidence that PBL curricula result in any improvement in general, content-free problem-solving skills (possibly because strategies that can be generalized for some classes of problems have yet to be identified and measured).
- Learning in a PBL format may initially reduce levels of learning (possibly because the components that make up problem solving have yet to be characterized and therefore measured).
- Some preliminary evidence suggests that PBL curricula may enhance both transfer of concepts to new problems and integration of basic science concepts into clinical problems.
- PBL enhances intrinsic interest in the subject matter.
- PBL appears to enhance self-directed learning skills (metacognition), and this enhancement may be maintained. (p. 557)

Additional studies indicate that students in a problem-based curriculum (compared to traditional educational settings) are able to determine what is relevant information, and they modify their learning to satisfy their own needs and interests (Dolmans, Gijselaers, Schmidt, & Van Der Meer, 1993).

The research conducted on the effectiveness of PBL is confined almost exclusively to medical school models. Within this narrow framework, we find both encouraging and discouraging data that may or may not be relevant to K-12 education. Based on these findings, Albanese and Mitchell (1993) offer words of wisdom to the overzealous advocate as well as to the pessimist: "Expertise, experience, and efficiency are the traditional curriculum's potential strengths. Yet to approach curriculum development as dichotomous, as a choice between either PBL or traditional (classical) curricula, imposes unnecessary limits on the creativity of teachers. Education is best when interactive, but how one chooses to promote interaction should depend on the aptitude of the students, the talents of the teachers, the content to be learned, and the available resources" (p. 86).

Since its inception in the medical school setting, PBL curriculums have also been implemented in pre-college educational programs as well (Stepien et al., 1993; Stepien & Gallagher, 1993). A major contributing factor to the success of PBL may indeed be its cooperative or collaborative component. Cooperative learning has found much acceptance and enjoyed much success as a valid approach to instruction.

Cooperative Learning

Cooperative learning, an increasingly popular alternative to traditional instruction, is among the most extensively evaluated learning methods in use today (Slavin, 1991). The term cooperative learning, also referred to as collaborative learning, is defined by Slavin (1980) as "classroom techniques in which students work on learning activities in small groups and receive rewards or recognition based on their group's performance" (p. 315). Johnson and Johnson (1978) point to many research studies indicating that cooperative learning experiences, as opposed to competitive or individualistic ones, are more successful in promoting achievement and positive attitudes toward the subject area, as well as toward the teacher, other students, and oneself (cited in Gunderson & Johnson, 1980).

Slavin (1990) suggests that cooperative learning is often misinterpreted by teachers who place students in groups and give them interesting materials or problems to solve. Or they allow groups to work together to produce a single product or solution. Instead, cooperative activities should supplement direct instruction and should always include individual accountability. Group success should depend on the sum of all group members' contributions to the team task.

Research suggests cooperative learning yields positive results. Following are the highlights of a synthesis of research on cooperative learning in elementary and secondary schools. The studies compared cooperative learning to traditionally taught control groups that studied the same objectives over a period of at least four weeks (Slavin, 1991).

> - For enhancing student achievement, the most successful approaches have incorporated two key elements: group goals and individual accountability. That is, groups are rewarded based on the individual learning of all group members.
> - When group goals and individual accountability are used, achievement effects of cooperative learning are consistently positive; 37 of 44 experimental/control comparisons of at least four weeks' duration have found significantly positive effects, and none have favored traditional methods.
> - Achievement effects of cooperative learning have been found to about the same degree at all grade levels (2-12), in all major subjects, and in urban, rural, and suburban schools. Effects are equally positive for high, average, and low achievers.
> - Positive effects of cooperative learning have been consistently found on such diverse outcomes as self-esteem, intergroup relations, acceptance of academically handicapped students, attitudes toward school, and ability to work cooperatively. (p. 71)

Cooperative learning is generally thought of as an in-classroom, face-to-face experience for students. However, computer mediated communication allows students to communicate and collaborate from any distance. The next section describes CMC and collaborative projects that utilize cooperative learning via CMC.

COMPUTER MEDIATED COMMUNICATION

> I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks. I should say that on the average we get about two percent efficiency out of schoolbooks as they are written today. The education of the future, as I see it, will be conducted through the medium of the motion picture…where it should be possible to obtain one hundred percent efficiency. Thomas Edison (as cited in Cuban, 1993, p. 187).

Technologies proposed to revolutionize education, from motion pictures to radio to television, have repeatedly fallen short of their intended impact. Is the latest revolutionary tool, the computer, destined for the same fate in the educational community? In the past decade, computers have inundated business and the home, but they have been used far less in classrooms than in other organizations (Cuban, 1993). The relatively marginal use of computers and telecommunications in schools is "due less to inadequate funds, unprepared teachers, and indifferent administrators than to dominant cultural beliefs about what teaching, learning, and proper knowledge are and how schools are organized for instruction" (Cuban, 1993, p.206).

If the education community is to keep pace with current technological advances, educators must change their views on instruction. The rise of Internet and electronic communication presents educators with the opportunity to tap unlimited and unexplored resources. Learners are no longer bound to single texts, static images, rote instruction, or even a single classroom. Connectedness and communication between learners and the world has never been possible on such a scale. Indeed, US school children increasingly use communication tools for both local and global electronic correspondence (Kongshem, 1994). The computer and its capabilities may very well prove to be the missing element in the quest to change existing curricula and provide students with more meaningful instruction.

Attributes of Computer-Mediated Communication

Computer-mediated communication includes electronic mail, computer conferencing, on-line databases, telecommunications projects, and other forms of computer-based network communications. Computer communications technology enables students and teachers to exchange, store, edit, broadcast, copy, and send written documents instantly, and cheaply over short or long distances (Kiesler, Siegel, & McGuire, 1984). Communication may take place one-on-one, as is common with electronic mail, or it may be a more comprehensive, shared experience among many, as in computer conferencing. The interactive nature of CMC has, not only technological and pedagogical implications for research and implementation, but is also rife with social implications.

In comparing CMC to face-to-face encounters, both offer advantages and disadvantages, depending on the intended goal(s) of the encounter. CMC is subject to certain constraints not associated with face-to-face interactions. CMC users have complained about the absence of spontaneous and real-time exchanges, the awkwardness of dialogue in a CMC environment (which undermines a further prerequisite of successful interaction--the need for continuity), the inability to complete a debate in one session, the time-consuming nature of electronic interactions (Grint, 1989, Paper 3, Part 3), and the reliance on others for timely and satisfactory communication (Somekh, 1989, Paper 16, Part 3).

On the other hand, CMC offers a time- and space-independent means of communication. Thus, unlike face-to-face encounters, it creates a democratic and relatively status-free environment. Turn-taking is more equally-distributed in CMC discussions. Opinions are often more thoughtfully composed in this text-based and asynchronous nature of the medium. A continuous written record of the discussions is maintained (Kaye, 1989). Multiple topics may be discussed simultaneously (Graddol, 1989, Paper 15, Part 3). And information may be stored, retrieved, and reprocessed (Rice, 1987).

For the reasons outlined above, among others, CMC systems are especially equipped to support group collaborative work. As with all technologies, it is what CMC can do better than other forms of communication (interpersonal, media, etc.) that provides positive expectancies and rationale for its existence and use in the educational arena. The Internet abounds with collaborative K-12 projects that involve students in writing and sharing their work with other students worldwide. E-mail, one of the most useful and least complicated features offered by the Internet, is used for much of this communication (Kongshem, 1994).

Electronic Mail

Electronic mail allows one to send and receive messages over a computer network. E-mail software uses computer text processing tools and computer network links to provide high-speed message processing and exchange services to persons who have "addresses" on a given computer network (Ruberg & Miller, 1993). “Countless researchers are proclaiming e-mail’s democratizing effects, citing substantial evidence that it flattens hierarchies, promotes teamwork, and increases involvement of peripheral workers within organizations” (Leslie, 1994). Electronic mail’s simplicity and cost-effectiveness (Romiszowski & de Haas, 1989), as well as the speed at which messages are exchanged make it an attractive communication medium for collaborative projects.

Additionally, according to Clements and Natasi (1988), “...studies indicate that debating with peers over a network might guide and challenge learners to new levels of growth and understanding” (as cited in Sugar & Bonk, 1998, p. 132). Such debate in electronic communities might create cognitive dissonance within learners when presented with alternative perspectives. This prods individuals to “seek additional information to resolve that conflict, and, as numerous computer-networking experiences indicate, they do not want to look dumb to their foreign peers” (see Golub, 1994; Riel, 1993, as cited in Sugar & Bonk, 1998, p. 133).

Communication and collaboration between students via electronic mail or other electronic communication is becoming increasingly common, and the Internet abounds with collaborative projects. The following are brief descriptions of key features and findings of some of the more prominent collaborative projects that have been and are being conducted using Internet technology.

COLLABORATIVE PROJECTS

Why are networks the medium of choice for many collaborative projects? Levin, Rogers, Waugh, and Smith (1989) describe the power of networking as having access to the diversity present in the world. Appropriate network projects have some commonality, but use diversity as a point of focus.

Clement (1992) maintains that network communication can provide better communication between and empower individuals “only if they have something to communicate about, and that means creating collaborations--shared projects that create an environment of higher learning and creative teaching in all schools" (p. 18). Clement recommends the widespread implementation of various models of network collaboration built around difficult or messy problems that collaborating groups may attack from many different angles. Such educational problem-solving projects are, as yet, "the least common kind of Internet-based activity that involves pre-college students, but they are among the best examples of how asynchronous connectivity can be used to support and enrich pre-college curricula" (Harris, May 1995, p. 59).

Examples of On-Line Collaborative Projects

According to Harris (1995), parallel problem-solving is a telecomputing activity that involves presenting a similar problem to students in several locations. Students solve the problem separately at each site, then share their problem-solving methods electronically. In one of the many parallel problem-solving project described by Harris, students used the statewide educational telecommunications network in Virginia (VaPEN) to participate in an interdisciplinary project called "Puzzle Now!" For this project, students from 25 sites within the state solved a common puzzle each week, comparing their methods and solutions.

Computer Supported Intentional Learning Environments (CSILE) is a network system that provides support for collaborative learning and inquiry. Using the CSILE software, students and teachers create databases and invite comment and critique from others on the network.

According to the CSILE website, evaluations comparing CSILE and non-CSILE classrooms at the elementary level have shown significant advantages for CSILE on

- Standardized test scores in reading comprehension, vocabulary, and spelling.
- Ability to read difficult texts.
- Quality of questions.
- Depth of Explanation.
- Math problem solving.
- Portfolio commentaries.
- Graphical literacy.

Chee (1996) describes MIND BRIDGES, a computer-based multimedia learning environment that "allows students to engage in collaborative knowledge construction through the creation of integrated multimedia documents that support the expressive richness of their articulations" (p. 150). The MIND BRIDGES environment is designed to reflect principles of social constructivism and stresses context and collaboration in meaning-making. The project follows in the footsteps of CSILE.

The Global Schoolhouse Project, funded in part by the National Science Foundation, joins students nationally and internationally in collaborative research efforts using various Internet tools. According to the Global Schoolhouse Project website, the Project was designed “to demonstrate the potential of high speed Internet connectivity in the public school classroom.”

The CoVis (Collaborative Visualization) Project website indicates that CoVis utilizes inquiry-based activities to create “distributed electronic communities dedicated to science learning.” Additionally, the Project is “a blueprint to inform educators, researchers, and policy makers on the effective and sustainable use of interpersonal, collaborative media in science education.” Throughout the Project, high school students work collaboratively with remote students, teachers, and scientists in learning environments that resemble the authentic practice of science.

The International Education and Resource Network (I*EARN) provides students, elementary through secondary, with interactive, collaborative projects. Its website literature describes the network as “a global community of youth, teachers and youth service leaders committed to using telecommunications to make a meaningful difference in the world as part of the educational process.” One teacher quoted on the website asserts that “I*EARN has been a popular communication tool in our state. Finding ways to connect students in meaningful dialogue that results in improvement of student learning, working to find solutions to world problems and bringing real life issues to the classroom are some of the main benefits of telecommunications. I*EARN conferences on PeaceNet meet those needs for students and teachers.”

Related Research

At the time of this writing, few studies have measured the effects of on-line collaboration on the quality of student written products. However, the effect of distant peer audiences on student writing has been investigated, and these results may have implications for this study. Cohen and Riel (1989) compared student papers written to communicate with peers to those written to demonstrate writing skill for teachers. The researchers found that the papers written for peers were rated significantly higher than the papers written for teachers. The study is described by Weir (1992) in the following way:

> Providing a network audience for writing can provide an unexpected effect. Two seventh-grade classes, 22 students in each class, wrote two compositions: one for a regular mid-term examination, and one addressed to peers in other countries on the InterCultural Learning Network. The compositions were graded by the classroom teacher on a 0-100 point scale. The classroom teachers were confident that the examination grades would be higher because students would take more care. They were surprised to find that they had judged the papers that were written to peers on the network significantly higher than those produced for the examination. Two independent raters evaluated the papers with respect to content, organization, vocabulary, language use, and mechanics. The scores on each of these criteria confirmed the superiority of the network compositions; the differences were statistically significant (p. 11).

SUMMARY AND HYPOTHESIS

This review has examined constructivism, problem-based and cooperative learning, and computer-mediated communication in order to investigate the effects of collaboration in an on-line problem-solving environment designed for high school science students. Research conducted on each of these components indicates success or promise in the area of education (e.g. Brown et al., 1989; Clements and Natasi, 1988; Dolmans et al., 1993; Harasim, 1990; Lave, 1988; Norman and Schmidt, 1992; Slavin, 1991), and all are key elements of this study.

Constructivist theory emphasizes the importance of placing students in authentic learning contexts where knowledge construction results from individual experiences and interpretations. The knowledge-construction process is socially negotiated when students work collaboratively to test and evaluate ideas. The ETE module used in this study capitalizes on constructivist learning theory by placing groups of students in an authentic science context and allowing them to analyze, reflect, and negotiate meaning.

The ETE module used in this study was designed to engage students in a problem-based learning environment. Following the problem-based learning model of Stepien et al. (1993), students take an active role in the learning process as they collaboratively address the ill-structured problem presented in the module. Research on problem-based learning in the medical school setting yields mixed results that cannot be generalized for K-12 education. The positive findings, however, are so overwhelmingly encouraging (e.g. students are able to determine what knowledge is necessary and relevant, and they modify their learning to satisfy their needs and interests (Dolmans et al., 1993)), that determining the effectiveness of problem-based learning in K-12 education seems a worthwhile endeavor.

Both constructivist theory and problem-based learning incorporate collaborative components into their designs. Collaboration among peers has met with much success in the K-12 classroom in the form of cooperative learning. Research indicates that, compared to traditional classroom teaching methods, cooperative learning positively affects student achievement, self-esteem, attitude, and cooperation (Slavin, 1991).

Computer-mediated communication, particularly the use of electronic mail, facilitates classroom learning in exciting ways. It democratizes communication (Leslie, 1994), and is simple and cost-effective to use (Romiszowski & de Haas, 1989). It allows collaboration among distant learners (Golub, 1994; Riel, 1993) and provides an external audience for students (Cohen & Riel, 1989).

The on-line collaborative projects described, many of which are ongoing, are yielding positive outcomes and high expectations for the future of on-line collaborative projects. As utilization and understanding of on-line, collaborative environments increases, the goal of science education reform through electronic learning communities may become a reality.

Research indicates promise in the areas of constructivism (e.g. Brown et al., 1989; Harasim, 1990; Lave, 1988), problem-based learning (e.g. Dolmans et al., 1993; Norman and Schmidt, 1992), cooperative learning (e.g. Slavin, 1991), and on-line collaborative projects (e.g. Clements and Natasi, 1988). However, the research also indicates that the following research question needs to be addressed:

Research Question: Is there a difference in the quality of work between students who collaborate with remote groups of students and students who do not collaborate with remote groups?

Research Hypothesis: Participants who are assigned to work with a parallel group will produce higher quality final products-- as reflected in the mean rank order of written product scores -- than participants in nonparallel groups.

ORGANIZATION OF THE STUDY

The subsequent chapters are organized in the following manner:

Chapter 2 outlines the procedures followed in conducting the study and the research methodology used in treating the data.

Chapter 3 presents and discusses the results of the study.

DEFINITIONS

In certain instances, the literature may use the terms, "collaboration" and "cooperation," synonymously. In this study, the term "collaboration" strictly refers to the partnership between on-line, remote cooperative groups (parallel groups). The term "cooperation" strictly refers to the partnership between cooperative group members in each class.

CHAPTER II

METHODOLOGY

THE EXPLORING THE ENVIRONMENT PROJECT

This study was conducted in conjunction with The Center for Educational Technologies, (CET) established in 1994 with the help of NASA (See Appendix A for description of CET). The Center provides training, conducts research, and develops products and tools to enhance teaching and learning through the effective use of technology to prepare teachers and students for the needs of the next century.

The CET houses the NASA Classroom of the Future (COTF) Program -- NASA's premier research and development program for educational technologies. The COTF develops technology-based tools and educational resources for learning communities that improve mathematics, science, geography and technology education in ways that are consistent with the national reform movement (See Appendix B for description of COTF). Exploring the Environment (ETE) is a three-year project intended to develop Earth Science modules that make use of NASA's Earth Science database. The classroom modules, delivered to high school classrooms via the Internet, are developed by the NASA Classroom of the Future and Wheeling Jesuit University as part of NASA's High Performance Computing and Communications (HPCC) initiative. The ETE project features include online collaboration, teacher training, and a problem-based approach to learning science. The modules are available to classrooms with Internet access and can be accessed through the COTF web site at (http://www.cotf.edu/ete).

BACKGROUND

The ETE Internet-based module used for this study was entitled “Tropical Poison.” This particular module introduced students to environmental issues related to the Amazonian rain forest, using the poison dart frog as an example. The module may be accessed at (http://www.cotf.edu). Over the course of four to six weeks, students identified and addressed various environmental issues and reported their findings in the form of written products.

Of particular interest to the researcher was the effect of inter-school collaboration on the quality of these final products. All students worked on the module in group settings within their classrooms (cooperative groups), and some of these groups were paired to work on the project collaboratively via e-mail with remote groups of students (parallel groups). Cooperative groups that were not paired with a remote group were referred to as nonparallel groups. The purpose of this study was to compare the quality of the written products of the parallel groups to the quality of the written products of the nonparallel groups. Specifically, the study was designed to test the hypothesis:

Participants who are assigned to work with a parallel group will produce higher quality final products-- as reflected in the mean rank order of written product scores -- than participants in nonparallel groups.

This study examines one aspect of the ETE modules--the effects of inter-school collaboration on the quality of student work. Classroom of the Future researchers affiliated with the ETE project conducted additional studies examining factors other than collaboration, including student motivation, engagement, and problem-solving. The effect of teacher training on student work was also studied. These researchers utilized teacher and student end-of-module questionnaires containing Likert scale response forms to examine these factors.

The remainder of this chapter describes the Internet-based ETE “Tropical Poison” module, the participants who worked on the module, and the procedures used. The development of the evaluation criteria used to compare student products and the method by which the products were analyzed are also described.

PARTICIPANTS

The original participants in this study were students from seven high schools throughout the United States. One teacher enrolled three classes in the study, another enrolled two classes, and the remaining five teachers enrolled one class each. The participants’ teachers were either affiliated with previous ETE projects or responded to an Internet-based call for participants. Criteria for participation in the study were World Wide Web access and willingness to utilize problem-based learning methodology. The grade levels of the students ranged from 9-12, with a wide variance in student background (urban, suburban, rural), ability level (average, advanced), and subject area (algebra, biology, earth science, ecology, environmental science, and special studies).

Though seven schools with a total of ten classes originally participated in the project, one participating teacher did not require each of his student groups to submit a collaborative final product. This particular teacher accounted for three classes -- one parallel class and two nonparallel classes. The scores from all three of these classes and the scores of the partner parallel groups were eliminated from the analysis. The resulting number of final written products that were analyzed was thirty-five.

The groups were purposively, rather than randomly, selected by the researcher for assignment into parallel or nonparallel groups. Several factors combined to determine the parallel and nonparallel group assignments.

To determine the parallel group composition, the researcher matched the grade levels and subject areas of classes as closely as possible. The researcher also attempted to match honors classes with non-honors classes. Hardware and software capabilities and compatibilities within the schools were also taken into consideration. Finally, geographic location of the schools was considered. Groups from geographically diverse locations were matched. As often as possible, nonparallel groups reflected the same variables - class subject, grade level, academic level, hardware and software compatibility, and geographic location - comparably. Table 3 shows a detailed breakdown of the parallel and nonparallel group participants.

Table 3
Participants Involved in Study

	Course	Grade Level	# Students
Parallel Group 1			
Class A Massachusetts	Earth Science	10, 11, 12	23
Class B West Virginia	Ecology	11, 12	25
Parallel Group 2			
Class C Pennsylvania	Cooperative Satellite Learning (Honors)	9, 10, 11, 12	24
Class D Washington	Algebra, Statistics, & Geometry	11, 12	24
Nonparallel Groups			
Class E Georgia	Biology (Honors)	9	16
Class F Pennsylvania	Environmental Science (Honors)	11, 12	15

PROCEDURES

After groups were assigned, teachers divided their students into cooperative groups according to the individual teacher's needs and preferences (i.e. consideration of pre-existing groups, personalities, individual academic strengths and weaknesses, etc.). Teachers of parallel groups introduced themselves to their partners via e-mail, then jointly paired the student cooperative groups. Students in parallel groups had existing e-mail accounts or were provided with accounts by their schools. E-mail served as the primary means of parallel group communication. The researcher suggested that the parallel groups introduce themselves to one another before beginning work on the module, although there were no mandated communication requirements.

Teachers then familiarized themselves with the guidelines and information contained in the "Teacher's Notes" section of the "Tropical Poison" module. This section described problem-based learning and suggestions for classroom implementation. Teacher questions or comments of general concern were posted electronically throughout the project, but no additional formal training was provided for the teachers in conjunction with this study. However, the researcher and ETE affiliates were available throughout the project to field questions and provide assistance or guidance.

The researcher provided teachers with "Group Notebooks" for all cooperative groups (parallel as well as nonparallel). These notebooks included suggested weekly time lines of activities that included individual and group response sheets. The notebooks were identical for nonparallel and parallel groups, with one exception--the parallel group notebooks suggested activities for sharing and critiquing ideas between collaborating groups. The response sheet activities prompted the students to reflect on the work they had done and provided direction for future investigation. These activities were designed to help the groups monitor the contributions of cooperative and parallel group members. Teachers were not required to use the notebooks. Appendix C shows the group notebook activities for the first week. Subsequent weeks follow a similar format.

Before the "Tropical Poison" module was introduced to the students, considerable organization and communication among the teachers, the researcher, and COTF was required. As time to begin the project neared, teachers were reminded to reserve the computer lab, library, or other resources in preparation for the students' research. A troubleshooting contact at COTF addressed technology-related concerns, but questions concerning the implementation of the module were addressed to the researcher or to the entire group via e-mail.

Some of the participating teachers and students had previous experience with ETE modules. Other classes had experience with problem-based learning not affiliated with ETE. And some had experience with neither. Because not all the teachers or students were familiar with problem-based learning, methods used to introduce "Tropical Poison" to students varied from classroom to classroom. Those familiar with the ETE modules required little formal introduction to the module or to problem-based learning. Several of the other teachers conducted scaled-down problem-based learning activities to introduce their students to the problem-based learning environment. Once the "Tropical Poison" module was available to students on-line, all teachers introduced the module to their classes using whole-class discussion.

The "Tropical Poison" module presented students with a problem related to authentic environmental issues. Unlike traditional classroom problem-solving approaches, the module was based on principles of problem-based learning. Students were presented with a problem scenario but given very little initial information with which to address it. Through the module, students were asked to examine issues like the worldwide decline of amphibian populations, of wildlife habitat destruction, and of biodiversity. The students were informed that the project would culminate in a final written product, and that the written product should include an assessment of and a possible solution to the problem. Each cooperative group was to submit one product (see Appendix D for sample product). Students received written guidelines for the final project during week one.

As students formulated plans for addressing the problems they identified, they were free to explore and utilize any resources available to them, e.g. the Internet, the library, and field experts. The module itself contained a wealth of information, including prompts and guidelines, recommended web sites, and suggested problem-solving processes. In the parallel groups, questions, responses, and research efforts were exchanged via e-mail.

Rather than assuming the typical didactic role in the classroom, the teacher became a facilitator. (S)he acted as a coach or tutor, answering questions, addressing concerns, and making suggestions, but (s)he did not dictate the learning process. The "Teacher's Notes" section of the module was the primary source of information for teachers, outlining for them their role in a problem-based learning environment.

INSTRUMENTS AND DATA ANALYSIS

A team of three educators not affiliated with the project conducted a blind evaluation of the students' work. The evaluators were chosen based on their backgrounds. One, a writing specialist from a local college, had experience in large-scale evaluation. The other two were science educators heavily involved in environmental projects. Over the course of several weeks, the team met to discuss the language of the evaluation criteria and to work through samples of student products.

The evaluators independently assigned scores to each product according to the evaluation criteria. Figure 2 shows the evaluation sheet used in the scoring process. The evaluation included five categories--problem statement, methodology, analysis of data, summary and conclusion, and application. Each category was divided into three subcategories. Evaluators scored each subcategory on a zero to five scale with zero indicating no evidence of the desired component. The subcategory scores for each area were averaged, and a single evaluator's total score for any written product was an average of the five area scores. The final score for each product was the average of the three evaluators' total scores for that product. An example of a completed student product is shown in Appendix D, and its accompanying evaluation sheets are shown in Appendix E. Raw scores for each written product are shown in Appendix F.

Paper Number _____________ Grader ________________________

PROBLEM STATEMENT

The problem is well defined	The problem statement is appropriate (useful for research)	The problem statement is valid (relates to the Brazilian rain forest and the influences upon it)	Total/Average

METHODOLOGY

How/Where was the data obtained - an explanation	The methodology is duplicable (reliable)	Sources are reasonable/valid/credible... Bibliography	Total/Average

ANALYSIS OF DATA

A premise relating to the problem statement is developed	A logical analysis is presented	Supporting facts are organized such that conclusions can be adequately drawn	Total/Average

SUMMARY & CONCLUSION

The argument is sound	A reasonable summary is stated	Conclusions are valid	Total/Average

APPLICATION

Reasonable and appropriate connections to the real world	Obvious connections are not omitted or overlooked	Includes problem solving suggestions	Total/Average

Total for the paper _____________

Figure 2. Evaluation sheet for student written products.

SUMMARY OF PROCEDURES USED

Following is a summary of the procedures used in conjunction with this study:

1. Participants attained through Internet call or through previous ETE connection.
2. Parallel groups designated by researcher.
3. Cooperative groups designated by individual teachers.
4. Parallel groups provided with e-mail accounts.
5. Group notebooks (see Appendix C) distributed.
6. ETE "Tropical Poison" module introduced to students.
7. Students engaged in problem identification, research, and writing of final product. Parallel groups shared information via e-mail.
8. Group written products (see Appendix D for example) submitted.
9. Group written products evaluated (accompanying evaluation sheets for sample product (Appendix D) are shown in Appendix E).

METHOD OF ANALYSIS

The Mann-Whitney *U* test, a nonparametric alternative to the *t*-test, was deemed appropriate to analyze differences in written product scores of students working in parallel versus nonparallel groups. The level of significance for the analysis was set at .05.

The Mann-Whitney *U* test is described by Haycock, Roth, and Gagnon (1994) in the following manner:

The Mann-Whitney *U* test is useful in the same cases as an unpaired t-test. It is the nonparametric version of the two group unpaired test. Recall that a t-test tests the hypothesis that the means of the two groups are equal, assuming normality of the observations. The Mann-Whitney *U* tests the hypothesis that the distributions underlying the two groups are the same. The requirements for validity of the Mann-Whitney test are that the two groups of observations come from continuous distributions and are independent of each other, both within and between groups. Since the Mann-Whitney test does not look at the observations but instead considers their ranks, it is resistant to outliers in either of the groups being compared (p. 344).

CHAPTER III

RESULTS AND DISCUSSION

INTRODUCTION

This study investigated the effects of inter-school collaboration on the quality of student written products. Student participants worked on the web-based ETE "Tropical Poison" module in cooperative groups. Some cooperative groups were paired with cooperative groups in remote locations (parallel groups) and some were not (nonparallel groups). Parallel groups communicated via e-mail.

Six teachers, who were either affiliated with previous ETE projects or responded to an Internet-based call for participants, were accepted to participate in the study. Each cooperative group, parallel or nonparallel, was to submit one written product at the completion of the module. Thirty-five total products were analyzed. A team of three evaluators scored the final products, and each evaluator's total score for a single product was averaged to determine the product's total score. The evaluators' average scores of the parallel groups' written products were compared to the average scores of the nonparallel groups' written products using the Mann-Whitney *U* test. Please note that due to the nonrandom nature of the study and to factors beyond the control of the researcher, (e.g. the variability in student age, ability level, course of study, and in teachers' experience level and background), generalization beyond this study is limited.

RESULTS

Hypothesis. Participants who are assigned to work with a parallel group will produce higher quality final products-- as reflected in the mean rank order of written product scores -- than participants in nonparallel groups.

To test the stated hypothesis, parallel and nonparallel group project scores were compared using the Mann-Whitney *U* nonparametric test. All scores of student written products were combined and rank ordered (see Appendix G). The ranks of all scores in the nonparallel group (n1) were then compared to the ranks of all scores of the parallel group (n2). Table 4 shows the mean rank for each group, n1 and n2.

Table 4
Mann-Whitney *U* Test

Groups	n	mean rank	Mann-Whitney *U*
nonparallel (n1)	10	28.2	23.000
parallel (n2)	25	13.92	

The difference in mean ranks was statistically significant at the .05 level ($p <= .0001$). The analysis, however, contradicted the stated hypothesis. Thus it cannot be concluded that the parallel groups outperformed the nonparallel groups, and in fact, the nonparallel groups outperformed the parallel groups. These unexpected results concurred with results arrived at by the more commonly used t-test ($|t| = 4.81$; $p < .0001$).

Analysis of E-mail Communication

Participants in parallel groups were asked to forward a copy of all group e-mails to the investigator. This substantial written record of the project gave me direct insight into the nature, quality, and quantity of electronic communication between groups. To analyze the inter-group communication, I categorized each e-mail sent between parallel groups into one of four categories:

Critique/Response/Suggestion (C/R/S) - offers either a critique, a response, or a suggestion related to e-mail received from parallel group.

Information (I) – provides the parallel group with facts or findings specific to the sender's own interest.

Question (Q) – asks the parallel group a question regarding work on the module.

Other (O) – reflects input unrelated to the project.

Figure 3 charts the number and types—C/R/S, I, Q, O—of e-mail communications exchanged by the parallel classes. Classes A and B (Group 1) worked in parallel, and Classes C and D (Group 2) worked in parallel.

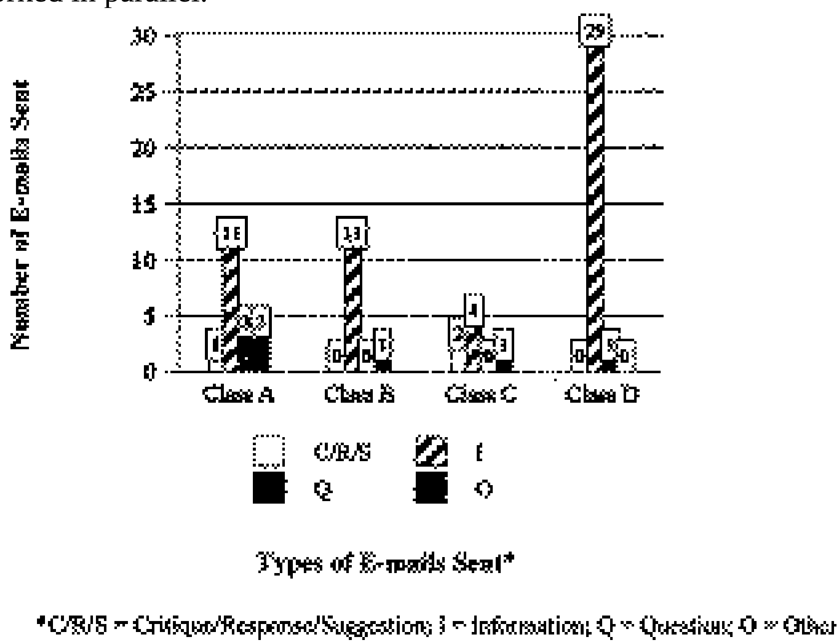

Figure 3. Number and type of e-mail communications between parallel groups, where Class A and Class B constitute one parallel group, and Class C and Class D constitute another.

As is evident from Figure 3, over a period of approximately four weeks, relatively little communication occurred between parallel groups. Additionally, the communication that did take place was generally confined to the sharing of information, with little or no reaction from the corresponding parallel groups. I suggest that the most useful type of communication in a project such as this would fall in the critique/response/suggestion category. Few of the e-mail communications qualified as C/R/S. Judging by the quantity and quality of the e-mail communication that took place between parallel groups, and certainly by the overall results of the study, it is evident that e-mail communication did not enhance or positively impact the final products of the parallel groups.

The results of this study clearly indicate that collaboration between remote groups of students via electronic mail did not result in superior student written products when compared to the written products of students who did not collaborate electronically. In fact, I conclude from this study that electronic collaboration via e-mail was a detriment to student performance.

Speculations

The results of this study indicate that on-line collaboration was a detriment to student achievement. However, the study was conducted at a time when electronic communication was relatively new to public schools. Since then, new and more sophisticated techniques for electronic communication have been developed. One could speculate in a study such as this that different results might have occurred with the use of new or different technologies. If one is interested in conducting similar or follow-up studies, the following speculations may be of some interest. However, these speculations are not based on the results of this particular study, only on the musings of researchers affiliated with ETE and myself.

Factors such as duration of classes, availability of computer labs, and unanticipated interruptions of schedules (e.g. snow days), render remote group communication asynchronous. E-mail communication, according to Leslie (1994), "can have some of the immediacy of verbal communications because messages are usually delivered in a matter of seconds. This immediacy often leads to expectations of a prompt reply and frustration when it is not forthcoming" (as cited in Kirkley, Savery, & Grabner-Hagen, 1998, p. 210). In light of this potential level of frustration, utilization of asynchronous threaded discussions instead of e-mail may prove advantageous for future projects. Coupled with means for promoting positive interdependence among learners, a process by which students learn that their actions affect the success of the group as a whole (Brandt, 1989), a threaded discussion format may keep students focused in their communication efforts thereby fostering productive communication among groups.

In retrospect, we questioned whether the students involved in this study were given sufficient reason to collaborate. In other words, did the project, as it was structured, provide the students a means by which the success of one group depends upon the success of its parallel group? Positive interdependence can be promoted in projects such as this if students' collaboration efforts are reflected in their grades, on both group and the individual levels. I suggest that, in similar projects, students' grades be directly affected by the quality of their interactions with their on-line partners. For example, students could be required to critique the problem statement, research efforts, and recommendations of the other groups. The requirement allows them to articulate their thoughts and provides them with a tool for revisiting, reflecting, and refining their ideas (Little & Myers, 1998).

In this study, perhaps students in parallel groups did not perceive the mutual benefits of on-line communication—e.g. as a source of ideas, tools, diverse data, and diverse audience (Levin et al., 1989)—to be worth the cost (e.g. time away from their particular research efforts). Designers attempted to provide useful communication guidelines with the notebooks, but the notebooks were met with staunch student resistance. The notebooks required only minutes of the students' time each day, asking them to reflect briefly on what they had learned, what they needed to do, and what they might contribute to the groups' efforts. Many students, however, perceived the notebooks as a waste of their time, and as a result, the teachers opted to discontinue use of the notebooks.

Another consideration discussed among the researchers was the importance of providing teachers with adequate training prior to their participation in projects that utilize non-traditional teaching theories and methods (e.g. constructivism, PBL). Students of teachers who had such training had better end-of-module final products than did the students of teachers who received no training (Myers, Botti, & Pompea, 1997). Please see Appendix H for further discussion of the Myers et al. study. Constructivist, PBL environments require a 'hands-off' approach unfamiliar to many teachers. Training can provide teachers with the knowledge and the skills necessary to function comfortably as facilitators in on-line, collaborative environments. A major emphasis of teacher training for on-line projects should include guidelines and recommendations for enhancing and sustaining productive electronic communication among remote partners.

The need for reform in science education in the U.S. is well documented. This study produces no evidence that integrating an electronic, collaborative component into on-line projects will help further reform efforts designed to help U.S. students become more scientifically literate. However, as the world becomes more connected through electronic communication and with advances in on-line collaborative environments, the ability to communicate and collaborate to solve problems becomes imperative. Providing students with essential critical thinking and communication skills will better enable them to thrive in an interconnected world. I feel that providing these skills for students can impact the science curriculum positively. It is an area ripe for investigation, and deserves attention.

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APPENDIX A
THE CENTER FOR EDUCATIONAL TECHNOLOGIES

Appendix A

The Center for Educational Technologies

The Center for Educational Technologies (CET) was established in 1994 with the help of the National Aeronautics and Space Administration (NASA). The mission for the Center is to provide training, conduct research, and develop products and tools to enhance teaching and learning through the effective use of technology to prepare teachers and students for the needs of the next century.

PHILOSOPHY

The philosophy guiding the Center for Educational Technologies' approach to the provision of products and services to learning communities are the beliefs that:

… The intelligent use of technology-based curriculum can advance learning and will foster profound changes in the nature of learning, teaching, assessment, and learning environments.

… Technological applications in education must be designed to benefit all learners and should be developed with consideration to individual and cultural differences.

… Equable access to CET materials must be made available to faculty, teachers, and learners across the United States by means of high-speed computer networks, video technologies, and educator-leader training.

… Increased opportunities for women, minorities and individuals with disabilities must be made available, to assure successful participation in CET programs.

… Current educational research into teaching and learning provides a theoretical base upon which to improve education.

… Development of products and services should be in accordance with the national standards developed by the National Council of Teachers Mathematics (NCTM), National Research Council (NRC) and the National Academy of Sciences (NAS).

… Application of technology-based curriculum materials must take into account training, technical assistance, and access to materials.

… The CET will succeed in its mission only by collaborating and cooperating with: the educational community; federal agencies; and representatives from the corporate and industrial sector including engineers, scientists and subject experts.

CET EXPERTISE

In order to successfully implement its mission, the CET has brought together experts in the following areas:

… Project management

… Content development

… Curriculum supplement development

… Multimedia software development

… Educator training

… Research, assessment, and evaluation

… Digital video and audio engineering

… Internet and multimedia network engineering

… Video production and broadcast engineering

… Intellectual property management

APPENDIX B
CLASSROOM OF THE FUTURE PROGRAM

Appendix B

Classroom of the Future Program

The Center for Education Technologies (CET) houses the NASA Classroom of the Future (COTF) Program -- NASA's premier research and development program for educational technologies. The COTF develops technology-based tools and educational resources for learning communities that improve mathematics, science, geography and technology education in ways that are consistent with the national reform movement. Also housed in the CET are a NASA Educator Resource Center and a Challenger Learning Center.

The COTF's mission is accomplished by:

… Developing high quality, technology intensive science and mathematics curriculum supplements that incorporate NASA and other scientific expertise and resources;

...Incorporating into its software designs current research findings on effective applications of technology in educational settings;

… Designing and delivering model pre-service and in-service educator preparation programs to improve the knowledge and competence of educators in the application of technologies in the teaching and learning process; and,

… Providing networked tools and resources to help assure equable access to NASA and other scientific expertise, data and technologies by all learning communities.

Technology-based tools and educational resources for learning communities are developed by the CET, utilizing resources from the four strategic enterprises of NASA, namely:

… Aeronautics and Space Transportation Technologies,

… Human Exploration and Development of Space,

… Earth Sciences, and

… Space Sciences.

In short, the COTF program is helping to bridge the gap between the classroom and NASA scientists, mathematicians, and engineers who have dramatically advanced the frontiers of knowledge in virtually every scientific and mathematical discipline.

APPENDIX C

Group Notebook Activities for Week 1

Appendix C

Group Notebook Activities for Week 1
Timeline for Group and Individual Tasks
(G = group task; I = individual task)

Date	Task
2/26	**G: Read and discuss information presented in module.** **I: Complete Response Sheet #1.**
2/27	**G: Complete Problem Sheet (Draft #1).** **I: Complete Response Sheet #2.**
2/28	**G: E-mail Problem Sheet (Draft #1) info. to parallel group.** **I: Research assigned area(s).**
2/29	**G: Analyze parallel group's response (Analysis Sheet); e-mail analysis to parallel group.** **I: Research assigned area(s).**
3/1	**G: Reassess problem statement and plans (Problem sheet - Draft #2).** **I: Complete Response Sheet #3.**

Name ________________
Monday, February 26

Tropical Poison
Individual
Response Sheet #1

1. I agree with the following statement (check one):

_____ I **do** think there is a problem presented in the Tropical Poison module. (Answer #2 only).
_____ I **do not** think there is a problem presented in the Tropical Poison module. (Answer 3# only).

2. This is the problem presented in the Tropical Poison module and at least three steps I would take to begin solving it:

3. I think there is no problem presented in the Tropical Poison module because:

Group Name __________
Tuesday, February 27

Tropical Poison
Problem Sheet - Draft #1

As a group, please complete the chart on the next page. You will e-mail this information to your parallel group tomorrow.

Here is an example of a chart with some issues that address the following problem:

You are the head of pediatrics at a large city hospital. Jane Barton is one of your patients. Doctor, what will you do in the case of Jane's baby?

Jane Barton is pregnant. She first came to you about two weeks ago after she and her husband received the results of tests ordered by her family doctor. The tests indicate that Jane and Ralph's baby is anencephalic. The couple is concerned about the fetus and wonder what to do if Jane cannot deliver a normal, healthy infant.

What do we know?	What do we need to know?	What should we do?
Jane Barton is pregnant.	What is the medical description of anencephaly?	Order another test to confirm the diagnosis.
Jane is married.	What is Jane's general health?	Discuss the condition of the fetus with the Bartons before too long.
Medical tests indicate that her fetus is anencephalic.	Does she have children?	Have technology ready to help the baby at birth.
Jane and Ralph feel that their baby might not be normal.	What test did she have? How accurate is it?	Use the tissue/organs of the fetus in some way.
	Is abortion possible in this case?	

-From Stepien & Gallagher

* A **Problem Statement** should be formulated after completing the "What Do We Know?" column. Please state the problem as concisely as possible in the area below the chart.

* The next two columns will define issues that need to be addressed and sources that will need to be consulted. Divide the responsibility for gathering this information among group members.

Tropical Poison Module
Problem Sheet (Draft #1)

What do we know?	What do we need to know?	What should we do?

***Problem Statement:**

Name ________________
Tuesday, February 27

Tropical Poison
Individual
Response Sheet #2

1. Here are the two best plans of action that my group developed today and why I think so:

2. It is my responsibility to gather information in the following areas. Listed beside each are at least two sources I will use to conduct research in those areas.

Group Name_____________
Thursday, February 29

Tropical Poison
Analysis of Parallel Group's
Problem (Draft #1)

* Please place a copy of your parallel group's Problem Draft #1 in this notebook for easy reference.

1. List some similarities in and differences between your group's Problem Statement and that of your parallel group's Problem Statement.

2. Did your parallel group raise any issues that your group had not thought about?

3. Were there any ideas presented by the parallel group that you wish to adopt? What are your plans for investigating additional ideas?

4. List any additional suggestions or comments.

Tropical Poison Module
Problem Sheet (Draft #2)

What do we know?	What do we need to know?	What should we do?

***Problem Statement:**

Name ________________
Monday, February 26

Tropical Poison
Individual
Response Sheet #3

1. These are the areas I have been researching and the resources I used for each:

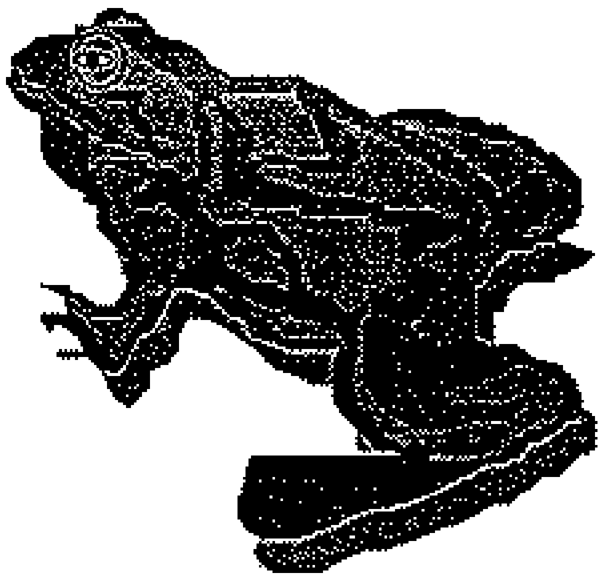
From my research, I have learned:

2. I consider my resources to be **reliable/unreliable** (please circle one) because:

APPENDIX D

EXAMPLE OF STUDENT WRITTEN PRODUCT

Appendix D
Example of Student Written Product



NE29

I. Statement of Problem

During the course of this module our problem statement changed about every four days. In the beginning, we focused on the Poison Dart frog and forest destruction. Our problem statement for 3/4 read:

> Populations of Poison Dart frogs are declining which may possibly be due to rainforest destruction, the harvest of their secreted poisons, or other less visible problems. We plan to uncover the causes and determine a solution.

As we researched for more information, we found articles supporting and expanding the tie between forest destruction and declining frog populations. As a result, our problem statement for 3/8 read:

> The destruction of the Amazon is affecting the Poison Dart frogs and possibly other species of frogs. Deforestation raises the level of carbon dioxide in the air which causes ozone depletion. Ozone depletion affects rainfall patterns and increases the amount of UVB radiation that penetrates our atmosphere.

In the next few days, we began to stray farther from our original problem statement because we were unable to find new information on Poison Dart frogs. Instead we found cases of frog populations declining in Australia, Switzerland, and the United States. So for 3/12, our problem statement read:

> The decline in frog populations is not limited to the Poison Dart frogs or to species of frogs in the Amazon. The disappearance of species is occurring worldwide. We plan to discover the main contributing factors.

We, then, researched different topics individually. It took us six days to formulate a statement problem from compiling all of our information because we printed out so many articles. Our problem statement for 3/18 read:

> Frog populations fluctuate in cycles. However, many species are actually declining. Forest destruction and UVB radiation seem to be the prime factors responsible for the die off of frog populations. Forest destruction affects frogs who lay their eggs among the ground's leaf litter. UVB radiation is the main factor contributing to the death of embryos from frogs who lay their eggs in pools of water.

II. Methodology

For the first week our group was restricted to using only the NASA module as a source for information. By the end of the second week we had begun to individually research for information using netscape, the Sewickley Public Library, and Quaker Valley's library. We continued to use netscape as a resource throughout the remainder of our project. However, netscape can be a limited resource so we e-mailed John Baker from the Declining Amphibian Population Task Force (DAPTF) and Gary M. Fellers from AmphibianDecline. Unfortunately, only John Baker responded to our e-mail.

no focus

III. Analysis of Data

*All data was taken and divided. Each section has a summarizing paragraph.

UVB Radiation and Radioactive Pollution

Life on Earth depends on a thin shell of gaseous ozone that is 10 to 25 miles above our heads. The ozone layer is the main barrier between us and the hazardous ultraviolet radiation that comes from the surface of the Sun. The short wave UVB radiations blocked by ozone are particularly damaging to organisms, because these wavelengths are absorbed in living matter by essential molecules, such as DNA, and damage them. UV radiation has been effecting the early stages of life such as larvae or the eggs of frogs in shallow water. Loss of biodiversity due to enhanced UV radiation may render an ecosystem more vulnerable to other stresses which are expected to accompany greenhouse induced climate change. Some scientists say that species are responding to the climatic changes by altering their breeding cycle times.

Radioactive pollution is also causing problems in frog populations in a few areas. Frogs tended to have elevated metabolic rates and changes in their liver and spleen. Fertility was reduced and eggs were smaller than normal.

Deforestation

Rainforests in the tropics are being cut at an unprecedented rate. Isolated mountain forests that are the last refuge of some of the most diverse ecosystems on the planet are now being cut. We are losing these forests to activities such as timber production, cattle ranching, and large-scale development projects. The cutting of these forests is thought to be contributing to amphibian decline. The habitat loss deprives native species of food, shelter, and breeding areas. Ecosystem functions such as the hydrological cycle are being disturbed. Native species are being crowded out because their habitats are too small.

Major corporations like Mitsubishi are among the greatest destroyers of forests on Earth. The South American timber cartel is defying human rights and the world's environmental well-being in a bloody frenzy to seize the Amazon's last remaining mahogany.

Declining Amphibians (Frogs) In General

Acid rain, drought, pesticides, ultraviolet radiation, and new predators are causing frog declines. Human influences causing frog declines are deforestation, pollution, and the draining of wetlands. But, no one really knows the main reason.

There are many reasons to think that amphibians might be particularly sensitive to changes in the environment. They live on land and in water so they are exposed to elements of both environments. They permeable skin which gives little protection to environmental change. Also, their eggs are not protected by a shell again giving little protection to environmental change.

Many different scientists around the world are trying to solve this problem. They are constantly monitoring species. If declining and non-declining species show consistent differences in their habitat requirements and shelter sites then this indicates that the factors should be investigated further.

The Declining Amphibian Populations Task Force operates through a network of Working Groups. They raise money and distribute it in the form of small grants to initiate research projects in key areas. The representing groups of the force collect geographical data on amphibian declines and their causes around the world.

*Also included in this section is the information we received when we E-Mailed John Baker on the Declining Amphibian Populations Task Force.

Amphibian Decline in Other Countries Other Than the Amazon

Frog populations are declining in all areas of the world from Amazon Rainforests to the mountainous regions of California. In Switzerland other species of amphibians besides frogs are declining. In Australia there are many species of frogs that are declining.

In Australia there is a dramatic decline of frogs in its wet tropics. In some areas a highly virulent pathogen is thought to be the most likely responsible agent. Pathological evidence from animals collected in declining populations clearly suggests viral infection.

IV. Summary and Conclusion

We focused on frog population declines in species that lay their eggs on the forest floor and in pools of water. We are hypothesizing that forest destruction and UVB radiation are responsible for the declines in frog populations. We plan to disprove that the declines in frog populations is due to natural fluctuations in numbers.

Frog populations are diminishing worldwide. Frogs are very sensitive to sunlight and toxins, therefore changes in climatic conditions are changes that many frogs are unable to adapt to. However, destruction of the frogs' natural habitat is still the greatest threat to their species.

Many frogs typically known for laying their eggs on the forest floor, live on the ground near, but not in streams. They hide under rocks, logs, moss, or some other form of cover. These frogs are diurnal, or active during the day, and spend most of their lives among the leaf litter on the rainforest floor. These frogs feed on the insect inhabitants that are typical of tropical rainforests.

An example of this would be the Poison Dart frogs. They lay their eggs in very small clutches, only two to twelve at a time, which is a relatively small number compared to other frogs. These clutches are deposited on the ground and are usually tended to by the male for about two weeks. After the tadpoles hatch, the parent frog transports them on his or her back up a tree to deposit them into a bromeliad filled with rainwater. There the tadpoles undergo metamorphosis and leave the pool some months later as small versions of their parents.

Recently there has been more and more talk about the disappearance of the frogs who lay their eggs on the forest floor. This disappearance is often due to the disappearance of the rainforest itself. This habitat loss takes several forms: basic loss of areas used by wild species like the frogs; degradation, which deprives native species of food, shelter, and breeding areas; and fragmentation, when native species are squeezed onto small patches of undisturbed land surrounded by areas cleared for agriculture and other purposes.

In most cases the rainforest land is being cleared for large scale cattle ranching, mining operations, logging, government road building, military operations, and the subsistence agriculture of peasants and landless settlers. The majority of the destruction is not due to the slash and burn agriculture of peasant farmers, but to large scale businesses who are there for cattle ranching or to obtain some other rainforest resource. Companies like Petroecuador, a government-owned oil company in Ecuador; Mitsubishi Corporation, a transnational company that deals in lumber interests; and the South American timber cartel are defying the world's environmental well-being in a frenzy to seize the Amazon's last remaining mahogany.

The destruction of the rainforest is a human induced problem that is affecting populations of frogs. However, there are natural environmental factors that are affecting numerous species that live in pristine reserves and in their natural habitat. This led scientists to look for answers to the questioning decline of frogs. UV radiation seems to be one of the key factors affecting the frog species of today.

The Sun is responsible for the development and continued existence of life on Earth. The Earth is warmed by the Sun's continuous streams of infrared rays. Harmful effects of sunlight on biological systems are due almost entirely to radiation within the ultraviolet spectrum. The ultraviolet spectrum is subdivided into three bands. UVB radiation is by far the most significant part of the ultraviolet spectrum. The levels of radiation of this band reaching the Earth's surface is controlled by a gas called ozone. Short wave UVB radiation is particularly damaging to organisms, because these wavelengths are absorbed in living matter by essential molecules, like DNA, and damage them.

All animals, plants, and other organisms that are exposed to the Sun have developed ways to cope with and protect themselves from the small fraction of solar UVB radiation that reaches the Earth. Organisms have a DNA repairing mechanism called photoreactivation. But, even a small amount of UVB radiation can have a significant effect on ecosystems. Ecosystems may be disturbed further by harmful UV radiation on animals. Frogs are more susceptible to immediate damage because they lack feathers or hair. For example, the early stages of life of frogs is affected because the UV radiation penetrates the surface of shallow water where many frogs lay their clear jelly-like eggs. The eggs are exposed to sunlight for a prolonged amount of time, which allows for the DNA to absorb the energy from the rays which produces new structures. This disrupts the functioning of the cells and sometimes causes death.

Although the larvae have a mechanism to repair the damaged strands of DNA, not all frogs are the same in their ability to repair the UVB damage. In 1993, John Hays and his research assistant conducted experiments, in Oregon, to find the effect

UVB radiation had on frog eggs. They made enclosures around different masses of fertilized eggs from different frog species. Some were blocked from exposure to UV radiation and others were not. The results showed that the Pacific tree frog was able to produce the same number of offspring regardless of whether they were protected or exposed. However, significant numbers of Cascade frog eggs never hatched when exposed to the Sun's rays. It is known that the Cascade frog produces low levels of photolyase, which are the enzymes that counter-act damage from UV exposure.

Those species of frogs that have low levels of photolyase can easily become infected because ultraviolet rays impair immune functions. A fungus that commonly infects frog eggs is *Saprolegnia*. It is a parasitic water mold that grows on the scales or eggs of fish. In many case fish that have been raised in hatcheries become the host of *Saprolegnia*. They are released into nearby streams and infect the eggs of frogs.

V. Application

The information we have gathered concerning amphibian decline will hopefully help us or someone else in the future. When we enter college we can use the information we have learned to help us in other projects. We may even get the chance to apply what we have learned and find the cause of the amphibian population problems.

This project gives us experience in working together on a large project. The process we went through was complex enough that it gave us many problems. We have learned that working together and dividing the work equally is usually quite impossible. In the future we will know how to handle things so that there a relatively few problems.

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APPENDIX E

EVALUATION SHEETS
CORRELATING WITH
STUDENT WRITTEN PRODUCT

(Appendix D)

Appendix E
Evaluation Sheets
Correlating with
Student Written Product
(Appendix D)

Paper Number NE29 No Title Grader [redacted]

PROBLEM STATEMENT

The problem is well defined	The problem statement is appropriate(Useful for research)	The problem statement is valid (relates to the Brazilian rain forest and the influences upon it)	Total/Average
4	4	4	4

METHODOLOGY

how/where was the data obtained - an explanation	The methodology is duplicable (reliable)	Sources are reasonable/valid/ credible... Bibliography	Total/Average
4	4	4	4

ANALYSIS OF DATA

A premise relating to the problem statement is developed.	A logical analysis is presented	Supporting facts are organized such that conclusions can be adequately drawn	Total/Average
4	4	2	3.3

SUMMARY & CONCLUSION

The argument is sound	A reasonable summary is stated	Conclusions are valid	Total/Average
4	4	2	3.3

APPLICATION

Reasonable and appropriate connections to the real world	Obvious connections are not omitted or overlooked.	Includes problem solving suggestions	Total/Average
4	0	2	2

Total for the paper 3.32

Comments - Great preparation, lacked significant conclusions due to lack of data supporting declining populations. I agree with the researchers, that this has been a valuable experience.

Paper Number NE 29 Grader [redacted]

PROBLEM STATEMENT

The problem is well defined	The problem statement is appropriate(Useful for research)	The problem statement is valid (relates to the Brazilian rain forest and the influences upon it)	Total/Average
4	4	4	4

METHODOLOGY

how/where was the data obtained - an explanation	The methodology is duplicable (reliable)	Sources are reasonable/valid/ credible… Bibliography	Total/Average
4	2	4	3.3

ANALYSIS OF DATA

A premise relating to the problem statement is developed.	A logical analysis is presented	Supporting facts are organized such that conclusions can be adequately drawn	Total/Average
4	4	4	4

SUMMARY & CONCLUSION

The argument is sound	A reasonable summary is stated	Conclusions are valid	Total/Average
4	4	4	4

APPLICATION

Reasonable and appropriate connections to the real world	Obvious connections are not omitted or overlooked.	Includes problem solving suggestions	Total/Average
4	0	2	2

Total for the paper 3.46

Paper Number NE29 Grader [redacted]

PROBLEM STATEMENT

The problem is well defined	The problem statement is appropriate(Useful for research)	The problem statement is valid (relates to the Brazilian rain forest and the influences upon it)	Total/Average
4	4	4	4

METHODOLOGY

how/where was the data obtained - an explanation	The methodology is duplicable (reliable)	Sources are reasonable/valid/ credible... Bibliography	Total/Average
2	2	4	2.7

ANALYSIS OF DATA

A premise relating to the problem statement is developed.	A logical analysis is presented	Supporting facts are organized such that conclusions can be adequately drawn	Total/Average
~~0~~ 4	~~0~~ 4	4	4

SUMMARY & CONCLUSION

The argument is sound	A reasonable summary is stated	Conclusions are valid	Total/Average
4 ~~0~~	2	2	2.7

APPLICATION

Reasonable and appropriate connections to the real world	Obvious connections are not omitted or overlooked.	Includes problem solving suggestions	Total/Average
2	4	0	2

Total for the paper 3.1

Appendix F

RAW AND AVERAGE SCORES FOR WRITTEN PRODUCTS

Appendix F
Raw and Average Scores for Written Products

	Raw Scores			
Product Code	**Evaluator 1**	**Evaluator 2**	**Evaluator 3**	**Average (Final) Scores**
PD23	1.06	.94	.54	0.846
PD24	2.28	2	2.5	2.26
PD25	1.6	1.3	1	1.3
PD26	1.88	1.7	2.3	1.96
PD27	1.62	1.1	1.6	1.44
PD41	2.4	2.1	2.5	2.33
PB12	2.94	3.18	2.5	2.87
PB13	2.52	2	2.3	2.27
PB14	1.44	1.6	2.1	1.71
PB15	1.88	1.7	1.7	1.76
PB16	2.68	2.8	2.9	2.79
PB17	3.08	2.8	2.9	2.926
NF33	2.7	2.7	3.18	2.86
NF34	1.58	2	1.2	1.59
NF35	2.12	2	2.14	2.086
NF36	1.72	1.6	2	1.77
NF37	2.14	2	2.5	2.21
NF38	2.54	2.4	2.26	2.4
NF39	3.32	3.2	3.72	3.41
NF40	2.1	1.6	1.88	1.86
NE28	3.2	3.44	3.2	3.28
NE29	3.46	3.32	3.1	3.29
NE30	3.06	3.2	2.8	3.02
NE31	3.18	3.3	3.5	3.326
NE32	2.38	2.2	2.6	2.39
NA01	3.46	3.46	3.1	3.34
NA02	3.6	3.2	3.7	3.5
NA03	2.8	3.1	2.8	2.9
NA04	3.46	3.44	3.7	3.53
NA05	2.2	2.3	1.96	2.15
PC18	1.08	1.06	1.2	1.11
PC19	1.6	1.2	.7	1.17
PC20	1.3	1.2	1.3	1.27
PC21	1.9	1.34	1.7	1.65
PC22	1.7	1.46	.9	1.35

APPENDIX G

Rank Order of Written Product Scores

Appendix G
Rank Order of Written Product Scores

Product Code	Parallel Groups =1 Nonparallel Groups=2	Product Score
PD23	1	0.846
PC18	1	1.11
PC19	1	1.17
PC20	1	1.27
PD25	1	1.3
PC22	1	1.35
PD27	1	1.44
NF34	1	1.59
PC21	1	1.65
PB14	1	1.71
PB15	1	1.76
NF36	1	1.77
NF40	1	1.86
PD26	1	1.96
NF35	1	2.086
NA05	2	2.15
NF37	1	2.21
PD24	1	2.26
PB13	1	2.27
PD41	1	2.33
NE32	2	2.39
NF38	1	2.4
PB16	1	2.79
NF33	1	2.86
PB12	1	2.87
NA03	2	2.9
PB17	1	2.926
NE30	2	3.02
NE28	2	3.28
NE29	2	3.29
NE31	2	3.326
NA01	2	3.34
NF39	1	3.41
NA02	2	3.5
NA04	2	3.53

APPENDIX H
Analyses from The Classroom of the Future

Appendix H

Analyses from The Classroom of the Future

Concurrent with the research associated with this study was research conducted by the ETE staff at the Classroom of the Future. An excerpt from a paper written for the American Educational Research Association describes their study as follows:

> A study was initiated at the inception of the Exploring the Environment (ETE) project to look at critical factors concerning the use of PBL in earth science classes. The modules were delivered via the World Wide Web. In addition to the use of inquiry-based methods, the ETE modules incorporated the use of NASA remote sensing images as a classroom resource. Of particular interest in this study was the impact of teacher training in using PBL, student engagement and motivation, and the quality of students' products [based on the findings of this study]. ETE was designed as a supplement to earth science courses by a team consisting of biologists, geologists, and educators. Each module within ETE is self contained and addresses the increasing interaction between the scientific and human dimensions (Myers et al., 1997).

To judge the effectiveness of their on-line modules and their application, an "ex-post facto," or causal-comparative research design was used to analyze Likert data from teacher and student surveys. Differences between classes were analyzed using ANOVA. Please note that the ETE research discussed in this section reflects data collected from the schools involved in my study as well as data collected from three additional schools involved in similar studies. The Myers et al. (1997) paper may be found in its entirety on the COTF website at (http://www.cotf.edu).

Particularly pertinent to this study are anecdotal comments from teachers and students regarding their work on the module, and analyses of the effect of teacher training on the quality of student end-of-module written products.

E-mail Communication Between Parallel Groups

ETE-administered student end-of-module questionnaires asked two questions that shed light on the students' attitudes toward working in parallel with remote groups. The first question was, "What was most exciting or interesting about working on the ETE module?" Besides answers that pointed to the computer aspect of the project (e.g. the Internet, the pictures, or the sound capability), parallel group work was the next most common answer. One student wrote, "I liked working with a corresponding group in another state. We could exchange information, and it seemed like we were educating across the nation." Extensive use of the computer, the Internet, and e-mail was a very exciting aspect of the project for students.

Interestingly, the answers to the second question, "What was most frustrating or hard about working on the ETE module?" paralleled the answers to the first. Students reported feeling frustrated by computer-related issues (e.g. lab availability, networking difficulties, and searching issues), and also reported a high level of frustration with parallel group communication. Telling comments included:

> "Communicating with other groups out of state was difficult due to scheduling and weather."
>
> "The most frustrating part was not having a corresponding group to work with. They never wrote us or knew what they were doing."

Students apparently enjoyed the idea of collaborating with remote groups on the project and even enjoyed the little amount of communication that did take place. It is also apparent from their questionnaire responses that they recognized the communication that actually took place did not further the goals of the project.

Teachers also reported a certain level of disappointment and frustration toward the parallel aspect of the project on their end-of-module questionnaires. Though teachers reported an overall enthusiasm and satisfaction with the project, their views on the success of the inter-school collaboration was less than enthusiastic. Responses to the question, “Was collaborative work successful in your classroom?” included:

> “Students did not do an adequate job of communicating with their parallel groups.”
>
> “Technical problems and computer lab availability conspired against success.”
>
> “Parallel collaboration broke down and was disappointing. I had high hopes, was anxious about it, and ...it did not materialize.”
>
> “In the end, e-mail just stopped flowing when each group of students reached their level of frustration.”

Teacher Background and Experience

Prior to this particular study, the ETE Project Team conducted one-week workshops for participating teachers, with four of the original seven teachers in this study attending the workshop. Final product scores of students whose teachers participated in the workshop were compared to the scores of students whose teachers did not attend the workshop. Results indicated that students whose teachers attended the ETE workshop prior to this study had significantly better end-of-module written products than the students of teachers who did not attend the ETE workshop (Myers et al., 1997).

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Doctor of Philosophy, Instructional Technology
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EXPERIENCE

Graduate Teaching Assistant
Virginia Polytechnic Institute & State University,
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Taught Psychological Foundations of Education to undergraduate education and psychology students.

Graduate Assistant
Virginia Polytechnic Institute & State University,
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Assisted college of education faculty and students in hardware and software use in Educational Technology Lab.

Graduate Assistant

Virginia Polytechnic Institute & State University,
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Assisted in the development of a database system to track education alumni for the deans office in the college of education.

K-12 Instructional Technology Consultant

Wythe County Public School System,
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Conducted workshops with Chapter I teachers on integrating computers into the curriculum.

Teacher

James Madison Middle School,
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Taught computers, math, science, social studies, and English to students enrolled in the Math, Science, and Computer Magnet School.

PROFESSIONAL ACTIVITIES

Presentations

Little, J. O. & Myers, R. J. (March, 1998). Students on-line: The effect of inter-school collaboration in a problem-based learning, constructivist environment. Annual Conference of the American Educational Research Association, San Diego, CA.

Myers, R., & Little, J. (May, 1996). Learning Environmental Earth Science Using Telecommunications and Parallel Problem Solving. Fourth Annual Conference on "Datafication," Marshall University, Huntington, WV.

Myers, R. J. & Little, J. O. (February, 1993). Enhancing hypermedia design through cognitive methodology. Annual meeting of the Eastern Educational Research Association Conference, Clearwater Beach, FL.

Papers

Myers, R., Purcell, S., Little, J., & Jaber, W. (1994). *A middle school's experience with hypermedia and problem -based learning.* In selected readings of the annual conference for the International Visual Literacy Association, Rochester, NY; ERIC document ED370567.

Academic Honors

Phi Kappa Phi National Honor Society
Virginia State Instructional Fee Scholarship (1992 – 1996)
Dean's List, Virginia Polytechnic Institute & State University (1989)