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Project-based Learning in Information Technology Environment

by

Rogheyeh Eskrootchi

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PROJECT-BASED LEARNING IN INFORMATION TECHNOLOGY ENVIRONMENT

By

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ABSTRACT

The purpose of this study was to investigate the effectiveness of project-based learning in a technology-rich environment. A science project, Land-use in Watershed, that takes advantage of Internet facilities was developed. The project was integrated with a simulation software package, STELLA, to promote deeper understanding of land use by students. Participants in the study were of 72 middle school students. The project consisted of three parts: reading the project material on-line, conducting the watershed experiment with the physical model of the watershed made from sponge and cardboard by the researcher, and performing a STELLA simulation on watershed concepts. A 58-question student survey was created by the researcher and four basic types of information were collected. Part A, addressed content knowledge of the watershed concept. Part B, referred to students' understanding of the watershed concept. Part C, addressed the students' attitudes toward the project, and Part D, referred to students' computer background. The analysis of data in Part A indicated that there is no significant difference between control group versus experimental group while a main effect of condition emerged in Part B. Students who participated in the watershed experiment and the STELLA simulation performed

the best on Part B. The analysis of data on Part C indicated that the majority of students had positive attitudes towards the project, especially the STELLA activity. Information regarding students' computer background indicated that 90% of students had used a computer before but very few had any experiences with STELLA simulation.

For my beautiful, smiling children,

Salmon and Samira.

You are my inspiration.

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CHAPTER ONE

THE RESEARCH PROBLEM

Introduction

Experienced educators tend to agree that students learn best through a project-based approach in which they are able to discover things for themselves. Project-based learning (PBL) blends traditional subject-matter goals and objectives with authentic learning environments. The primary rationale for using authentic activity as the model for appropriate learning activities is the enhanced understanding that develops through application and manipulation of knowledge within context. Authentic learning activities support a related set of values: collaboration, autonomy, multiple perspectives, pluralism, activity, reflectivity, generativity, authenticity, and ownership (Lebow,& Wager 1994).

Authentic activities are models for appropriate learning activity in the design of computer-based simulations and project-based learning activities. However, computer-based simulations and reality-centered projects do not guarantee that students will assume a positive orientation to learning nor derive the benefits of in-context learning. Additional support is required to strengthen the tendency of the learner to engage in intentional learning processes and to help the learner

progressively assume responsibility for learning (Lebow & Wager, 1994).

Furthermore, curriculum innovations are never easy to implement or to examine systematically. The introduction of microcomputers into classrooms has generated innumerable instances of such innovations. The innovations involve considerable change in classroom management, lesson structure, and student assessment. They often involve designing projects that are not related to students' lives and are discrete rather than connected to a particular set of questions.

The National Research Council's (1996) standards for science education suggest long-term inquiry activities to learn subject matter. These include such elements as argumentation and explanation, communicating ideas to others, and using a wide range of manipulative, cognitive, and procedural skills. The standards suggest that in order to enhance understanding, students need to relate new information to previous information and build connected networks of concepts. Researchers (Lamb and Smith, 1997) have studied the ways in which students develop projects, and have developed information-processing models that incorporate the information.

For instance, according to the study done by Lamb and Smith (1997), "8 Ws" are the core of the process of project-based learning development. "8 Ws" include

Project watching, wondering, webbing, weaving, wiggling, wrapping, waving, and wishing. Students move through this process at their own paces and ability levels. Some students wiggle physically, while others wiggle mentally. Being aware of individual interests and needs can help to facilitate projects that help students move from collecting information to creating knowledge. Lamb and Smith argue that the "8 Ws" help students turn information into knowledge, share that knowledge, and learn from the experience.

In addition, Krajick et al. (1994) suggested that there are five features of PBL that help communicate the complexity of the innovation in terms that are familiar to teachers. The features of PBL (Krajcik et al., 1994) include driving questions, investigations, artifacts, collaboration, and technological tools.

Collaborative project-based learning is a hybrid approach, drawing on a variety of educational theories and instructional design research, including collaborative learning (Brown, 1990; Kaye, 1992), active learning (Bork, 1992), intentional learning (Bereiter and Scardamalia, 1989; Scardamalia, et al., 1989), distributed expertise (Brown, 1994; Brown et al., 1993), resource-based learning (Rakes, 1996; Taylor and Laurillard, 1995), and project-based instruction (Honebein et al., 1993).

This approach can be supported by multimedia and network technologies such as the Internet and the World Wide Web. The advent of the microcomputer revolution brings with it the potential for people to increase their understanding of our environment. Powerful hardware and sophisticated software tools are becoming available at a rapid pace. Technologies are becoming available that enable people to become more active learners about their environment (Jackson et al., 1997).

While technology can be valuable in supporting students and teachers in projects requiring higher level thinking (Blumenfeld, et al., 1991), it is not the kind of technology that matters most, but rather how it is used (Dyrli and Kinnaman, 1994; Ehrmann, 1995; Green and Gilbert, 1995).

From an instructional design perspective, educational simulations support predetermined learning outcomes by providing participants with opportunities to deal with the consequences of their actions and to respond to feedback. Within Pea's (as cited in Lebow & Wager, 1994) framework of distributed intelligence, computer-assisted simulations have the potential to reorganize mental processes by "closing of the temporal gaps between thought and action [and] between hypothesis and experiment" (p. 85). Pea has proposed that by allowing the user to engage in "what-if thinking"

through a partnership between user and technology, deep qualitative effects are made possible on how problem solving occurs (Lebow & Wager, 1994).

STELLA, which stands for Structural Thinking and Experiential Learning Laboratory, with Animation, is a program designed to assist users in creating their own simulations using system dynamics. STELLA is one technology that can enable individuals to enhance their understanding of and appreciation for the complex web of interrelationships that govern environmental behavior (Peterson, 1985).

Understanding how a simulation construction kit, like STELLA, can be used to refine thinking is important. Simulation models are simplified representations of real-world systems over hypothetical time. They are used to examine the structure of systems. Using simulation software, characteristics of selected variables can be altered and their effects on other variables and the entire system assessed (Steed, 1992).

Although theory supports using technology to engage students in project-based learning, and the literature provides descriptions of suitable classroom technology to engage students, we have few case studies of elementary teachers describing their development (Steed, 1992).

Statement of the Problem

With the re-emergence of experiential learning as a dominant model of learning in education and the recent research on infusing information technologies into classrooms, it is a good time to examine the effectiveness of project-based learning in technology-rich environments. The purpose of the present study was to investigate the effectiveness of the project-based learning in a technology-rich environment.

The following research question was proposed: How effective is the reality-centered project in engaging students in meaningful learning and enhancing their motivational attitude, especially when integrated in a technology-rich environment?

To answer this research question a science project was developed, Land-use in Watershed, which takes advantage of Internet facilities. This project was integrated with a simulation software, STELLA, to enhance deeper understanding for students. Land-use in Watershed was a collaborative science project which was developed on-line by the researcher for the Kansas Collaborative Research Network (KanCRN). Two simulation applications using STELLA software were also designed by the researcher to further emphasize the concept of watershed and in particular the effect of land-use on runoff in a

watershed. (See appendix A for complete description of the project).

A 58-item student survey consisting of 58 questions was administered at the end of the study. Four basic types of information were collected. Part A, consisted of ten True/False questions to measure content knowledge; part B, consisted of seven open-ended questions to measure students' understanding of the watershed concept; part C, consisted of twenty-three multiple-choice questions that referred to the students' attitude toward the project, and part D, consisted of five multiple-choice questions which addressed students' computer background. The questionnaire administered to the control group included parts A and B, four items from part C and no part D. In addition, several types of data were collected through observation, such as the amount of the time spent, small-group interaction and number of times students asked for help in different parts of the project.

Rationale for the Study

An often-stated belief is that producing transfer is the main job of education. However, an increasing body of research shows that the way knowledge is presented to students in school and the kinds of operations they are asked to perform often result in students knowing something but failing to use it when relevant. Brown, et

al. (1989) believed that classroom activities lack the contextual features of real-life problem-solving situations and therefore weaken the ability of students to transfer and apply their knowledge from the school setting to the outside world.

Studies suggested that in order to facilitate transfer, promote metacognitive and affective learning, support an adaptive motivational pattern to learning, and encourage a high degree of ownership and personal relevance, educators should provide training on real tasks. Similarly, researchers believe that cases and examples must be studied as they really occur, in their natural contexts, not as stripped-down 'textbook examples' that conveniently illustrate some principle (Blumenfeld et al., 1991).

Theorists and educators are promoting reality-centered projects, theme-based learning, and other kinds of activities situated in real-life and life-like contexts as ways to engage students in meaningful learning (Blumenfeld, et al., 1991; Clinchy, 1989; Wager, 1994). However, transformation of the conventional classroom into an authentic learning environment involves much more than incorporating features of real-life situations into school work.

It is the intention of the researcher in this study to examine and discuss ways in which learners engage in

an intentional learning processes and analyze the effectiveness of such an approach which consists of three areas: a) an authentic learning activity in the content of project-based learning; b) technology-based learning utilizing the Internet; and c) educational simulations.

Assumptions

This study rests on three assumptions. The first is that the students responded truthfully to the questionnaire administered at the end of the study. The second is that students were representative of Northwest Middle School in Kansas City, Kansas (KCK) district. The third is that there was no ambiguity in the questions to cause the students to interpret them differently.

Limitation

This study was limited in scope because the students were not randomly selected. Since every classroom may have different environments, the results may not reflect the effect of project-based learning in the technology-rich environment for Northwest Middle School children as a whole, nor can it be generalized to other schools because of the diversity in the socio-economic status of the students, their attitudes towards school and schooling, their computer backgrounds, or financial constraints of individual schools. A major limitation in this study was the two weeks time scope in which the project was conducted. The lack of sufficient time to

deliver the complete project caused elimination of components and modification to the original plan. Larger groups were formed to conduct the experimental part of the project instead of the intended small groups; only one of the two applications of the STELLA simulation was explored by students.

Overview

Literature related to project-based learning in a technology-rich environment is presented in Chapter Two. Chapter Three contains the discussion of the method used to obtain the information to answer the research question. This chapter describes the subjects, instrument, and the procedure employed in gathering data. In Chapter Four the information gathered from the students' survey is presented. Chapter Five contains a summary, conclusion, and recommendations related to this study.

CHAPTER TWO

REVIEW OF THE LITERATURE

Introduction

It is an often stated belief that producing transfer is the main job of education. However, an increasing body of research shows that the way knowledge is presented to students in school and the kinds of operations they are asked to perform often result in students knowing something but failing to use it when relevant. Brown, et al. (1989) have concluded that this condition, referred to as a transfer problem or the problem of inert knowledge, occurs because classroom activities lack the contextual features of real-life problem-solving situations. Today, interest is widespread in learning through authentic activity as the theory base for situated learning matures and as innovations in computer-based multi-media systems outstrip development of theory-based instructional strategies (Dick, 1991). Theorists and educators are promoting reality-centered projects, theme-based learning, and other kinds of activities situated in real-life and life-like contexts as ways to engage students in meaningful learning (Blumenfeld, et al. 1991; Clinchy, 1989).

Implications of authentic activity are considered as a model for appropriate learning activity, particularly in the design of computer-based simulations and project-based learning (PBL) activities. Transformation of the conventional classroom into an authentic learning environment involves much more than incorporating features of real-life situations into school work (Lebow & Wager, 1992).

Preparation of computer-based simulations and reality-centered projects does not guarantee that a student will assume a positive orientation to learning nor derive the benefits of in-context learning. Much additional support is required to strengthen the tendency of the learner to engage in intentional learning processes and to help the learner progressively assume responsibility for learning.

This chapter intends to review and discuss ways in which learners engage in intentional learning process and is divided into three sections, with each section organized around one of the following three questions, and each question serving as a topic for one section:

(a) What are the characteristics of an authentic learning activity and project-based learning (PBL), and how is such learning related to problem-solving in real life?

(b) What are the characteristics of technology-based learning, especially the Internet?

(c) What are the characteristics of educational simulations, and what do people learn from them?

Authentic Activity through Project-Based Learning and Real-life Problem Solving

In the cognitive indenture framework, understanding develops through application and manipulation of knowledge within the context, in other words, through authentic activity. This principle explains the primary rationale for using authentic activity as the model for appropriate learning activities. As Brown, et al. (1989) suggested, conventional classroom tasks frequently lack the contextual features that support transfer from the school setting to the outside world. The use of authentic activity in schools would increase cognitive engagement, support meaningful learning, and facilitate transfer.

Authentic activity represents a holistic and generative view of appropriate learning activity that treats learning and motivation as interdependent processes and places emphasis on self-directed learning and on development of metacognitive ability necessary to support it. Authentic learning situations retain some of the complexity and messiness of real-world

problem-solving situations, as well as some of the advantages of simulation (Lebow & Wager, 1994).

Authentic learning activity is designed to support a related set of values: collaboration, autonomy, multiple perspectives, pluralism, activity, reflectivity, generativity, authenticity, and ownership (Lebow & Wager, 1994). In this view of instruction, ends are integrated with means. For example, a goal of instruction, to develop interpersonal skills for sustaining cooperative group work, is also a means to achieving the very same goal by practicing group process skills in the context of personally relevant goals. Another goal, to develop the ability to reflect on one's own learning processes, is also a means of self-correction and self-regulation of the learning process. In effect, instruction within an authentic learning activity is a model for the values that instruction is designed to support.

Carroll (1990) has suggested that in order to facilitate transfer, promote metacognitive and affective learning, support an adaptive motivational pattern to learning, and encourage a high degree of ownership and personal relevance, educators should provide training on real tasks. Similarly, Lebow and Wager (1994) believe that cases and examples must be studied as they really occur, in their natural contexts, not as stripped down

'textbook examples' that conveniently illustrate some principle.

Real-Life Project Development

From term papers to Web pages, the "project" has become the standard activity in many instructional units. The question is, are students constructing knowledge as they construct projects? There is more to developing a meaningful project than simply choosing a topic and writing a paper (Lamb & Smith, 1997).

In some cases, projects were designed to show abstract principles, general procedures were specified, and results were already known. The activities were not related to students' lives and were discrete rather than connected to a particular set of questions or organized around a phenomenon. Students often did not discover the intended ideas and relationships or accommodate their understandings in light of experimental results. They did not relate the activities to everyday experiences, so that, even when students could explain experimental results and answer test questions correctly in school, their misconceptions about the phenomenon persisted outside school. Teacher implementation varied considerably. The innovations involved considerable change in classroom management, lesson structure, and student assessment. Although students were active and on task, much of their focus was on carrying out procedures

rather than thinking deeply about important science concepts. In fact, work on activities was characterized as hands-on, but not necessarily minds-on (Tobin, et al. 1994).

Recent recommendations for science education reform (American Association for the Advancement of Science, 1993; National Research Council, 1996) reflect new concepts of teaching and learning that assign primary importance to the way students attempt to make sense of what they are learning rather than to how teachers should deliver information. This current view pictures students as actively constructing their knowledge by working on authentic tasks in which they must apply and represent ideas (Brown, et al. 1989; Newmann, et al. 1989; Resnick, 1987).

The National Research Council's (1996) standards for science education suggest that a smaller number of science concepts be studied and integrated across disciplines. The standards propose long-term inquiry activities to learn subject matter that include such elements as argumentation and explanation, communicating ideas to others, and using a wide range of manipulative, cognitive, and procedural skills. Earlier science reform (Karplus, 1977) relied on hands-on activities to promote the discovery of ideas. In some instances, students' achievement and attitudes improved after students

participated in these hands-on, activity-based programs (Bredderman, 1983). However, the effect of these efforts was limited by problems related to the design of activities, student learning, and classroom implementation.

The newer approach to instruction, activity-based science, is premised on new research on learning that examines how knowledge is organized and stored in memory. A large body of research (McGilly, 1995) has shown that when information is acquired through the memorization of discrete facts, it will be isolated. As a result, it is hard for students to access the information and apply it to new situations. Alternatively, knowledge can be robust when it is organized into large, conceptually linked networks. This kind of organization facilitates flexible access and use of knowledge so that the learner can ask and answer questions, draw analogies to new situations, and solve problems. To enhance understanding, students need to relate new information to previous information in order to build connected networks of concepts. To do so they need to use memory, elaboration, and organizational strategies to elaborate, organize, and remember new information, and they need to employ metacognitive strategies to evaluate the effectiveness of their strategy use and understanding. Knowledge also grows as students reorganize and restructure existing ideas that

prove to be inadequate to explain new phenomena. Knowledge growth is influenced by several factors (Lundeberg et al, 1997).

First, how students store information depends on existing knowledge and beliefs. Second, learning is situational; knowledge is contextualized and cannot be easily separated from the situation in which it develops (Brown et al., 1989). Knowledge is not an abstraction that can be transferred readily from how it is learned in the classroom to how it needs to be used out of school. Moreover, how students are asked to demonstrate knowledge affects what they learn. Therefore, authentic activities and assessments need to be designed carefully. These activities should mirror real-world situations; they should afford students opportunities to engage ideas in many different ways so that they build representations of concepts under study and see how they can be applied. The use of alternative assessments is encouraged, rather than reliance on standardized tests that tap fragmented and decontextualized knowledge. Assessment should focus on students' mastery of the discipline and knowledge integration. For example, Perkins (1992) calls for "understanding performances" in which students engage in demonstrations of thoughtfulness that go beyond answering test questions or writing brief reports for the teacher (Lundeberg et al., 1997)

Third, environment and culture affect knowledge. What students learn is influenced by social interaction; students can learn by talking and collaborating with others and with more experienced adults. Through collaboration, they encounter and explore ideas in a subject and ways that ideas are validated; that is, students learn what constitutes legitimate knowledge in a field.

Fourth, learning also is tangled with the use of cognitive tools. The possibility exists for supporting robust learning, with the explosive growth and accessibility of new technologies. Such tools include interactive videodisks, telecommunications, microcomputer-based laboratories, and software applications for modeling, visualizing, and simulating. Learners are supported by these tools as they solve complex and ambiguous problems by providing access to data and information, and opportunities to collaborate, investigate, and create representations (Lundeberg et al., 1997).

In general, the teacher is viewed as a co-learner and guide in the new approaches who is mediating between the child's everyday world and the world of science. Driver, et al. (1994) suggest that the teacher's role is to acquaint learners with new ideas or cultural tools and

to support and guide students as they make sense of these.

For project-based learning to succeed, teachers may need to assume an active role, provide choices within limits, and state clear expectations without restricting student creativity. Moreover, teachers will need to assess students' construction of knowledge, not just their construction of projects, and try to see projects from the students' perspectives, which may be different from their own. Figuring out how to assess complex understanding in technology-rich elementary classrooms that provide choices to students will not be an easy task (Lundeberg et al., 1997).

For instance, a study was conducted to examine the changing beliefs, practices, and reflections of two elementary teachers who engaged students in project-based learning in a technology-rich environment. Researchers visited the class daily collecting videotapes of interactions, informal and structural interviews with teachers and students, written notes of class activities, survey data of students' beliefs about what they had learned, and computer HyperCard projects created by students. Three core beliefs related to knowledge construction were evident through classroom observations, teacher interviews, and videotapes: (a) strategic knowledge of how to find and organize information is

important; (b) construction of projects leads to constructing and organizing knowledge, and (c) knowledge of student learning is evident from group interaction (Lundeberg et al., 1997).

The focus of the study was a geography class, students were required to develop HyperCard applications in geography. Two teachers taught this course and forty students, ranging from fourth to seventh graders, with a mix of males and females, enrolled for class (Lundeberg et al., 1997).

In some ways the teachers assumed that for students to be active, teachers had to take on a passive role. This worked well for some skilled and/or self-motivated students but not for all the students observed. These elementary students needed more guidance and clarification of expectations regarding a project (Lundeberg et al., 1997).

According to this study, both teachers believed that, students learned best when they were allowed to work together to share ideas, exchange expertise, take initiative, and evaluate one another's work. A second core belief was that doing is learning. The teachers believed that constructing projects would enable students to learn both geography and HyperCard. Third, as students found information, selected information, decided how to

reorganize and present that information, teachers surmised that learning occurred (Lundeberg et al., 1997).

In general, the survey results indicated a high degree of task engagement and excitement about learning geography and HyperCard, increased skills in providing meaningful evaluative feedback to peers, and increased skills in technology (HyperCard skills). However, both teachers and students had several questions about what exactly students were learning through this course (Lundeberg et al., 1997).

The teachers believed that the construction of projects would lead to constructing and organizing knowledge. Yet, they assumed that because students were active, they themselves should be passive. A common misconception about project-based learning is to think content will emerge and that teachers do not have to teach content directly. In addition teachers were unsure of how to assess students' learning using projects their students created. They also wondered whether students were actually achieving the higher-level thinking skills they sought to promote (Lunderberg et al., 1997)

Furthermore, the teachers viewed technology primarily as a context in which students could find, manipulate, organize, and present information. Students, however, did not see technology simply as a means to learn geography, but rather they saw learning technology,

particularly HyperCard, as an end in itself. It was not clear to students that there were different expectations for technology-as-content and technology-as-context. The differences between students' and teachers' assumptions about technology often resulted in different interpretations of student learning. In other words, teachers viewed the course as learning *with* technology; students viewed it as learning about technology (Lundeberg et al., 1997).

Assessment practices used by the teachers in this study showed mixed results. Although the teachers asked many good questions, they missed others. For example, the teachers did not raise questions about project revision for either technology-as-content or technology-as-context. The emphasis was on products; as a result, the course was viewed as a collection of discrete activities. Furthermore, the teachers did not always form questions from a student's perspective. For example, organizing and representing information was reviewed from the teachers' perspective of technology (as context). They seemed unaware of many implications of prior HyperCard knowledge. While they recognized the presence of such knowledge at the beginning of the course, they seemed unable to understand how knowledge (or lack of knowledge) would play out in the course. On one hand, students would need to work through the bells and

whistles stage as they developed skills and confidence. Frequently, this time spilled over to the second and third projects. On the other hand, if a student had better developed skills than a team member, he or she was more likely to control the keyboard rather than take time to explain a process. Such behavior delayed access for students who needed keyboarding time (Lundeberg et al., 1997).

Moreover, it was likely that technology masked the lack of quality of some of these projects. A number of these projects probably would have been more critically assessed if they had been in traditional form. In some cases information was copied verbatim, missing, or simply erroneous.

In conclusion, these teachers' beliefs were ahead of their practice. They understood the importance of teaching students how to find and organize information. However, in some cases, they neglected to provide critical information themselves or to ensure that students were making appropriate choices regarding resources. Finally, these teachers believed that knowledge of student learning was evident from group project presentations. It was not always explicit if the teachers assessed projects based on their original (though vague) guidelines.

How do teachers develop learner-centered, information-rich, problem-based projects? Many researchers have studied the ways in which students develop projects, and they have developed many information-processing models.

According to the study done by Lamb and Smith (1997) the following "8 Ws" are the core of the process of project-based learning development. Project-based learning (PBL) blends traditional subject-matter goals and objectives with authentic learning environments. Project development involves watching, wondering, webbing, weaving, and wishing. Students move through this process at their own pace and ability level. Some students wiggle physically, while others wiggle mentally. Being aware of individual interests and needs can help you facilitate projects that help students move from collecting information to creating knowledge.

1- *Watching*--requires *students to* become observers of their environment. Students become more in tune with the world around them, from family needs to global concerns.

2- *Wondering*--focuses on the exploration of ideas such as brainstorming, discussing, and reflecting on questions, and concerns.

3- *Webbing*--requires students to begin locating information and connecting ideas. During this phase,

students select those resources that are relevant and organize them into meaningful clusters.

4- *Wiggling*--involves twisting and turning information to look for clues, ideas, and perspectives. Wiggling is often the toughest phase for students.

5- *Weaving*--requires the highest levels of thinking. At this stage, students begin to originate new ideas, create models, and formulate plans.

6- *Wrapping*--involves packaging the ideas, solutions, and communications. Students are faced with the following questions: Why is this topic important? Who needs to know about it? How can I effectively communicate my ideas to others?

7- *Waving*--requires students to share their ideas, try out new approaches, and ask for feedback. It is the publishing aspect of the project.

8- *Wishing*--demands students begin thinking about how the project went and consider possibilities for the future. It is the reflection point in the project.

Following the above "8 Ws" would help students begin to understand this information-processing model. It helps students to turn information into knowledge, share that knowledge, and learn from the experience (Lamb & smith, 1997).

A key to promoting PBL and similar innovations is to support teachers as they change from information-

transmission models to those that stress students' transformation of ideas. The literature on teacher change is clear and indicates that change will not take root and innovation will not be sustained if one adopts traditional top-down models of dissemination that rely on single workshops, distribution of curriculum materials to be used exactly as prepared, and lists of prescribed practices (Cohen and Ball, 1990; Hall and Hord, 1987; Joyce and Showers, 1988; Kaestle, 1993).

Fullan (1993) argues that staff development must lead to improvement of school organization, not merely the skills of individual teachers. In order to accomplish school change through staff development, efforts should focus on teacher learning; quality leadership as a result of change attention to fostering an organizational culture that supports efforts to change and engagement of local and regional agencies in the school's efforts.

Five features of PBL help communicate the complexity of the innovation in terms that are familiar to teachers. The features of PBL (Krajcik et al., 1994) include a driving question, investigations and artifacts, collaboration, and technological tools.

Driving question. Three essential characteristics of good driving questions need to be discussed in order to overcome the persistent problem that school learning is focused on ideas whose connections are not apparent

(Perkins, 1992). First, questions need to be worthwhile in that they are consistent with existing curriculum frameworks. Students develop conceptual understandings stipulated by district and state curriculum frameworks when exploring the driving question. Second, driving questions need to encompass real-world problems that students find meaningful, thereby motivating them to take ownership of the questions and to thoughtfully pursue answers to them. Third, students need the prerequisite knowledge and skills to design and conduct investigations to find answers to their questions; therefore, questions need to be feasible. Students answer the driving question with the aid of projects that last from two weeks up to the entire school year. Well-designed projects enable students to ask their own sub-questions that personalize the driving question. Questions like "What is air?" involve important science content but are not authentic. The same content can be learned and more authenticity is afforded by a question like, "Will breathing the air in my city make me sick?"

Investigations and artifacts. If students are to understand complex ideas in science, they need to engage in deep cognitive processing of the content. Investigations emulate the real work of science; they engage students in planning, designing, and conducting real-world research to collect and analyze data and draw

inferences from those data. Investigations are not mere activities. They need to be open enough that the method and the answer are not known to students before beginning. Similarly, students need to create products that contribute to and reflect their learning. These products are called artifacts. Artifacts are real results of the process of investigation that represent student understanding. Artifacts can be computer programs, multimedia documents, written reports, posters, group presentations, or any complex representation (or preferably, multiple representations) of the students' thinking (Perkins, 1992).

Collaboration. In PBL, teachers should structure the classroom environment so that students work in groups. Group activities can foster collaboration--literally laboring together to accomplish a task. Collaboration is an essential component of PBL. It provides opportunities for students to share ideas, extend their thinking, draw on the expertise of others, and experience the value of thinking intelligently (Bruer, 1995). It is important to distinguish between collaboration and cooperative learning. The latter is often highly structured and students are assigned roles, tasks, and procedures. In contrast, collaboration is more loosely structured with roles largely negotiated among participants. Cooperation focuses on small groups within the classroom;

collaboration envisions a wider sphere of communities of learners.

Technological tools. Technological tools are emerging as an important component of the PBL classroom: they enable more authentic investigations as well as support deep understanding and learning in ways that are not possible with paper and pencil (Gordin et al., 1994; Linn, in press; Wisnudel, et al in press). In many respects, technology pervades all of the other features, although PBL can be conducted (and in many cases because of limited resources must be conducted) without new technologies. Thus, technology is considered as a separate feature in order to highlight its unique and promising potential. This feature will be discussed separately, later in this chapter.

Potential benefit of Project-based Learning

Many reasons explains why real-life project-based learning methods that are relevant to the design of authentic learning environments are beneficial:

a) According to, Lebow and Wager(1994), understanding develops through experience in multiple case contexts and from multiple perspectives within the same context because conditions are frequently ill-structured and problems are ill-formulated.

b) When reasons for performing procedures, even tedious ones, are understood within the context of a

broad global task environment, individuals assume responsibility for establishing and monitoring their goals and strategies (Honebein, et al. 1994).

c) Project-based learning allows people to have opportunities to engage in active and generative problem-solving activities that involve personal values and beliefs. As a result, they experience a feeling of ownership over the activity and its goals, and thus, the tendency to engage in intentional and self-regulated learning processes is enhanced (Lebow & Wager, 1994).

d) People work together in project-based activity where the intelligence to solve a problem or perform an activity is distributed across a group of peers, a learner-mentor system, and/or an electronic performance support tool (EPSS) or other form of cognitive technology (Gordin, et al. 1994). The quality of interactions between participants is frequently of primary importance in undertaking a project or accomplishing a goal.

e) When people work collaboratively on solving real-life problems, they share in substantive conversation, which has a different quality from conventional school talk (Newmann, et al. 1989). An individual's orientation toward learning is qualitatively different when learning is embedded in the context of achieving personally relevant and valued

goals versus working for a grade or some goal that is far off in the future.

Potential Problems with Project-based Learning

There are several barriers to implementing successful project-based learning:

a) Students' expectation--Innovative instruction might conflict with students' expectations and abilities. For, example, students who have been successful at memorization might be reluctant to embrace new approaches that require greater thoughtfulness and initiative. Also, students who lack the skill to negotiate roles or engage in productive discussions as they work on collaborative tasks might prefer to work by themselves (Blumenfeld et al.,1991).

b) Required time-- Most teachers face common problems when enacting PBL (Blumenfeld et al., 1994). Investigations and discussions often take longer than anticipated. Also, in-depth exploration of ideas takes longer than the more familiar broad and superficial survey of concepts. A related challenge is how to meet district curriculum guidelines while incorporating new in-depth approaches. Teachers need to select driving questions carefully in order to ensure that students' investigations enable them to learn the science content stipulated in curriculum frameworks.

c) Classroom management--Some teachers have difficulty organizing and monitoring simultaneous tasks and dealing with increased activity and noise. Teachers must balance the need to allow students the freedom to talk together and explore the design with the need to maintain order so that students can work and converse productively. In addition, teachers often feel a need to control the flow of information because of concerns about learning. They assume that students need to master lower-level material and facts; however, they also think that students need to build their own understanding. They want to direct lessons to ensure that students get the right information(Blumenfeld et al., 1994).

d) Support of student learning--Teachers have difficulty scaffolding experiences so that students can take responsibility for learning, and they frequently give students too much independence without adequately modeling thinking, structuring the situation, or providing feedback. Often teachers' ability to scaffold is related to their own mastery of the subject matter (Blumenfeld et al, 1994).

e) Technology use-- Teachers who are not proficient users and have not used technology as a cognitive tool have difficulty incorporating technology into the classroom. They might use it to enhance their previous instructional practices, such as using multimedia for

demonstrations, but it takes considerable time and skill before they can help students exploit technology's benefits as a tool (Blumenfeld et al., 1994)

f) Assessment--Students who are heavily involved in project-based investigations are not all exposed to the same content in the same way, thus rendering conventional tests inadequate. Teachers have difficulty designing assessments that measure student understanding. The artifacts they ask students to produce often involve participating in a public performance or sharing reports, but do not always require students to generate conceptual representations in the production of some artifacts (Blumenfeld et al., 1994).

Integrating Technology-based Learning Especially the Internet, in PBL

Curriculum innovations are never easy to implement or to examine systematically. The introduction of microcomputers into classrooms has generated innumerable instances of such innovations. While researchers attempt to document the cognitive, affective, and social effects of the innovations, teachers struggle to adapt the technological advances and their potential implications for instructional and classroom procedures (Mandinach, 1988). Teachers have their reservations in implementing a new pedagogical approach depending on potential payoff, while researchers may look for the opportunity

to study the innovation even if the instructional machinery is not yet in place. Both practitioners and researchers are trying to keep pace with and identify ways of functioning effectively within the technological revolution. A delicate balance must be struck with teachers and researchers working toward a mutual understanding of the factors, constraints, and perspectives under which the other must function (Mandinach and Thorpe, 1987b).

The advent of the microcomputer revolution brings with it the potential for people to increase their understanding of our environment. Powerful hardware and sophisticated software tools are becoming available at a rapid pace. Technologies are becoming available that enable people to become more active learners about their environment (Mandinach, 1988).

While technology can be valuable in supporting students and teachers in projects requiring higher level thinking (Blumenfeld, et al., 1991), it is not the kind of technology that matters most, but rather how it is used.

Technology-based Learning

The effective use of technology from both the teachers' perspectives and the students' perspectives including interactive access to information, individualized student-teacher interactions, and

assessment practices (Auten, 1994) begins with helping teachers ask key questions about the instructional tasks and the context in which they will take place (Lundeberg et al., 1997). When students use hypermedia to design projects, they engage in a number of cognitive tasks, such as formulating questions, collaborating with team members, finding relevant information, selecting and organizing that information, representing the information in multiple ways (text, graphs, pictures, animations, sound), revising their work, and evaluating themselves.

Similarly, giving opportunities to design software programs in order to explain something to their peers creates a powerful learning environment (e.g., the best way to learn is to teach (Scott, et al., 1991). Explanation and design are important components of constructing knowledge. Papert (1990) differentiates between constructivism and constructionism by saying that the former stresses that knowledge is built by the learner, whereas the latter emphasizes how that knowledge is built (when learners are engaged in the construction of something). However, expecting teachers to allow students to create multimedia computer projects requires more than just technology support (Lundeberg, et al., 1997). In their study of teachers encouraging students to create multimedia projects, Gillingham and Scarborough (1994) found that one key element of success was

teachers' understanding of project-based learning. "The ability of a teacher to embrace elements of project-based learning, rather than technology knowledge alone, determined whether students' multimedia projects were successful" (p. 2). Putting ideas such as project-based teaming into practice depends on beliefs teachers hold about how students learn. Teachers' instructional practices are related to their beliefs about teaching and learning (Dwyer, et al., 1990).

As teachers become more steeped in using technology effectively to promote thinking, they become less didactic (academic) and more constructivist; they lecture less and coach more, and they expect individual differences rather than expecting students to learn all the same information (Collins, 1991). Their practices change as they work toward classroom technology implementation. Some researchers describe implementation effectiveness of PBL in terms of needed technology support: personal and professional productivity, teaching enhancement, changing pedagogy, and changing content (Green & Gilbert, 1995). Using technology to restructure education according to constructivist views (Collins, 1991) is an involving process. Three key principles emerge from constructivist views: (a) People learn from new experiences based on prior knowledge and beliefs; (b) new knowledge is always situated in a context; and (c)

learning is socially mediated and acquired within learning communities (Anderson, et al., 1995). This perspective assumes that not only the student should be actively involved in constructing knowledge, but that the teacher should be equally active in mediating this learning (Scott et al., 1992). From this perspective, communications, interactions, and social relations are essential components of the learning process (Scott, et al., 1992).

Learning and Communication

"In learning and communication, there have been several paradigm shifts: 50,000 years ago, spoken words were used for the first time in history; 5,000 years ago, letters were used for the first time; 500 years ago, printing of books introduced a new era; 50 years ago information technology started to revolutionize communication; and 5 years ago, web technology made one global communication room"(Jackson, 1998, p. 155). The rapid development of information technology indicates that we are at the beginning of this paradigm shift.

The information age is about to change classical teaching completely. The student studies what is interesting, and society tells the university to provide the graduates and the research that society needs. These changes are parallel and integrated with changes in

technology, particularly information and communication technology (Johan, 1998).

A recognized goal of using information technology is to "deliver content, provide access to information, allow students and faculty to find and manipulate information, to take new meaning from it, and to have new learning experiences"(Green & Gilbert, 1995, p. 16-17).

Web technology is part of the learning environment. Network technologies offer the potential for many-to-many communication. Providing facilities in classrooms for such communication between students opens up possibilities to alter traditional teacher centered classroom discourse in ways that allow students to engage in knowledge-advancing discourse with each other (Ward & Tissen, 1997)). Communication involves individuals sharing what they already know. While communication is an important component of collaboration, collaboration is qualitatively different from communication in that it involves people working together to build new understanding which could not be achieved by the participants individually (Schrage, 1990). Beyond communication, collaborative learning also requires the ability of students to share documents, workspaces, resources, etc., in order to advance the knowledge of individual students as well as a whole group (Ward & Tiessen, 1997).

Collaborative project-based learning is a hybrid approach, drawing on a variety of educational theories and instructional design research, including collaborative learning (Brown, 1990), active learning, intentional learning (Scardamalia, et al., 1989), distributed expertise (Brown, 1994), resource-based learning 1996; Taylor & Laurillard, 1995), and project-based instruction. This approach can be supported by multimedia and network technologies such as the Internet and the World Wide Web. The decentralized, worldwide telecommunications network known as the Internet or, as popularized by the Vice President of the U. S., the "Information Superhighway" (Gore, 1995), is seen by many educators as the most exciting technological development in recent history. Many compilations of anecdotal reports (U. S. Department of Education, 1994) provide tantalizing examples of the great potential of the Internet as a resource for teaching and learning.

Internet

Many educational technologists have heralded the potential benefits of Internet technology across the curriculum for reshaping education around the idea of independent problem solving by students of all ages (Kelly and Wiebe, 1994). Some public schools and districts already have poured vast amounts of money and human resources into making selected schools fully

"wired" internally and bringing them "on-line" externally, and encouraging teachers in all subjects to experiment with the potential benefits of network access (Wilson and Utecht, 1995).

In science education in particular, introductory "how-to" articles have appeared in both practitioner--oriented journals (Gauger, 1994) and in the literature aimed primarily at teacher educators (Shepardson, 1995), outlining various ways to connect to the potentially unlimited capabilities of scientific and pedagogical information access and dissemination which the Internet can provide. At least four research groups (Jackson et al., 1997) have initiated science education projects at the middle school level in particular of which "Internetworking" is a crucial component.

"With the introduction of new Internet technologies into classrooms, possibilities arise for developing new instructional approaches that: (a) take advantage of new technologies and (b) are difficult to do without the technologies"(Ward & Tissen, 1997, p. 22).

PBL and Internet. Constructivist educational theories highlight the importance of two dimensions of learning: the engagement of students in the intentional pursuit of their own learning goals and the role of social interactions in learning processes (Hawkins,

1993). A collaborative project-based approach is an instructional approach that addresses both of these dimensions and is supported by a new Web-based technology. The main activities of learning in this instructional approach involve students (and teachers) working together to collect resources and add intellectual value to them. From an instructional perspective, this approach has the following characteristics: (Ward & Tissen, 1997).

- Information resources are used by students in their research.
- Value is added to the resources as students manipulate and construct representations of their own knowledge.
- Students' activities are organized around those which are likely to be educationally profitable.
- Students have individual and group responsibilities in their projects.
- Students share information, communicate to coordinate activities, and collaborate to build communal knowledge products.

In project-based learning at Norwegian University of Science and Technology (NTNU) the students work and report on the web, and teachers present the projects on the web. Most of the written information to students from teachers is presented on the web. Special subject modules made by the teachers are available for the students in a

database. Immediate messages and responses may be by e-mail (Wager & Tissen, 1997).

The findings from NTNU indicate that most students are positive about PBL because they become more motivated than in traditional classes. In the beginning, many students are frustrated because they are used to being told what to do step-by- step. After a while, they find that this situation gives them freedom to act and to create, and most students prefer that situation. Some teachers are enthusiastic about PBL and some are not, probably in equal numbers. The teachers' attitudes will be the crucial issue for the further development and introduction of the learning methods and learning environment (Wager & Tissen, 1997).

Interviews of students in traditional lecture classes gave the clear message that students learned least from lectures, more from exercises, and definitely most from fellow students (Wager & Tissen, 1997).

The explosion of Internet technology affords educational opportunities that resonate with PBL. Although traditional print resources will continue to have their place, the World Wide Web's access to primary sources, current information, and dynamic and computational media provides unique learning opportunities. Using readily available information-

manipulation tools, students build on resources from the network and construct their own relationships and representations. Moreover, students can use the Web to have others read and comment on their work, thus enhancing student motivation and sense of community. For example, students published a set of articles on diseases that affect teenagers. Of course, the real challenge is not the technology per se but how it is used by classroom teachers, curriculum designers, school media specialists, and students; going beyond surface accomplishments takes considerable effort, energy, planning, and experience (Blumenfeld et al.,1994).

In several cases, teachers also have been pleasantly surprised at the substantive value which students place on even simple graphics which are not necessarily intended to have any explicit educational value. When they see a visual image on the Web rather than in a textbook illustration or teacher drawing or even a three-dimensional classroom model, it is more "real," immediate, and meaningful to them in some way (Blumenfeld et al., 1994).

Real Value of Internet. What is the real value of multimedia information from the Internet, as opposed to well-produced and well-chosen videotapes or videodisks?

Part of the answer is the potential for the Internet to provide continuously updated information. Surprisingly to some of us, another primary reason is that at least some students see this information as not impersonal but actually *more* personal than other media, even when the flow *of* information *is* only one-way.

To illustrate just how high are the expectations of many people, here are a few excerpts from some of the most glowing reports

Connecting our nation's schools to the Information Superhighway would allow millions of students to find and access information that would otherwise be unavailable to them. Students could thus access and download mathematics and scientific information, data, or images, then analyze or interpret the information or data, and construct understandings about the mathematics or science concepts (Shepardson, 1995).

Digital libraries will allow teachers and students to use information resources and tools that have traditionally been physically and conceptually inaccessible (Jackson, et al., 1997).

While excitement and optimism are widespread, several authors who are highly knowledgeable in the fields of computers, telecommunications, education, and science (Salvador, 1994) are also highly skeptical of the claims made by Internet enthusiasts. Even some

commentators who are very enthusiastic about the educational potential of the Internet in general realize that the path of the Information Superhighway is not without potholes and its destination is far from certain. It has often been said that the Internet is starting to provide the largest library humankind has ever had. As true as this may be, the Internet is also the messiest library that has ever existed (Jackson et al., 1997).

The latest technological panacea for fixing education is to just connect all the students to the Internet; with all that information out there, surely they will learn however, students need mentorship in order to use the tools of their trade effectively. The Internet is no exception; just connecting students is not enough--the trick, of course, is to know where to look on the Net. While the indexes are helpful, Internet surfing is more like stumbling around a library with thousands of long bookshelves all marked "miscellaneous" (Soloway, 1995).

The strengths and weaknesses of the Internet as a tool for middle school science teaching and learning, as viewed by the participants in an ongoing teacher education and curriculum development effort known as the Science Connections Project, was examined (Jackson et al., 1997). The project involved collaboration among teachers, administrators, science educators, scientists,

and technical experts. Observation of students who were using the Internet as a resource for project development, showed that the most successful learning experiences were those in which the teacher acted as a facilitator, paying careful attention to students and guiding them through critical stages of their projects. It was found, also, that many teachers were not just using the Internet to provide their students with information access; they were also using the Internet to teach search strategies, critical evaluation, decision making, problem solving, and communication skills (Jackson et al., 1997).

The result of this study indicates that teachers expressed an appreciation not only for the possibilities which Internet access may open up, but also for the potential problems created by both the nearly unlimited quantity of information available on the Internet and the limited quality and relevance of much of that information (Jackson et al., 1997).

The simplest and most immediate problem faced by the teachers was the current technical unreliability of network connections. Several of the teachers have politely but firmly refused to make any effort to use the technology at all until such time as "the bugs are all out." Others feel that purely technical problems have significantly affected their substantive use, both in terms of access to information and as an outlet for

communication. A major concern of almost all of the teachers was that at least strong teacher guidance and possibly an unrealistic level of teacher supervision might be required to avoid pitfalls in flexible, open-ended student use of Internet searches (Jackson et al.,1997).

While several teachers have had very encouraging results from their initial explorations, the element that is still missing is a coherent set of strategies to guide the information seeking, gathering, and utilizing process. Sometimes one of the hierarchically structured "Net Directories" can lead them to useful sites under the "Education" or "Science" headings, but most often thus far, more specific searches have been needed. Teachers are finding that this is very much an art rather than a science, and that experience is much more valuable than any general principles (Jackson et al., 1997).

The problem is not restricted to the potential for students to actively try to locate "adult" sites, but the fact that titles and summaries of such inappropriate material can often appear on the screen as a by-product of a well-intentioned search in an academic context (Jackson et al., 1997).

Many of these students have had limited exposure in the past to multimedia databases located in the school's media center or computer lab, enough to have overcome the

effect *of* motivation through pure novelty. Most students, however, are coming to understand and value the capability *of* rapid and flexible access to information, despite all of the aforementioned problems (Jackson, et al., 1997).

Furthermore, a number of other problems with existing Web-based technologies need to be addressed in order for their potential for collaborative project-based learning to be realized.

Active Learning in Virtual Environments (ALIVE!) Project was developed to construct innovative network-based multimedia tools to address these problems, and support collaborative project-based learning activities for K-12 education. The *ALIVE!* suite of tools takes advantage of and builds on advances in Web-based network technologies and information resources in ways that enhance the use of these technologies and resources in the classroom setting (Wager & Tissen, 1997).

The availability of unmanageably large volumes of information can make it difficult for teachers to incorporate resources into classroom activities in meaningful ways, and for students to focus on their specific learning goals. The *ALIVE!* technology provides teachers and students with resource- management tools which support the construction of collections of information resources from a variety of media and

sources, including WWW, CD-ROM, and student-created resources. These collections can be stored for future use and shared with other teachers and students (Wager & Tissen, 1997).

The *ALIVE!* technology provides tools for students to engage in constructive activities, adding value to existing resources, by building their representations within existing Web pages.

Although theory supports using technology to engage students in project-based learning, and the literature provides descriptions of suitable classroom technology to engage students, we have few case studies of elementary teachers describing their development and growth in using technology in a constructivist classroom (Wager & Tissen, 1997).

It is ideal to believe that technology will help students better understand the world. It is desirable to find an easy way to prepare children for a most challenging future. Experience and common sense suggest otherwise: learning is slow and difficult!

Characteristics of educational simulations, and what people learn from them

Interest in the design and development of simulations has come from the availability of powerful low-cost computers. Simulations can be used to deliver instruction in educational, military, and industrial

settings. Simulation increase the ability of participants to apply what they have learned in the classroom to the real-world or transfer situation. Due to the variety of purposes for which simulation are used and the contexts in which they appear, the theoretical assumptions underlying the design of simulations are varied. According to Cunningham (1984), a simulation duplicates some essential aspect of reality for purposes of experimentation, prediction, evaluation, or learning. An educational simulation is designed to increase one's ability to respond appropriately in a real-world or transfer setting. Participants practice decision-making, problem solving, and/or role playing in the context of a controlled representation of a real situation.

From an instructional design perspective, educational simulations support predetermined learning outcomes by providing participants with opportunities to experience the consequences of their actions and to respond to feedback. Within Pea's (as cited in Lebow & Wager, 1994) framework of distributed intelligence, computer-assisted simulations have the potential to reorganize mental processes by "closing of the temporal gaps between thought and action [and] between hypothesis and experiment" (p. 85). Pea has proposed that by allowing the user to engage in "what-if thinking"

through a partnership between user and technology, deep qualitative effects are possible in problem solving.

The definition of fidelity appears to vary depending on the context to which it is applied and the theoretical orientation of the author. For example, in proposing a model for assessing the fidelity of task simulators used in industry, Bruce (1987) proposed three criteria: (a) physical similarity, (b) functional similarity, and (c) task communality. The fidelity of a simulator within Bruce's fidelity (accuracy) verification model is determined by assigning a value to each of these categories and combining them to produce a fidelity index for a particular training device. In contrast, Smith (as cited in Lebow & Wager, 1994) believes that the essential reality factor in a simulation is not the form of the simulation but the information-processing demands it imposes on the learner. He has referred to this characteristic of a simulation as its "cognitive realism," the degree to which the simulation engages participants in a decision-making or problem-solving process that parallels the mental activities required in the real situation.

Contrary to what intuitively may seem the case, research does not support the idea that maximizing realism or fidelity of a simulation results in

maximizing learning outcomes (Alessi, 1987). Reigeluth and Schwartz (as cited in Lebow & Wager, 1994) have recommended that the best way to handle complexity in a simulation, when designing for a novice learner, is to start with low fidelity and to add fidelity and complexity progressively. Similarly, Blumenfeld et al. (1991) have proposed that a great strength of simulation for instructional purposes is its potential to allow students active exploration in simplified environments. They believe that when extraneous details are minimized, interactions between variables are easier to notice than in a highly realistic simulation or in the transfer environment itself. The simplifying conditions method proposed by Lebow and Wager (1994) seems to take advantage of strengths inherent in simulation without sacrificing authenticity of the learning activity. In this method, experts identify a simple kind of case that is as representative as possible of a real-world task and the ways in which this "epitome" version of the task differs from more complex versions. Over time, complexity and variation are added to the learning activity in a systematic manner with the expectation that the method preserves the potential benefits of in-context learning.

Reigeluth and Schwartz (as cited in Lebow & Wager, 1994) have described three major elements in the design

of a simulation that they believe determine its effectiveness: the scenario, the underlying model, and the instructional overlay.

They have suggested that the scenario and the model should duplicate to some degree the essential characteristics of the transfer situation. In other words, the characteristics of the scenario and the model determine the fidelity of the simulation, although how to identify the essential characteristics of the transfer situation is not addressed. Also, Lebow and Wager (1994) have concluded that the instructional overlay, the features in the simulation that function to optimize learning and motivation, are generally the weakest aspect in educational simulations.

One element of the instructional overlay that Reigeluth and Schwartz (as cited in Lebow & Wager, 1994) feel should receive more attention from designers is the provision of artificial feedback. Alessi and Trollip (1985) have distinguished between natural feedback that the real-life situation provides and artificial feedback that the designer builds into the simulation. One of the strengths of simulation for instructional purposes is its potential to shelter learners from costly forms of natural feedback (skidding into a snow bank) and to provide real-time artificial feedback (turn in the direction of the skid.)

STELLA, which stands for Structural Thinking and Experiential Learning Laboratory, with Animation, is a program designed to assist users in creating their own simulations using system dynamics. STELLA is one technology that can enable individuals to enhance their understanding of, and appreciation for, the complex web of interrelationships that govern environmental behavior (Peterson, 1985).

STELLA as a Learning Tool

Systems thinking is a scientific analysis technique given fame by Jay Forrester and his colleagues at the Massachusetts Institute of Technology. Work on computer modeling of systems thinking started over 30 years ago. Early models focused on urban growth and development and global patterns of the consumption of natural resources. In recent years appreciation has developed particularly for the inquisitive value of systems thinking. The creation and manipulation of models is increasingly recognized as a potentially powerful teaching technique (Steed, 1992).

The fundamental concepts for programs like STELLA come from a system dynamics viewpoint. Feedback is a fundamental concept of system dynamics. This program takes the idea of causal loops and elaborates on them. This feature is the result of a causal factor that either directly or indirectly, loops back to affect

itself. Feedback loops can help define the boundaries of a system. The influences within the causal loop are usually the most important ones. Instead of thinking in terms of "A affects C", you should think: "A has a causal relationship to C", and "C then has feedback to influence A"(Steed, 1992).

The field of system dynamics provides a means to understand the behavior of complex phenomena over time. It is based on the concepts: (a) variables characterize a system and change over time; (b) relationships among variables are interconnected by cause-and-effect feedback loops; and (c) status of one or more variables subsequently affects the status of other variables. Instead of diagrams that just represent causal loops, other aspects of dynamic systems have to be taken into account. STELLA provides iconic forms of levels, flows, converters, and connectors. With these tools one can create a sophisticated simulation that contains complicated causal loops. STELLA makes use of four fundamental building blocks in the development of explicit system models: the stock, the flow and flow regulator, the converter, and the input link. The user hooks up these building blocks on the computer screen to make his thoughts explicit about a system (Peterson, 1985). Thus system dynamics focuses on the connections among the elements of the system and provides a means to

understand how the elements contribute to the whole (Andersen, et al., 1983).

Often the model is not an exact match with reality, only an abstraction. Models can be created in many ways; there are mathematical models, mental models, physical models, computer models, or some combination of the above. The idea is that once a model is in place a simulation can occur by giving the user control of the parameters. Computer simulation will be the focus of this section; in particular, continuous simulations. Continuous refers to the concept of change over time. Discrete simulation refers to individual actions that are not connected, simply a single event in time or a series of isolated events (Mandinach, 1988).

A simulation is an attempt to imitate or approximate something while to model means to build a representation of something. It should be noted that there is a semantic difference between a model and simulation. A model is a representation of structures whereas a simulation infers a process of interaction between the structures of the model to create a behavior. However, the two notions are so closely aligned that sometimes it is difficult to draw a distinction between them; in many instances, these two terms are used interchangeably.

Understanding how a simulation construction kit, like STELLA, can be used to refine thinking is important. Simulation models are simplified representations of real-world systems over hypothetical time. They are used to examine the structure of systems. Using simulation software, characteristics of selected variables can be altered and their effects on other variables and the entire system assessed.

The simulation modeling generally takes two forms. Depending on the courses, students are (a) required to develop their own models of scientific phenomena, or (b) given existing models and are asked to alter particular parameters to examine the subsequent effects on the entire system. These two distinct approaches to modeling are likely to produce different cognitive outcomes in terms of content knowledge and general problem-solving skills (Peterson, 1985).

STELLA is a sophisticated computer-based learning tool, appropriate for anyone interested in learning about systems. STELLA makes it easy for users to develop their dynamic intuition, test their understanding, and subject their assumptions to critical scrutiny. With continual use of STELLA, users systematically become better, more efficient thinkers. Students of our environment can use STELLA to clarify and deepen their

understanding of environmental interactions (Peterson, 1985).

STELLA facilitates student introduction to the analytic and problem-solving perspectives inherent in systems thinking. Hence, modeling now can be incorporated into science education at the secondary level. Recently the Mathematical Sciences Education Board (1987) recommended that modeling become a major emphasis in mathematics and science education (National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, 1983). Because the costs of the microcomputers and STELLA now are affordable for many secondary schools, it is possible to implement the Board's recommendation on a wide-scale basis.

STELLA IN EDUCATION

Education needs tools to teach thinking, not just tools to teach concepts. Those applications that facilitate scientific thought and encourage problem solving are of interest. Until recently, the instructional use of system (Mandinach, 1988) thinking was constrained to environments that had powerful mainframe computers. The advent of a new software product STELLA (Structural Thinking Experimental Learning Laboratory with Animation; Richmond, 1985) has made it possible to operationalize these concepts on a

microcomputer. STELLA minimizes the mathematical and technical skills needed to construct models through capitalization on graphics and icon technology of the Macintosh microcomputer and facilitates the creation and manipulation of complex models of system phenomena (Steed, 1992).

Simply described, STELLA is a modeling "language" that removes much of the technical burden associated with the development of explicit system models. STELLA provides users with a set of tools and structural "building blocks." Users make their thoughts about a system explicit as they piece together the building blocks. Once the user has finished a structural diagram and has specified relationships between elements, STELLA will simulate the behavior implied by the system of assumptions. If the simulation does not generate the expected behavior, the user is obligated to modify their assumptions until they discover that set of assumptions that is capable of generating the behavior of interest. Throughout this iterative process of active experimentation, the user learns about the system under investigation. The user learns, by discovering for themselves, the relationships that can give rise to the phenomenon of interest (Peterson, 1985). STELLA software gives us an exciting facility for questioning the way we view the world.

Many of the so called hard sciences have little problem being translated into STELLA equations, yet numerous disciplines and applications are not so easily given to quantification. Despite this potential shortcoming, STELLA purports to be a system that creates simulations from even the affective domain. One of the assumptions many people use is the notion that because something can not be measured it can not be quantified. The authors of STELLA argue that by giving qualitative information quantitative values, one can think about them in a rigorous way and yet not reduce their qualitative value (Peterson, 1985).

The idea is to quantify something even if it can not be measured. Measurement and quantification are not necessarily the same thing. The process does not need to have anything to do with accuracy or being able to measure a factor. Quantification allows the ability to investigate assumptions and explore the dynamics of the qualitative variables. What is important is that the numbers are internally consistent with each other, meaning that variables make sense relative to each other. For instance, take the example of fear. The first step in quantifying fear is to choose an arbitrary, but well-defined numerical scale; 0 = complete absence, 1 = maximum value. When the fear variable has a value of somewhere between 0 and 1, it has a corresponding affect

on a connected factor, and a graphing function helps illustrate how another factor changes as fear fluctuates. Nevertheless, there would be a danger that some people would start to use the numbers in absolute terms. Any tool has the potential for misuse, but this problem does not diminish the implications of this application (Peterson, 1985).

The generic nature of this program makes it ideal for education because it can be used in so many different ways. There are a number of levels of interactions at which this program can engage the learner. (In the first level, by using STELLA simulation templates, students will be provided with a set of predefined elements and connections with which to work. They could then begin by testing the model as part of the scientific process. Another way is to have a diagram created but leave the relationships between the variables unspecified. This would allow students to go into the structure and deduce their own relationships. In another level of simulation, programming would place students in a discovery-oriented laboratory situation (Manfinach, 1988).

In the lab students begin to develop a model in a structured way. Students will be stopped at key points in the development so they can express assumptions, test hypotheses, and explain discrepancies. Doing so,

students would be expected to discover concepts (Mandinach, 1988).

In the second level, the student would be presented with the problem and asked to create a simulation from scratch. In this level there is additional value in having the students create their own models. This allows students to analyze systems, recognize the causal loops and evaluate what elements are important and where to draw the boundaries.

Yet at another level, students can use the system as a class demonstration. An instructor together with students can build a model and focus on communication as a model. Students can contribute ideas for the creation of the model and engage in group problem solving as individuals (Mandinach, 1988).

Often the meaning of a concept can be ambiguous and abstract. Translation of concepts or processes from textbooks into dynamic models could be done through building simulation programs. Students can translate words into an "operational map" of how the process works. Ambiguities become clarified, abstractions become concrete structures, and participation can focus on inconsistencies (Mandinach, 1988).

In addition, a rigorous environment in which to develop theories can be provided by the model. Students can create their own theories to explain the phenomena.

First they can specify assumptions, test those assumptions, and modify their theory. In this level, students play the role of the scientist.

Modeling is a nice way to explain dynamic behavior. Students attempting to describe a particular concept that is made explicit through a STELLA model could use the diagram as an overhead, or notes to look at (Mandinach, 1988).

STELLA as a Computer Simulation

One of the main issues for any simulation is: " To what extent should the simulation approach reality?" As Dr. Einstein indicates "An explanation should be as simple as possible but not simpler." A simulation is an elaborate explanation; therefore, the same principle holds true. The STELLA manual refers to this as "elegant simplification." Indeed one of the major challenges to the creation of a useful simulation is getting just enough detail to illustrate the main effect of a system. How close the simulation should approach reality depends on the situation. The heuristic is to keep it simple (Mandinach, 1988).

The STACI Project, which examined the impact of one such curriculum innovation on learning outcomes, was based on *systems* thinking and intellectual problem-solving tools. This research project (STACT) was designed to investigate the cognitive and curricular

impact of using systems thinking and STELLA in secondary-school science and social-studies courses. The project was a two-year research project conducted by Educational Testing Service under the supervision of the Educational Technology Center at the Harvard Graduate School of Education (see Mandinach and Thorpe, 1987a, 1987b, for second year).

The study also examined the effectiveness of using STELLA as a tool by which to teach systems thinking, content knowledge, and problem-solving skills. The research focuses on (a) the learning outcomes and transfer that result from using such an approach and software in classroom settings, and (b) the organizational impact of the curriculum innovation (Mandinach, 1988).

The study was conducted at Brattleboro Union High School (BUHS), Brattleboro, Vermont. Four teachers comprised the core of the systems group at BUHS. All were trained by experts to use the system-thinking approach and integrate this perspective into their courses. In the first year of the project, systems thinking was integrated into three general physical science, four biology, and three chemistry classes. An equivalent number of traditional (control) courses were taught concurrently by other members of the faculty. An experimental history course entitled "War and

Revolution" also was taught with the systems approach. Traditional and systems-thinking classes received the same test within a subject area. Comparisons were drawn between traditionally taught courses and those using the systems approach to determine the treatment's effect on learning, teaching, and instructional activities (Mandinach, 1988).

The result of this study indicated that the manipulation of parameters in an existing model may promote scientific inquiry skills (e.g., understanding of causality and variation) and may directly influence the acquisition of content knowledge. In contrast, model building may be less explicitly related to the acquisition of content knowledge; however it may promote more general problem-solving skills.

Results indicated that students were able to acquire knowledge of systems thinking concepts and apply them to scientific problems at varying levels of complexity and sophistication. (Mandinach, 1988)

Cognitive Process and STELLA

Theories are built that affect how our world is explored and color interpretations of observations. It seems that the definitions of the words, model and theory, are sometimes synonymous. The notion of theory and model used in this context is the organization of ideas and their relationships to each other. The model

is important because it tends to direct scientific inquiry (Steed, 1992).

One of the potential benefits of creating simulations is making mental models explicit. Most mental models contain a lot of information but they are not always well organized. Any time a model is-built, simplification and symbolization are involved that makes them available for inspection, and editing. Since models are a pervasive part of learning, reflection on mental constructs of how the world works is necessary (Steed, 1992).

The STELLA program expresses internal structures in a dynamic way. "The constructivist perspective teaches that one builds on current understanding. Being told something is one thing, but to investigate and use metacognitive processes requires deep thinking." Taking a casual look at a topic does not provide undersanding. Deep learning takes time. As knowledge is built, it becomes owned. The activity is more likely to involve learning when engaging the mind. "STELLA is a program that certainly engages the mind, it becomes a construction site where systems can be built piece by piece through the explicit expression of assumptions." (Steed, 1992, p. 49)

Ost (1987) argues that modeling should be a part of the curriculum, he stated that models are part of the

fabric of science. Individuals learn to cope with new theories while modeling. Models are such a ubiquitous part of the learning process therefore, those who do not think in this manner will be overwhelmed when introduced to new theories. STELLA seems like an effective tool to learn the critical modeling process.
Metacognition, reflection on ones cognitive structures, is another potential benefit of constructing simulations. As one builds and tests mental theories under the rigors of a computer model, many of the original ideas and organizing schemas come under scrutiny.

Perhaps the biggest benefit of simulation construction kit would be an improved aptitude toward understanding. One realizes there is more than one way these structures can be created and one begins to recognize how some systems might respond if one increased, decreased or eliminated a particular factor through playing with dynamic models. Theories are only ideas and through rigorous thinking can be understood.

What seems most beneficial about the STELLA program is its use of the graphic interface to illustrate the structural diagram. This feature allows the user to see at a glance the overall structure of the system and see all the connections at once, which might be hard to visualize in a typical set of programming language

instructions. Not only can one view the structure but they can edit the graphical representation of the system to reflect the desired change in thinking. This adds considerably to the value of the program.

STELLA follows the Macintosh interface, in that it uses the familiar pull-down menus and icons that can be clicked and dragged. A lot of the programming is transparent, it is done
by the computer and this leaves the user with more time to deal with important tasks like making the system logical and balanced.

Benefits of using STELLA

There are many reasons for performing simulations. Simulations are desirable when:

(a) Performing the experiments would be impossible.

(b) The experiment would be too dangerous.

(c) The time frame to perform experiments is too long.

(d) A simulation allows control of one parameter at a time, which might not be possible to do in the real world.

STELLA software can fulfill these purposes, and at the same time, extend the type of modeling well beyond these limited purposes. The following outlines suggest further reasons why STELLA simulation would be beneficial and appropriate for a wider range of activities.

1- The most important learning comes through experience. Discovery evokes ownership. STELLA encourages experiential learning and discovery. The first step in developing a simulation is to detail the working of the simulation, make explicit assumptions through the structural diagram, develop hypotheses, and then make predictions concerning how the model is expected to behave. Designing an investigation to test the predictions, inspection by using available assumptions, testing, and editing ideas are further steps that can be challenged. The STELLA model can be viewed as a mirror, reflecting the mental models of concepts (Steed, 1992).

2- In another point of view the simulation construction kit is a laboratory for scientific inquiry, for exploration, explanation, and testing. STELLA seems to facilitate this disciplined approach to inquiry (Steed, 1992).

3- A STELLA model is highly simplified. Many of the real-world situations are so complex that it would be impossible to imitate those situations accurately on a computer. To simplify the real-world model or mental models so the main effects can be translated into a STELLA diagram is valuable. A student can only focus on so many factors at one time. Although the STELLA model does not encourage simplification, the philosophy

behind the system certainly does. The only limitation on the size of a model is the existing memory of a computer. However, "elegant simplification" is mentioned as the key and seems to stimulate pruning of extraneous factors and loops throughout the documentation (Steed, 1992).

4- A STELLA model is highly symbolized. The models are composed of meaningful icons that can be arranged and customized in formal schemes to make them concrete. Such customization makes schemes available for inspection and rearrangement of relationships. These representations are the mathematical equations and graphical relations in the converter icons. The visual representation of these structures makes relationships more accessible to understanding (Steed, 1992).

5- STELLA helps to make even fuzzy causal relationships unambiguous. Connecting these relationships and identifying how the relationships interact helps translate these fuzzy relationships from mental models to a STELLA model. The discipline that it takes to create a simulation will clarify ambiguous associations that are inherent in the meaning of words (Steed, 1992).

6- Many textbooks make the assumption that words are adequate to convey meaning to many dynamic processes. By translating the textbook concept into a

computer model, the problems of using words to illustrate concepts becomes evident. Previously understandable reading can become ambiguous and additional questions can be inspired through constructing a model and testing it (Steed, 1992).

7- Putting your thoughts into a simulation can clarify relationships between factors and can help flesh out other ideas that might not have been considered. Further, as relationships are discovered, a simulation gives true ownership of ideas. A sense of constructing individual understanding of the issue is experienced. Specifying the connections between the components of the system and explicit diagramming lead to understanding. A model becomes like a pair of binoculars for understanding--it narrows the field of view, but it allows magnification of the factors and their interactions (Steed, 1992).

8-STELLA helps make the connection between a system process and its structure concrete. As STELLA models are built and modified, discovery of the process of underlying structures takes place. Through experimenting with STELLA models, it becomes evident that the dynamics of the system spring from its underlying structure Mandinach, 1988).

The real world influences can be explored without sophisticated mathematical knowledge. For instance, the

concepts of velocity and momentum were developed in one of the examples in the STELLA manual. Influences of friction and resistance can be included in the model without using the mathematical equations required for precise analysis.

9- STELLA simulation makes it easy to explore alternative procedures or policies in a fast, relatively inexpensive manner. "This "what-if" kind of experimentation is extremely powerful, because in many instances one will get fooled, a certain change will result in unexpected behavior. Then, back to the model to determine if the unanticipated results were a product of a lack of understanding, an inaccurate model, an incomplete model, or a model that is not internally consistent." (Steed, 1992, p. 51)

10- STELLA models give some unique benefits as one begins to experiment with the modeled system from a scientific point of view. Simulations can be used to anticipate the affect of an alternate design on the system. Simulations can also be used to project future behavior of a system (Steed, 1992).

11- The real benefit of STELLA is that simulating is an engaging activity. When a person creates a good simulation, intense thought about what is being modeled has to go on as the development of the model proceeds.

This elaboration process is a source for deep understanding (Steed, 1992).

12- One of the nice aspects of the STELLA package is its general appeal. Imagination is practically the only limitation to the types of learning situations that could be applied to the program. The construction of simulations promote higher level skills, like evaluation, synthesis, and analysis. The following is the list of the kinds of skills that are encouraged by STELLA application:(a) Predicting- attempting to guess the behavior of the structure before the simulation runs.(b) Developing and testing hypotheses by constructing models, and conducting experiments.(c) Analytical reasoning- studying the output of simulations and attempting to interpret the results.(d) Explanation skills- working with the model, explaining the model, and justifying the model to oneself. The STELLA program seems to be an excellent means of explaining dynamic behavior (Steed, 1992).

13- Identifying hidden causal factors is another benefit of simulation. For example, if the simulated curve is significantly different than the actual curve, it might be suspected that an unknown factor plays a part as a possible explanation of the inconsistency (Steed, 1992).

14- STELLA is a package that can facilitate the art of building theories where the external behavior is well documented but the internal workings are not well understood (Steed, 1992).

Potential problems with STELLA

There are some potential problems that could compromise the value of a simulation:

When a simulation attempts to replicate every detail of the actual situation, it might encounter a problem. Replicating from a mental model into the STELLA model is probably too much detail. As stated previously, the elegant simplification suggests inclusion of all the pertinent factors without cluttering the issues. This can not be reduced to some formula. Each simulation will be idiosyncratic requiring different levels of detail. Gleick (1987) suggests in his classic investigation seemly insignificant factors and small changes in initial parameters can result in substantial differences in the overall behavior of systems.

The real world is fuzzy with uncertainty (Steed, 1992). Our observations and interpretations of reality influences causal factors. Different simulations of the same event will produced different perspectives or perceptions. Compensating causal loops may make it difficult to identify causal factors because the affect is negated. For instance, when positive and negative

loops cancel each other out. In addition, causal affects are not always clearly positive or negative, and empirical evidence may not exist. In reality, relationships may be difficult to measure. The implications are that the more, inductive a system, the less one can use the results for prediction and product design, but just for insight and understanding (Steed, 1992).

Third, the time involved for creating a simulation, is certainly an issue. Creating a simulation takes time. It boils down to the issue of whether additional insight is wanted or not, and weigh that against the time it would take to create and test the model (Steed, 1992).

Another problem is that students may use an over simplified concept of casual factors. Correlation does not mean causation. Students may misrepresent factors as being causal when all that one observes is a correlation. One must be careful not to confuse these two concepts (Steed, 1992).

In addition, some people will begin to look to the model instead of reality for verification. "By placing too much confidence in one's predictions, based on a model; many plans have gone a miss" (Steed, 1992, P. 47). Differentiation must be made between the model and reality. "Models should be taken seriously but not literally" (Ost 1987). Knowing the limitations and

assumptions that a particular model are based on are essential to maintain the need to be tested, not just the model. Further, a model is neither true nor false, but more or less useful.

Furthermore, STELLA models turn out to be partial explanations. This is presumably a weakness, but, even here, if it helps to clarify the underlying elements and their relationships, it has some value. Obviously a model with more of the contributing causal factors will be of more use than one that has fewer (steed, 1992).

Summary

In summary, authentic activity is an appropriate learning activity when the perceptions of the learner and the affordances of the environment represent an integral and inseparable context of learner/environment. The implications for instruction are primarily two-fold: design must support the learner in establishing a learning enterprise within the larger global task environment, and the learning situation must afford the kinds of activities that are essential for success in the transfer environment. New approaches to science education like PBL are based on the idea that understanding is a result of active construction by the learner. Learners must relate information to what they know and use information in a variety of ways and situations so that it becomes connected rather than remaining isolated. Students need to decide whether new information is compatible with or requires accommodation of previous ideas. This requires that students be intentional rather than passive; they must use learning strategies, elaborating and organizing new information to make sense of it, and use metacognitive strategies to evaluate the success of their attempts.

Learning cannot be separated from the tasks and conditions in which it occurs. Consequently students need

to work on tasks that afford opportunities for inquiry and to deal with problems that do not have ready solutions if they are to use what they learn outside the classroom. Moreover, new technologies can be employed to aid information access, exploration, representation of ideas, and generation of artifacts. Artifacts that represent student understanding should require students to integrate ideas and display their knowledge of content and of the discipline. Such artifacts should also be authentic in that they have value beyond the classroom. Finally, learning is inherently a social enterprise. As students converse and collaborate with peers and adults in and out of the classroom, they share and justify ideas and draw on the expertise of others for information and ways of thinking. Thus, they extend their understanding. The role of the teacher is to introduce students to scientific ideas, premises, and ways of gathering information and validating hypotheses. The teacher provides a framework to aid students by modeling expert thinking, coaching, diagnosing learning difficulties, giving feedback, and orchestrating opportunities for learning.

PBL poses considerable challenges for pedagogy and teacher professional development that must be met if the approach is to be adopted and maintained. Teachers need to gain an understanding of the innovation as well as

strategies to meet the problems of classroom enactment to develop "warranted practice" that is theoretically and practically justifiable.

New ways to deal with subject-matter content, activities, time, classroom management and organization, technology use, and assessment must be explored. This process takes time and entails considerable risk as teachers alter well-established practices. Older models of professional development that stressed top-down delivery of information and implementation of prescribed practices and curriculum models are not sufficient to help teachers accomplish these changes. Professional development needs to reflect the fact that teachers, like students, construct understanding; they need to collaborate with others, try things out, reflect on the results, modify their attempts, and try again. Obviously, this requires more support than one or two workshops. Because the process is time consuming and labor intensive, technology can help; multimedia systems illustrate the new approaches, telecommunication packages for teachers allow immediate collaboration with others rather than relying on face to face meetings. In addition, Web technology is part of the learning environment. Network technologies offer the potential for many-to-many communication. Providing facilities in classrooms for such communication between students opens

up possibilities to alter traditional teacher centered classroom discourse in ways that allow students to engage in knowledge-advancing discourse with each other.

On the other hand, planning software aids in integrating new ideas and tailoring them for particular classrooms. The design and development of simulations has become an interest due to the availability of powerful low-cost computers. Simulations can be used to deliver instruction in educational, military, and industrial settings because they increase the ability of participants to apply what they have learned in the classroom to the real-world or transfer situation. An educational simulation is designed to increase one's ability to respond appropriately in a real-world or transfer setting.

STELLA, which stands for Structural Thinking and Experiential Learning Laboratory, with Animation, is a program designed to assist users in creating their own simulations using system dynamics. STELLA is one technology that can enable individuals to enhance their understanding of, and appreciation for, the complex web of interrelationships that govern environmental behavior. The creation and manipulation of models is increasingly recognized as a potentially powerful teaching technique.

The real value of the STELLA modeling package is the cognitive processing that goes on in the creation and development of its model. Good science is good questions. Through creating simulations one has to generate good questions and as the simulation evolves interesting inquires are naturally pursued.

The manual brings out the point that "disciplined thinking always will be hard work." Development of good simulation is not an easy chore. Programs like STELLA require a change in the static way that processes are considered. One needs to think in terms of dynamic processes, positive and negative causal loops, flows, accumulation, and converters. STELLA allows the user to look for patterns in the dynamics by identifying shifts in dominance between positive and negative causal loops. One looks to the structure of the system as the basis for behavior.

Computer model developments are mirrors of one's own mental development and can become a scratch pad for making our assumption explicit. Model building is an interactive process, moving from identification of causal loops to computer simulation and returning to hypothesizing important causal loops. Deep involvement in the topic and consequently deep understanding is enhanced through this process.

Although there are few components, STELLA is not necessarily an easy system to master. The variety of ways these seemingly few components can be combined, the shift in thinking, and the disciplined thinking it takes to make the model internally consistent and put it into equilibrium makes it difficult. It takes rigorous thinking to create an effective simulation.

CHAPTER THREE

METHODOLOGY

Introduction

The purpose of this study was to investigate the effectiveness of project-based learning in a technology-rich environment. The following general research question was proposed: How effective is a reality-centered project integrated into a technology-rich environment in engaging students in meaningful learning and enhancing their motivation?

To answer this research question, a science project was developed, Land-use in Watershed, that takes advantage of Internet facilities. Land-use in Watershed was a collaborative science project that was developed on-line by the researcher for the Kansas Collaborative Research Network (KanCRN). This organization uses the Internet facility to connect students and teachers all over the world to do science projects. Students could access different projects, read the instructions, collaborate, share the results and publish their paper, all on-line (See Appendix A for complete description of the watershed project.)

This project was integrated with simulation software, STELLA, to promote deeper understanding for students. STELLA, which stands for Structural Thinking

and Experiential Learning Laboratory, with Animation, is a program designed to assist users in creating their own simulations using system dynamics (See Appendix B for complete description of the STELLA Simulations). Two simulation units using STELLA software were designed by the researcher to further emphasize the concept of watershed and in particular the effect of land-use on runoff in a watershed. In this activity, students were given existing models and were asked to alter particular parameters to examine the subsequent effect on the entire system.

In this chapter, the methods used to obtain the information to answer the research question are discussed. The sample is described, the instruments used are discussed and the teaching methodology is presented.

Participants

The participants of this study were 72 sixth to eighth graders, (males, n=32 and females, n=40). The experimental group included 53 students while 19 students were included as a control group. The student sample was a convenience sample. Three separate multiage classrooms (with 19,14, and 20 students in each) were included in the experimental group, and one multi age classroom with 19 students comprised the control group (see Table 3-1).

Table 3-1 discuss the sample and the various sub-grouping within the sample. As presented in Table 3-1,

sixth, seventh and eighth graders were enrolled in all classrooms with the exception of the smallest class, hour-six, with 14 students. This class had 11 sixth graders, three seventh graders, and no eighth graders. Hour-two multi-age experimental class consisted of three, seven, and nine sixth, seventh, and eight graders respectively; hour-eight experimental class consisted of eight, nine, and three; hour-seven control class consisted of eight, eight, and three sixth graders, seventh graders and eighth graders, respectively.

Instrument

A 58-question student survey was created by the researcher to gather information to answer the research question (See Appendix C for the complete description of the questionnaire). In general four basic types of information were collected.

A. Ten true/false questions; eight were used in statistical analysis to measure content knowledge (see Technical Problems later in this chapter).
B. Seven open-ended questions to measure students' understanding of the watershed concept.
C. Twenty-three multiple-choice questions that measured the students' attitude toward the project.

D. Five true/false questions that gathered information about students' computer background knowledge.

Table 3-1

Composition of the Experimental and Control Classes Used in the Experiment-Frequency Refers to the Number of Students in Class

classroom	Grade-level	Gender	Frequency	Percent	Valid Percent	Cumulative Percent
hr_2 exp.	6Th	male	1	33.3	33.3	33.3
		female	2	66.7	66.7	100.0
		Total	3	100.0	100.0	
	7Th	male	1	14.3	14.3	14.3
		female	6	85.7	85.7	100.0
		Total	7	100.0	100.0	
	8th	male	6	66.7	66.7	66.7
		female	3	33.3	33.3	100.0
		Total	9	100.0	100.0	
hr_6 exp	6Th	male	5	45.5	45.5	45.5
		female	6	54.5	54.5	100.0
		Total	11	100.0	100.0	
	7Th	male	2	66.7	66.7	66.7
		female	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
hr_8 exp	6Th	male	4	50.0	50.0	50.0
		female	4	50.0	50.0	100.0
		Total	8	100.0	100.0	
	7Th	male	5	55.6	55.6	55.6
		female	4	44.4	44.4	100.0
		Total	9	100.0	100.0	
	8th	male	2	66.7	66.7	66.7
		female	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
control	6Th	male	2	25.0	25.0	25.0
		female	6	75.0	75.0	100.0
		female	6	75.0	75.0	100.0
		Total	8	100.0	100.0	
		Total	8	100.0	100.0	
	7Th	male	1	12.5	12.5	12.5
	7Th	male	1	12.5	12.5	12.5
		female	7	87.5	87.5	100.0
		female	7	87.5	87.5	100.0
		Total	8	100.0	100.0	
		Total	8	100.0	100.0	
	8th	male	3	100.0	100.0	100.0
	8th	male	3	100.0	100.0	100.0

The control group was administered Parts A and B in the same format as the experimental group. Part C was reduced to four items due to the elimination of questions related to STELLA and the Sponge experiment. Part D was not administered to the control group since it was concerned with students' computer background and it was irrelevant for the control group who did not use the computer in this project.

In addition, information about the amount of the time spent on reading the project on-line, type and amount of small-group interaction and number of requests for help in different parts of the project were collected by observation (See Appendix D for the observation sheet).

These measures were gathered as descriptive information that would aid in comparing student behavior in the control and experimental environment.

Procedure

The researcher visited the class twice a week for two weeks during which the experimental classes met four times and the control class met three times. The project consisted of three parts:

- reading the project material on-line.

- conducting the watershed experiment with the physical model of the watershed made from sponge and cardboard by the researcher (See Appendix A, Research Methodology, for the complete description of the watershed model).
- performing STELLA simulation on the watershed concept.

Session one was delivered by the primary investigator to familiarize students with the researcher and the project topic and its process. Students were introduced to the watershed concept and engaged in some related discussion in a large group (traditional classroom setting).

In the second session, students in the experimental group were arranged in small groups of three to five students. The researcher directed and supervised students in reading the project materials on-line. She then demonstrated the sponge experiment at the end of the hour for the whole class. The control group read the project on-line in the same format as the experimental group, but spent the rest of the time in direct instruction and discussion about factors that affect a watershed.

In the third session, experimental group students conducted the sponge experiment in small groups, one at a time under the researcher's supervision. The control

group did not work on the watershed project in that period.

In the fourth session, the researcher supervised experimental students while they were conducting the STELLA simulation unit in small groups. During this session the control group reviewed watershed factors and their effects with the use of graphs to cover the same material as the STELLA simulation. The researcher used a five-minute sampling to keep track of the amount of time spent and the amount of interactions encountered by students in these three activities and recorded this information on the Observation Sheet.

The survey was administered to all students at the end of the fourth session. The control group had sufficient amount of time (40 minutes) to complete the test. However, due to the lack of sufficient time to complete the test (25 to 30 minutes) for the experimental group, students were asked to move to the next section even if they had not of completed the previous one. Students were asked to move to part C in the last 12 minutes of the class if they had not done so and the last 4 minutes was devoted to answer the questions in part D.

Technical problems

In general, introduction and elaboration of two related watershed issues were eliminated as a result of limited class time. For the same reason, only one STELLA

simulation model was presented and explored by the students. This in turn lead to elimination of two multiple-choice questions in part A.

Furthermore, because of an unpredicted change in the classroom schedule in week two, one classroom was unable to conduct the watershed experiment due to the cancellation of the class, and another class had to form larger groups for the watershed experiment because of the reduction of the class time. In addition, computers exhibited technical problems from time to time and some groups were merged as a result. Most importantly, small sample sizes was a major technical problem that limited the generalizability of the results of this study.

Data Analysis

The design of the study included four independent variables: two levels of gender (male or female), two levels of condition (control or experimental), three levels of grade (sixth, seventh, or eighth), and four levels of classrooms (hour-two, hour-six, and hour-eight as experimental classes and hour-seven as a control class).

The dependent variables included four measures, the first measure addressed content knowledge, Part A, the second measure referred to comprehension of the subject, Part B; third measure assessed students' attitudes

towards the project, Part C; and fourth measure addressed students' computer background, Part D.

The purpose of these measures was to gather information to answer the research question. In general two hypotheses were formulated. The first null hypothesis stated that there was no significant differences between the experimental group and control group on students' content knowledge and was tested against an alternative hypothesis that the treatment condition changed students' content knowledge of the watershed.

The second null hypothesis stated that students' comprehension knowledge was not different for experimental and control group as a result of experimental treatment condition and was tested against an alternative hypothesis through the General Linear Model, General Factorial. This analysis used the total score in Part B. The .05 level of significance was used for each test of significance.

In addition, information regarding the amount of time spent and the amount of interactions encountered by students in these three activities were recorded and analyzed. Furthermore, descriptive analysis was conducted to describe students' computer background and students' attitudes towards the project as a whole as well as various components involved in the project.

Summary

In summary, a general research question was proposed: Will a project integrated into a technology-rich environment be effective engaging students in meaningful learning and in enhancing their motivation? A science project was developed, Land-use in Watershed, that takes advantage of Internet facilities. This project was integrated with simulation software, STELLA, to promote deeper understanding for students. The Participants of this study were 72 sixth to eighth graders, (males, n=32 and females, n=40). The experimental group included 53 students while 19 students were included as a control group. To answer the research questions four specific measures were addressed:

1. Are there differences in student's content knowledge?
   1.1. Ten true/false questions were designed; eight were used in statistical analysis to measure content knowledge.
2. Are there differences in student's comprehension?
   2.1. Seven open-ended questions were designed to measure student's understanding of the watershed concept.
3. What is the student's attitude towards the project?

3.1. Twenty-three multiple-choice questions were designed that measured the students' attitude toward the project.

4. What is the student's computer background?

4.1. Five true/false questions were designed that gathered specific students' computer background knowledge.

In addition, information regarding the amount of time spent and the amount of interactions encountered by students in these three activities were recorded and analyzed.

CHAPTER FOUR

RESULTS

Introduction

The purpose of this study was to investigate the effectiveness of project-based learning in a technology-rich environment by examining two variables, content knowledge (Part A of the questionnaire), and comprehension (Part B of the questionnaire) as the dependent variables in relation with four independent variables: two levels of condition (control or experimental), two levels of gender (male or female), three levels of grade (sixth, seventh, or eighth), and four levels of classrooms (hour-two, hour-six, and hour-eight as experimental classes and hour-seven as a control class).

In general, the project consisted of three parts: reading the project material on-line, conducting the watershed experiment with the physical model of the watershed made from sponge and cardboard by the researcher and performing STELLA simulation on the watershed concept.

Four basic types of information were collected. The first part of the questionnaire, Part A, addressed content knowledge of the watershed concept; the second part of the questionnaire, Part B, referred to students'

understanding of the watershed concept. The third part of the questionnaire, Part C, addressed the students' attitudes toward the project, and the fourth part, Part D, referred to students' computer background.

In addition, information about the amount of the time spent on the project, type and amount of small-group interaction and number of times of requests for help in different parts of the project were collected by observation.

Data Analysis

The questionnaire consisted of 17 items (see Appendix C) that were intended to assess a range of skills, 22 items to evaluated students' attitudes and five items to assessed students' computer background. Alpha reliabilities for Part A, Part B, Part C and Part D were .33, .71, .82, and .37 respectively. Part A consisted of 10 True/False questions that measured students' content knowledge, however, only eight questions were used in the final data analysis (see Technical Problems in Chapter Three). Part B consisted of seven open-ended questions that required the interpretation of graphs. Students were asked to interpret a graph and provide a verbal description. This subscale measured students' comprehension of the watershed concept. Part C consisted of 22 multiple-choice questions to evaluate students' attitude towards the

project and Part D had 5 True/False questions to assess students' computer background. It should be emphasized that the results of this study are based on a limited sample size and further research with larger sample sizes is needed to generalize these findings.

Content Knowledge

Hypothesis 1: *students' content knowledge will be significantly different for the experimental group when compared to students' content knowledge in the control group.*

For the first set of analyses, the responses were examined in a between-group ANOVA. No significant differences emerged for the condition variable (experimental versus control group).

In Part A subscale analysis, Table 4-1a and 4-1b, indicated that there was no significant difference between control group (M = 4.8) versus experimental group (M = 5.0), F= .181, N.S.

Table 4-1a

Mean and Standard Deviation of Part A, Content Knowledge, for Experimental Group and Control Group

Group	M	N	SD
Control	4.7895	19	1.5484
Experimental	4.9623	53	1.5059
Total	4.9167	72	1.5082

Table 4-1b

Result of statistical analysis on part A, measuring content knowledge showing no significant differences between the experimental group and the control group

Source	df	SS	MS	F	Sig.
GROUP	1	.418	.418	.181	.671
Error	70	161.082	2.301		
Total	72	1902.000			

It was also noted that this result was consistent within each gender. There was no significant effect between control and experimental group within male or female category (See Table 4-2a and 4-2b).

The result of the analysis revealed that there were no significant differences between control and experimental group on content knowledge within male and female category. For male, F = .744, N.S. and for female, F= .025, N.S. This means that females in the experimental group did not perform significantly better than the females in control group on Part A. This result was consistent for male participants and the project did not significantly improve their content knowledge in experimental group.

Table 4-2a

Mean and Standard Deviation for Experimental and Control Group Within Male and Female Category on Content Knowledge, Part A

Gender	Group	M	N	SD
male	Control	4.3333	6	2.1602
	Experimental	5.0000	26	1.6000
	Total	4.8750	32	1.6991
female	Control	5.0000	13	1.2247
	Experimental	4.9259	27	1.4392
	Total	4.9500	40	1.3578

Table 4-2b

Result of Statistical Analysis on Part A, Measuring Content Knowledge Showing no Treatment Effect for Condition Variable (Experimental vs. Control) Within Male or Female Category

Gender	Source	df	SS	MS	F	Sig.
male	GROUP	1	2.167	2.167	.744	.395
	Error	30	87.333	2.911		
	Total	32	850.000			
female	GROUP	1	4.815E-02	4.815E-02	.025	.874
	Error	38	71.852	1.891		
	Total	40	1052.000			

Furthermore, since the experimental group consisted of three different classes, the researcher conducted further analysis to observe any potential differences between the control group and individual classes on the outcome variable, content knowledge, part A (see Table 4-3a, 4-3b).

Analysis of data indicated that there were no significant differences between any of the multi-age experimental classes and the multi-age control class on Part A, $F = 1.16$, N.S. This means that no experimental class performed significantly different than the control class on content knowledge. It also means that there were no significant differences among the experimental classes. Therefore, the variable was dropped from further analysis and discussion.

Table 4-3a

Mean and Standard Deviation of Part A, Content Knowledge, for Different Classes

Classroom	M	N	SD
hr_2 exp.	5.4211	19	1.3464
hr_6 exp.	4.9286	14	1.5915
hr_8 exp.	4.5500	20	1.5381
control	4.7895	19	1.5484
Total	4.9167	72	1.5082

Table 4-3b

Result Of Statistical Analysis On Part A, Measuring Content Knowledge Which Shows No Treatment Effect For Classroom Variable

Source	df	SS	MS	F	Sig.
Classroom	3	7.832	2.611	1.155	.333
Error	68	153.668	2.260		
Total	72	1902.000			

In addition, analysis showed that there were no significant differences between experimental group and control group within each grade-level on Part A. The result of content knowledge analysis indicated that the sixth graders in the experimental setting did not perform significantly different than the sixth graders in the control group. This conclusion held for the seventh and the eight graders also, Table 4-4.

Table 4-4

Result Of Statistical Analysis On Part A, Measuring Content Knowledge Which Shows No Treatment Effect For Different Condition Within Each Grade-Level

Grade-Level	Source	df	SS	MS	F	Sig.
6Th	GROUP	1	.825	.825	.348	.560
	Error	28	66.375	2.371		
	Total	30	648.000			
7Th	GROUP	1	.219	.219	.129	.722
	Error	25	42.447	1.698		
	Total	27	748.000			
8th	GROUP	1	.267	.267	.098	.759
	Error	13	35.333	2.718		
	Total	15	506.000			

Moreover, gender within each group had no effect on the outcome variable, content knowledge. This means that there were no significant differences between males and females in the experimental group. The same result was obtained for the males and females in the control group, Table 4-5.

Table 4-5

Result Of Statistical Analysis On Part A, Measuring Content Knowledge Which Shows No Treatment Effect For Different Gender Within Each Condition (Control Vs. Experimental)

Group	Source	df	SS	MS	F	Sig.
Control	Gender	1	1.825	1.825	.750	.398
	Error	17	41.333	2.431		
	Total	19	479.000			
Experimental	Gender	1	7.268E-02	7.268E-02	.031	.860
	Error	51	117.852	2.311		
	Total	53	1423.000			

Comprehension knowledge

- ***Hypothesis 2:*** *Students' comprehension knowledge will be significantly different for the experimental group when compared to students' comprehension knowledge for the control group.*

A one way ANOVA was computed to examine comprehension scores. A main effect of condition emerged, F (1,41)= 8.597, $p < .005$. The result indicated that students in the experimental group outperformed the control group on Part B, subject comprehension, (see Table 4-6a, 4-6b).

The experimental group mean (M = 7.16) was significantly higher than the mean score of the control group (M = 4.15). Examination of the students' responses in Part B indicated that the experimental group achieved better and deeper understanding of the watershed concept. They were able to obtain a higher score for interpreting the graphs of runoff, absorbed water in the ground, and inflow correctly and in more detail.

Table 4-6a

Mean And Standard Deviation Of Control And Experimental Group On Comprehension, Part B

Group	M	N	SD
Control	4.1579	19	2.5443
Experimental	7.1667	24	3.8523
Total	5.8372	43	3.6314

Table 4-6b

Result Of Statistical Analysis On Part B, Measuring Comprehension knowledge, Showing Significant Differences Between The Experimental Group And The Control Group

Source	SS	df	M	F	Sig.
GROUP	96.001	1	96.001	8.597	.005
Error	457.860	41	11.167		
Total	2019.00	43			

Further analysis revealed that this finding was consistent within female groups but not within male groups (see Table 4-7a, 4-7b).

Table 4-7a

Mean And Standard Deviation For Experimental And Control Group Within Male And Female Category On Comprehension, Part B

Gender	Group	M	N	SD
Male	Control	5.3333	6	2.3381
	Experimental	6.4444	9	3.9087
	Total	6.0000	15	3.3166
Female	Control	3.6154	13	2.5344
	Experimental	7.6000	15	3.8877
	Total	5.7500	28	3.8454

Table 4-7b

Result Of Statistical Analysis On Part B, Measuring Comprehension knowledge , Showing Treatment Effect For Condition Variable (Experimental Vs. Control) For Female But No Significant Effect For Male

Gender	Source	df	SS	M	F	Sig.
Male	Group	1	4.444	4.444	.386	.545
	Error	13	149.556	11.504		
	Total	15	694.000			
Female	Group	1	110.573	110.573	9.959	.004
	Error	26	288.677	11.103		
	Total	28	1325.000			

Analysis of interaction between gender and condition showed that there were no significant differences between the control (M = 5.3) and experimental group (M = 6.3) within the male category while the females in the experimental group (M = 7.6) performed significantly higher than the females in the control group (M = 3.6). This interaction between gender and group variables indicated that the project had a stronger effect on females and led to the higher mean score for the experimental group in comparison to the control group. In contrast experimental treatment had no significant effect on the male students (see the graph of interaction in figure 4-1a, 4-1b).

Figure 4-1a

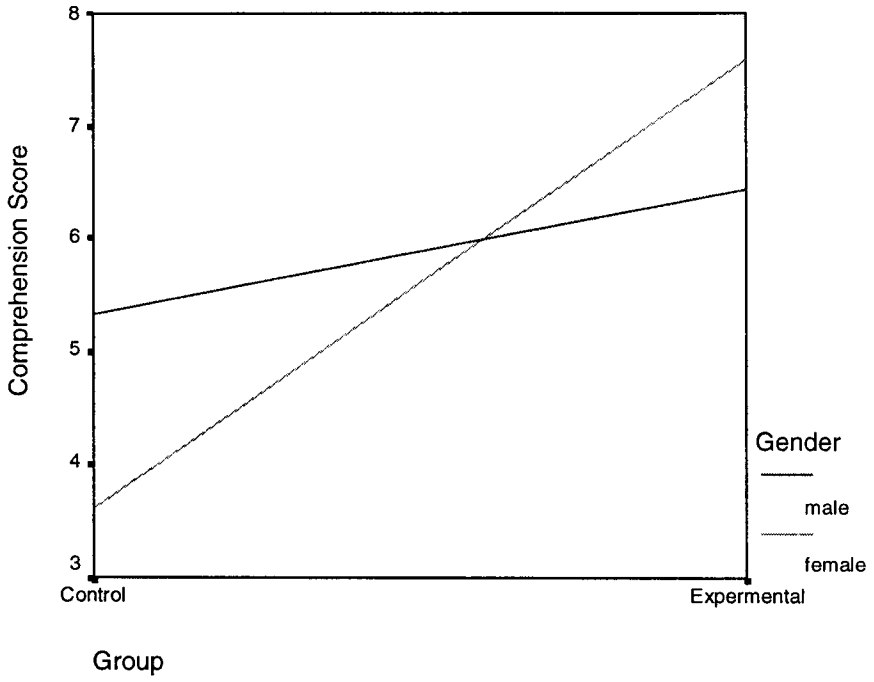
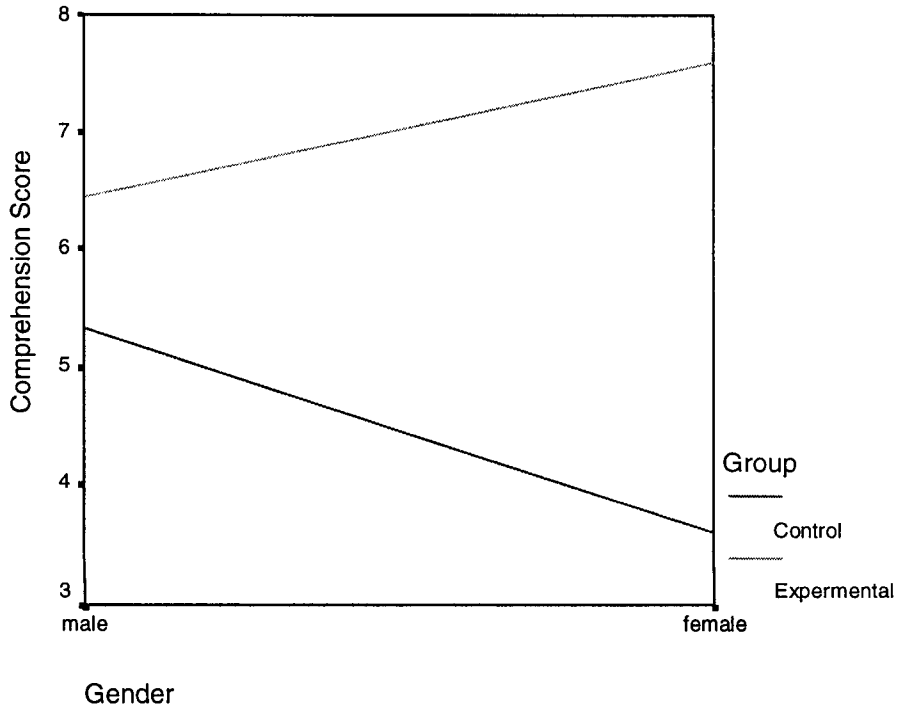


Figure 4-1b



Furthermore, the results of data analysis indicated that in contrast to Part A, the classroom variable was significant on Part B. See Table 4-8a. Mean and standard deviations for the four classrooms are reported in Table 4-8b. Additional analyses were required to determine which classrooms had higher performance. Post hoc analyses using Tukey HSD indicated that two of the experimental classes, hour-two and hour-six had scored significantly higher than the control group, Table 4-8c.

Both, the hour-two class (mean differences = 3.62, $\underline{P} < .032$) and the hour-six class (mean differences = 6.34, $\underline{P} < .004$) had scored higher than the control group. These classes had achieved a better understanding of the watershed concept and manipulation of graphs than the control group had. At the same time, there were no significant differences between hour-eight class and the control class. It should be noted that the hour-eight experimental class did not perform the experiment.

Table 4-8a

Result Of Statistical Analysis On Part B, Measuring Comprehension knowledge, Showing Significant Differences Between Classrooms

Source	df	SS	M	F	Sig.
Classroom	3	176.051	58.684	6.058	.002
Error	39	377.809	9.687		
Total	43	2019.000			

Table 4-8b

Mean and Standard Deviation of Part B, Comprehension Knowledge, for Different Classes

Classroom	N	M	SD
hr_2 exp.	9	7.777	1.5635
hr_6 exp.	4	10.50	5.7446
hr_8 exp.	11	5.454	3.7779
control	19	4.157	2.5443
Total	43	5.837	3.6314

Table 4-8c

Result Of Statistical Analysis (Tukey HSD) On Part B, Measuring Comprehension, Showing Mean Differences Among Classrooms

(I)Classroom	(J)Classroom	MD (I-J)	S. Error	Sig.
Hour-two	Hour-six	-2.7222	1.870	.474
	Hour-eight	2.3232	1.399	.358
	control	3.6199	1.259	.032
Hour-six	Hour-two	2.7222	1.870	.474
	Hour-eight	5.0455	1.817	.040
	control	6.3421	1.712	.004
Hour-eight	Hour-two	-2.3232	1.399	.358
	Hour-six	-5.0455	1.817	.040
	control	1.2967	1.179	.692
control	Hour-two	-3.6199	1.259	.032
	Hour-six	-6.3421	1.712	.004
	Hour-eight	-1.2967	1.179	.692

Based on observed means.
The mean difference is significant at the .05 level.

Moreover, analyses were conducted to find any differences in subject comprehension between control and experimental group within each grade-level, Table 4-9. Results of the analysis revealed that there were no significant differences between the experimental groups and the control group within each grade-level. For example the experimental sixth graders did not perform significantly different than the control sixth graders. This result was consistent for the seventh and eighth graders also. In general, the analysis indicated that the effect of the project is independent of the grade-level and the multi-age experimental group outperformed the multi-age control group.

Table 4-9

Result Of Statistical Analysis On Part B, Comprehension, Which Shows No Treatment Effect For Different Condition Within Each Grade-Level

Grade-Level	Source	df	SS	MS	F	Sig.
6Th	GROUP	1	48.133	48.133	3.134	.094
	Error	18	276.417	15.356		
	Total	20	1081.000			
7Th	GROUP	1	34.811	34.811	4.369	.057
	Error	13	103.589	7.968		
	Total	15	484.000			
8th	GROUP	1	4.800	4.800	.503	.505
	Error	6	57.200	9.533		
	Total	8	454.000			

Students' Attitudes

According to the result of the study, students' attitudes towards the project as well as various components of the project, especially the STELLA activity were positive, Table 4-10 summarizes data from the attitude portion of the survey. Data analysis on part C indicated that 33% of the students reported strongly in favor when asked about their feeling towards the STELLA activity, and 27% were moderately in favor of the STELLA activity. This result revealed that 60% of the students had positive attitudes toward the STELLA simulation. In addition, 66% (37% agree, 29% moderately agree) of students reported that a STELLA simulation is an interesting way to learn about watershed. Furthermore, 67% of students indicated that they enjoyed exploring "what if" scenarios with STELLA modeling. 57% of the Students strongly agreed that STELLA aroused their curiosity. While 85% of students felt that STELLA simulation helped them understand how runoff affects the watershed. When asked about clarity of instruction in the STELLA model, 52% of students responded positively. In addition, more than half (54%) of the students in the experimental group would like to learn to create their own Stella models.

In general, comparison between students in the control group and the experimental group indicated that

63% of experimental students reported that this project increased their interest in the land-use subject while only 37% of students in the control group felt the same way. Another interesting finding indicated that 78% of students in experimental group disagreed that the reading part of the project was too difficult in comparison to 47% of the students in control group.

Table 4-10

Result Of Analysis Based On Students' Attitude Towards The Project

Item	%Agreement (experimental)	%Agreement (control)
I Like STELLA simulation.	60	--
STELLA is interesting way to learn about watershed.	66	--
STELLA aroused my curiosity.	57	--
Enjoyed "what if scenarios".	67	--
STELLA helped me understand how runoff affect watershed.	84	--
STELLA instruction were not clear.	48	--
I Like to create my own STELLA.	54	--
The project increased my interest in Land-use.	63	37
Reading part of the project was too difficult.	22	53

Students' computer background

Based on the analysis of data on Part D, information regarding students' computer background was provided in Table 4-11. Each row in the table corresponds to a specific question in Part D.

Table 4-11

Percent Of Students Responding "Yes" To Questions About Students' Computer Background

Items	%Agreement
Never used a computer before.	2
Use a computer at home.	61
Never used any computer simulation before.	24
Never worked with STELLA simulation.	80
Never had a project on-line before.	31

The analysis indicated that only 2% of the students have never used a computer before. Furthermore, descriptive analysis revealed that 61% of students use a computer at home. With regard to the computer simulation, 76% of students had previous experience with computer simulation. Among these students, 80% of students never worked with STELLA. Finally, in response to the students' experience with on-line projects, 31% reported that this project was their first experience with on-line projects.

Observation

Observations were made throughout the project and recorded on a structured observation-sheet. Analysis of the amount of time spent on each activity, reading project on-line, Sponge experiment and STELLA simulation is reported in Table 4-12, 4-13.

Table 4-12

Amount Of Time Spent for Each Activity In Each Classroom

Classroom	Time spent on reading on-line (minutes)	Time spent on SPONGE exp. (minutes)	Time spent on STELLA (minutes)
control	30	0	0
Hour-two	30	15	30
Hour-six	30	15	30
Hour-eight	30	0	30

Table 4-13

Number Of Active Students Based On Their Interactions With Peers And Adults For Each Activity In Each Classroom

Classroom	Active students (reading on-line)	Active students (Sponge exp.)	Active students (STELLA)	Asked for help (# of times)
Control (19)	16 (84%)	0	0	7
Hour-two (19)	15 (78%)	14 (73%)	15 (78%)	6
Hour-six (14)	14 (100%)	12 (85%)	14 (100%)	10
Hour-eight (20)	12 (60%)	0 (0%)	10 (50%)	4

All classrooms, control and experimental, spent 30 minutes reading the materials on-line. Hour six and hour-two experimental groups each spent 15 minutes on the Sponge experiment while hour-eight group did not perform this activity by themselves. All experimental classrooms spent 30 minutes on STELLA activity. Observation data revealed that hour-six experimental group had the maximum number of interaction among themselves, with the researcher and the teacher. A one to one interaction between the adults and students was more possible due to the lesser number of students in hour-six classroom (14 students).

Summary

The purpose of this study was to investigate the effectiveness of project-based learning in a technology-rich environment. In general two hypothesizes were formulated, and two descriptive analyses were conducted.

The analysis of content knowledge data in Part A indicated that there is no significant difference between the control and experimental groups. In other words, condition, gender, classroom and grade-level had no effect on the outcome variable, content knowledge. On the other hand, a main effect of condition emerged in

Part B. The result indicated that students in the experimental group outperformed the control group in Part B, comprehension. Although, gender had no effect on the outcome variable, comprehension, more in-depth analysis on gender and condition variables showed that females in the experimental group performed significantly higher than females in control group while there were no differences between the control and experimental group within the male category.

Furthermore, the results of data analysis revealed that the classroom variable was significant on the comprehension outcome variable Part B. Further analysis indicated that two of the experimental classes, hour-two class and hour-six class, had scored significantly higher than the control class. At the same time, there were no significant differences seen between hour-eight class and the control class.

The majority of the students (60%) reported strongly in favor when asked about their feeling towards the STELLA activity. In addition, 70% of students reported that STELLA simulation was an interesting way to learn about watershed and indicated that they enjoyed exploring "what if" scenarios with STELLA modeling. More than three-fourths (85%) of students felt that STELLA simulation helped them understand how runoff affects the watershed. In addition, more than half of the students in

the experimental group would like to do more research on water runoff.

In general, comparison between students in the control group and the experimental group indicated that higher percentage of students in the experimental group reported that this project increased their interest in the land-use subject. Another interesting finding indicated that about three-quarter (74%) of students in the control group thought that the reading part of the project was too difficult, this percentage was reduced to less than half in experimental group. Information regarding students' computer background indicated that 90% of students had used a computer before. Furthermore, descriptive analysis revealed that more than half of the students have a computer at home. With regard to the computer simulation, about three-quarters of students had previous experience with computer simulation. Among these students, three-quarters had never worked with STELLA simulation. Finally, in response to the students' experience on on-line projects, 64% of students indicated having a previous project on-line.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate the effectiveness of project-based learning in a technology-rich environment. The following research question was proposed: How effective is a reality-centered project integrated into a technology-rich environment in engaging students in meaningful learning and enhancing their motivation? To answer this research question a science project was developed, Land-use in Watershed, that takes advantage of Internet facilities (See Appendix A for complete description of the project.

This project was integrated with a simulation software, STELLA, to promote deeper understanding for students (See Appendix B for complete description of the STELLA Simulation). Land-use in Watershed was a collaborative science project that was developed on-line by the researcher for the Kansas Collaborative Research Network (KanCRN). Two simulation applications using STELLA software also was designed by the researcher to further emphasize the concept of watershed and in particular the effect of land-use on runoff in a watershed. In this activity, students were given existing

models and were asked to alter particular parameters to examine the subsequent effect on the entire system.

It was the intention of the researcher to review and discuss ways in which learners engage in an intentional learning processes and analyze the effectiveness of such an approach which consisted of three areas: a) authentic learning activity and project-based learning; b) technology-based learning, especially the Internet; and c) educational simulations.

It is an often-stated belief that producing transfer is the main job of education. However, an increasing body of research shows that the way knowledge is presented to students in school and the kinds of operations they are asked to perform often result in students knowing something but failing to use it when relevant.

Brown, et al. (1989) believed that classroom activities lack the contextual features of real-life problem-solving situations and therefore weaken the ability of students to transfer and apply their knowledge from the school setting to the outside world. Theorists and educators are promoting reality-centered projects, theme-based learning, and other kinds of activities situated in real-life and life-like contexts as ways to engage students in meaningful learning (Blumenfeld, et al. 1991; Clinchy, 1989; Wager, 1994).

Authentic activity is an appropriate learning activity when the perceptions of the learner and the affordances of the environment represent an integral and inseparable context of learner/environment. The implications for instruction are primarily two-fold: design must support the learner in establishing a learning enterprise within the larger global task environment, and the learning situation must afford the kinds of activities that are essential for success in the transfer environment. New approaches to science education like PBL are based on the idea that understanding is a result of active construction by the learner. Learners must relate information to what they know and use information in a variety of ways and situations so that it becomes connected rather than remains isolated. Students need to decide whether new information is compatible with or requires accommodation of previous ideas. This requires that students be intentional rather than passive; they must use learning strategies, elaborating and organizing new information to make sense of it, and use metacognitive strategies to evaluate the success of their attempts.

PBL poses considerable challenges for pedagogy and teacher professional development that must be met if the approach is to be adopted and maintained. Teachers need to gain an understanding of the innovation as well as

strategies to meet the problems of classroom enactment to develop "warranted practice" that is theoretically and practically justifiable.

Nevertheless, transformation of the conventional classroom into an authentic learning environment involves much more than incorporating features of real-life situations into school work. Preparation of computer-based simulations and reality-centered projects does not guarantee that a student will assume a positive orientation to learning nor derive the benefits of in-context learning. Much additional support is required to strengthen the tendency of the learner to engage in intentional learning processes and to help the learner progressively assume responsibility for learning.

Planning software aids in integrating new ideas and tailoring them for particular classrooms. The design and development of simulations has become an interest due to the availability of powerful low-cost computers. Simulations can be used to deliver instruction in educational, military, and industrial settings because they increase the ability of participants to apply what they have learned in the classroom to the real-world or transfer situation. An educational simulation is designed to increase one's ability to respond appropriately in a real-world or transfer setting.

STELLA, which stands for Structural Thinking and Experiential Learning Laboratory, with Animation, is a program designed to assist users in creating their own simulations using system dynamics. STELLA is one technology that can enable individuals to enhance their understanding of, and appreciation for, the complex web of interrelationships that govern environmental behavior. The creation and manipulation of models is increasingly recognized as a potentially powerful teaching technique.

The real value of the STELLA modeling package is the cognitive processing that goes on in the creation and development of its model. Good science is good questions. Through creating simulations one has to generate good questions and as the simulation evolves interesting inquires are naturally pursued.

The manual brings out the point that "disciplined thinking always will be hard work." Development of good simulation is not an easy chore. Program like STELLA requires a change in the static way that processes are considered. One needs to think in terms of dynamic processes, positive and negative causal loops, flows, accumulation, and converters. STELLA allows to look for patterns in the dynamics by identifying shifts in dominance between positive and negative causal loops.

One looks to the structure of the system as the basis for behavior.

Although there are few components, STELLA is not necessarily an easy system to master. The variety of ways these seemingly few components can be combined, the shift in thinking, and the disciplined thinking it takes to make the model internally consistent and put it into equilibrium makes it difficult. It takes rigorous thinking to create an effective simulation.

The participants of this study consisted of 72 students enrolled in from sixth to eighth graders, with a mix of males and females. The researcher visited the class twice a week for two weeks for each class. The project consisted of three parts: reading the project material on-line, conducting the watershed experiment with the physical model of the watershed made from sponge and cardboard by the researcher (See Appendix A, research Methodology, for the complete description of the watershed model), and performing STELLA simulation on watershed concept.

A 58-question student survey was created by the researcher to gather information to answer the research question. Four basic types of information were collected. The first part of the questionnaire, Part A, addressed content knowledge of the watershed concept; the second part of the questionnaire, Part B, referred to students'

understanding of the watershed concept. The third part of the questionnaire, Part C, addressed the students' attitudes toward the project, and the fourth part, Part D, referred to students' computer background (See Appendix C for the complete description of the questionnaire). Control group was administered Parts A and B in the same format as the experimental group. Part C was reduced to four items. Part D was not administered to the control group.

Furthermore, information about the amount of the time spent on the project, type and amount of small-group interaction and number of times of requests for help in different parts of the project were collected by observation (See Appendix D for the observational sheet).

The purpose of these measures was to gather information to answer the research question. In general two hypothesizes were formulated, and two descriptive analysis were conducted.

Hypothesis#1-The first null hypothesis was tested against an alternative hypothesis that the treatment condition changed students' content knowledge of the subject. The analysis of data in Part A indicated that there is no significant difference between control group versus experimental group. In other words, condition, gender, classroom and grade-level had no effect on the outcome variable, content knowledge.

Hypothesis#2-The second null hypothesis was tested against an alternative hypothesis that students' comprehension knowledge was different for experimental and the control group as a result of experimental treatment condition. A main effect of condition emerged in Part B. The result indicated that students in the experimental group outperformed the control group in Part B.

Although, gender had no effect on the outcome variable, comprehension, more in-depth analysis on gender and condition variables showed that females in the experimental group performed significantly higher than females in control group while there were no differences between the control and experimental group within the male category.

Furthermore, the results of data analysis revealed that classroom variable was significant on the outcome variable in comprehension, Part B. Further analysis indicated that two of the experimental classes, hour-two class and hour-six class, had scored significantly higher than the control class. At the same time, there were no significant differences seen between hour-eight class and the control class. It should be noted that the hour-six experimental class outperformed the hour-eight experimental class. This interesting finding might be due

to the technical problem cited in Chapter Three and will be discussed further in this chapter.

Analysis#1-Data analysis on part C indicated that the majority of the students (60%) reported strongly in favor when asked about their feeling towards the STELLA activity. In addition, 70% of students reported that STELLA simulation is an interesting way to learn about watershed and indicated that they enjoyed exploring "what if" scenarios with STELLA modeling. More than three-fourths (85%) of students felt that STELLA simulation helped them understand how runoff affects the watershed. In addition, more than half of the students in experimental group would like to do more research on water runoff.

In general, comparison between students in control group and experimental group indicated that higher percentage of students in experimental group reported that this project increased their interest in the land-use subject than in control group. Another interesting finding indicated that about three-fourths (74%) of students in control group thought that the reading part of the project was too difficult, this percentage was reduced to less than half in experimental group.

Analysis#2-Information regarding students' computer background indicated that 90% of students had used a

computer before. Furthermore, descriptive analysis revealed that more than half of the students have a computer at home. With regard to the computer simulation, about three-quarters of students had previous experience with computer simulation. Among these students, three-quarters had never worked with STELLA simulation. Finally, in response to the students' experience on on-line projects, 64% of students indicated having a previous project on-line.

Conclusions and Discussion

In conclusion, the findings of this study supported the use of the project-based learning in a technology-rich environment. The result of this study indicated that the students' comprehension of the watershed concept had improved as a result of the innovative approach, although it did not improve students' content knowledge significantly. One possible explanation for this finding is the lack of sufficient time to cover multiple concepts in the experimental group. While the experimental group spent their time on various activities to comprehend a few concepts deeply, the control group focused on direct instruction for receiving and memorizing multiple concepts. This in turn will explain why experimental students performed better in Part B. Examination of the

students' responses in Part B indicated that they achieved better and deeper understanding of the watershed concept. They were able to interpret the graphs of runoff, absorbed water in the ground, and inflow correctly and in more detail.

The hour-two and the hour-six classes performed significantly higher than the control class. The hour-eight class which did not perform the Sponge experiment and consequently could not benefit from STELLA activity to its full potential did not score higher than the control class. In addition, the hour-six experimental class outperformed the hour-eight experimental class. It is interesting to note that the hour-eight class was the highest ability class and the hour-six class was the lowest in the teacher's opinion. Another explanation of hour-six high performance in contrast to hour-eight could be due to one-to-one interactions between the adults and students which was more feasible due to the fewer number of students in the hour-six classroom (14 students). According to observation data the hour-six experimental group had the maximum number of interactions among themselves, with the researcher, and with the teacher.

The results further suggested that students' comprehension of the watershed concept in this approach was independent of the students' grade-level. This means that the sixth graders in the experimental group did not

perform any significantly different than the sixth graders in the control group. The same conclusion was true for the seventh and eight graders. This finding further emphasized that the multi-age experimental group as a whole performed better in comprehension than the multi-age control group.

Students' attitudes toward the project, especially, toward STELLA simulation were promising. Students who experienced STELLA units and enhanced their understanding about the watershed through this activity found the reading part of the project that they encountered prior to the STELLA lesson less difficult. This result might be due to their positive perception of the whole project afterwards.

Limitations and recommendations

This study was limited in scope because the students were not randomly selected and the sample size was much too small. Since every classroom may have different environments, the results may not reflect the effect of project-based learning in the technology-rich environment for Northwest Middle School children as a whole, nor can it be generalized to other schools because of the diversity in the socio-economic status of the students, their attitudes towards school and schooling, their computer backgrounds, or financial constraints of individual schools. It is recommended that further

research be conducted with randomly selected participants to be truly representative for the study. It also would be worthwhile to conduct this investigation on upper grade-level participants, namely, high-school students.

Another major limitation in this study was the two-week time scope in which the project was conducted. The lack of sufficient time to deliver the complete project caused elimination of components and modification to the original plan. Larger groups were formed to conduct the experimental part of the project instead of the intended small groups; only one of the two applications of the STELLA simulation was explored by students. It is essential to devote sufficient time and allow students to construct their own knowledge through any authentic activity. In order to construct understanding, students need to collaborate with others, try things out, reflect on the results, modify their attempts, and try again. This process is time consuming.

In addition, as an enhancement to this project, development and evaluation of further PBL in which students are required to create their own STELLA models is highly recommended. Computer model developments are mirrors of one's own mental development. Model building is an interactive process; moving from identification of causal loops to computer simulation provides deep

involvement in the topic and consequently deep understanding of the subject.

As another limitation, the researcher was the primary instructor and administrator of the project; therefore, this finding may not be generalized to a setting where multiple teachers are involved. A large scale replication of the study is necessary to allow generalization of findings to general population of students and teachers.

Further research to gather some information about student's achievement level, IQ, and their base knowledge of the subject as a pre-test also is recommended. The question of knowledge and process learned is central to making intelligent decisions about simulations such as STELLA as an effective instructional strategy.

The results of this study indicated that although gender did not have any effect on the students' comprehension of watershed, the interaction between gender and group variables indicated that the project had a stronger effect on females and led to the higher mean score for females in the experimental group in comparison to females in the control group. In contrast experimental treatment had no significant effect on the male students. This finding suggests further research on the effect of project-based learning in a technology-rich environment based on the gender differences found.

Certainly, there is a need for further research concerning the issues raised. Most important is the necessity to establish just how widespread is the use of such instruction. Then if found to provide significant advantages, there must be concerted effort to broaden its usage to more and more schools and classrooms. Perhaps the major obstacle is and will continue to be confidence in the Technology.

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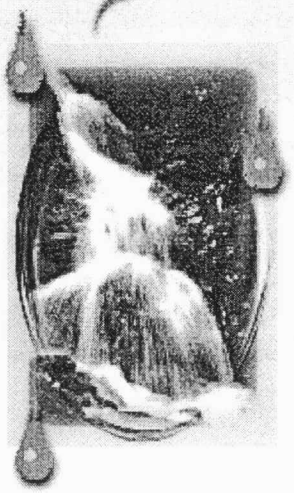
APPENDIX A

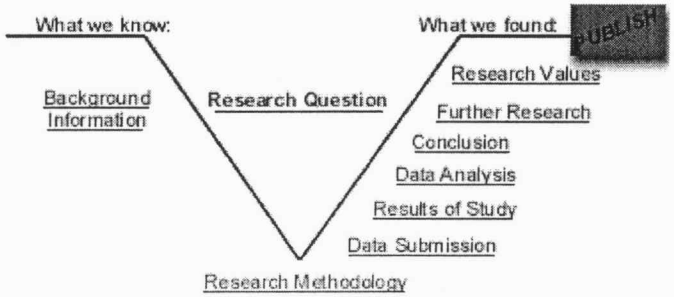
Land-Use in watershed

On-line Project

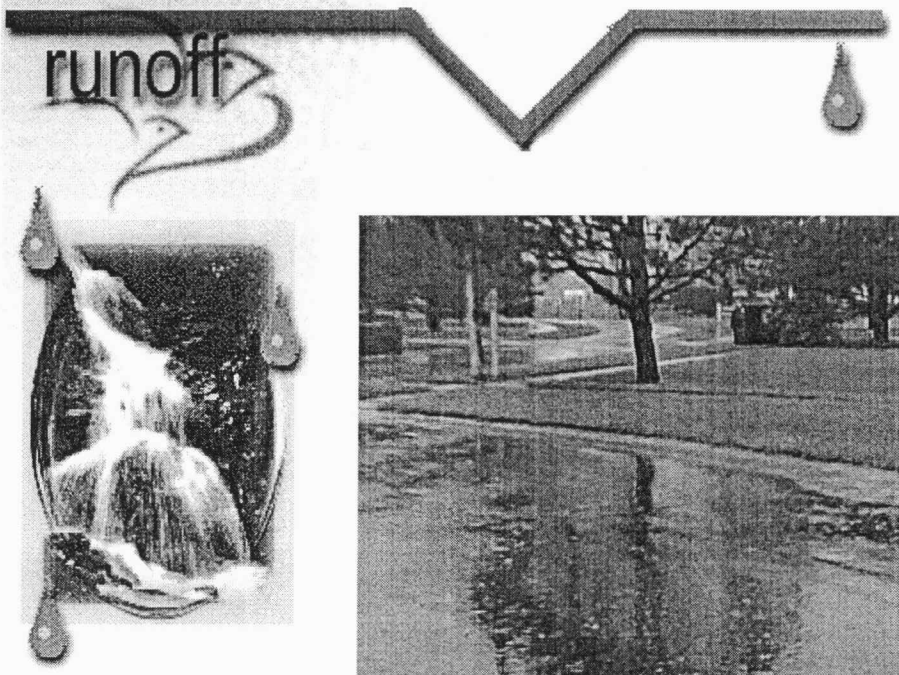
Land Use In Watershed



Population growth and settlement cause changes in land use. It is important to know how land use variation in a watershed can effect the runoff of water. Learning about these factors refines our current perspectives and helps us plan for the future. We can recognize trends in development, by comparing past and current land use practices; this knowledge can help us appreciate the importance of watershed management.



Guided Research



The moment the raindrop falls to the earth it begins its return to the sea. Most of the water moves across the surface toward the lower lever, but some of the water soaks to the ground. This movement of water on the surface of earth is called **runoff.**

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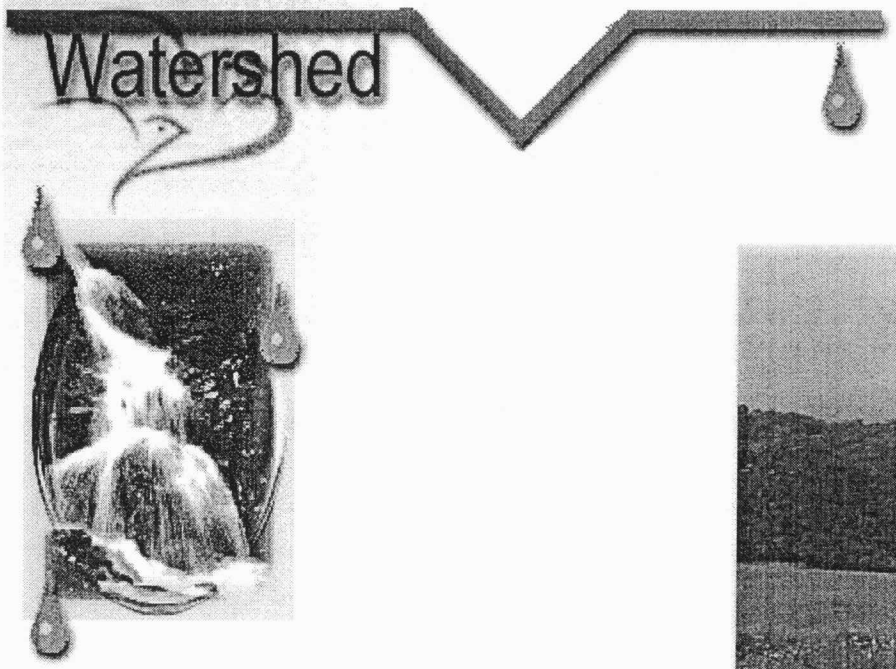
Data Analysis
Conclusion
Further Research
Research Values

Student Research
Publish



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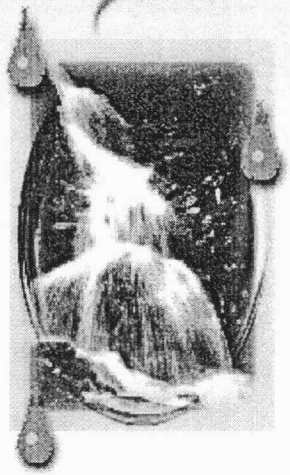
Student Research

Publish

All the land area from which water drains into a particular stream or river is known as the **watershed** of that stream or river.

background



Why are we concerned about the land use in our watersheds?

Kansas Watersheds

- Streams are drying out
- Shortage of water to support wildlife
- Anything that happens on the land will sooner or later show up in the streams
- Clean, fresh water is necessary for life
- Concern about water supply, increase chance of contamination, and flood control

You may recall that water molecules evaporate into the atmosphere from surface of the ocean. Then, water vapor may be carried over a landmass by the wind and condense into cloud droplets. The water molecules fall to the earth surface as drops of rain. This movement of water is called the "water cycle".

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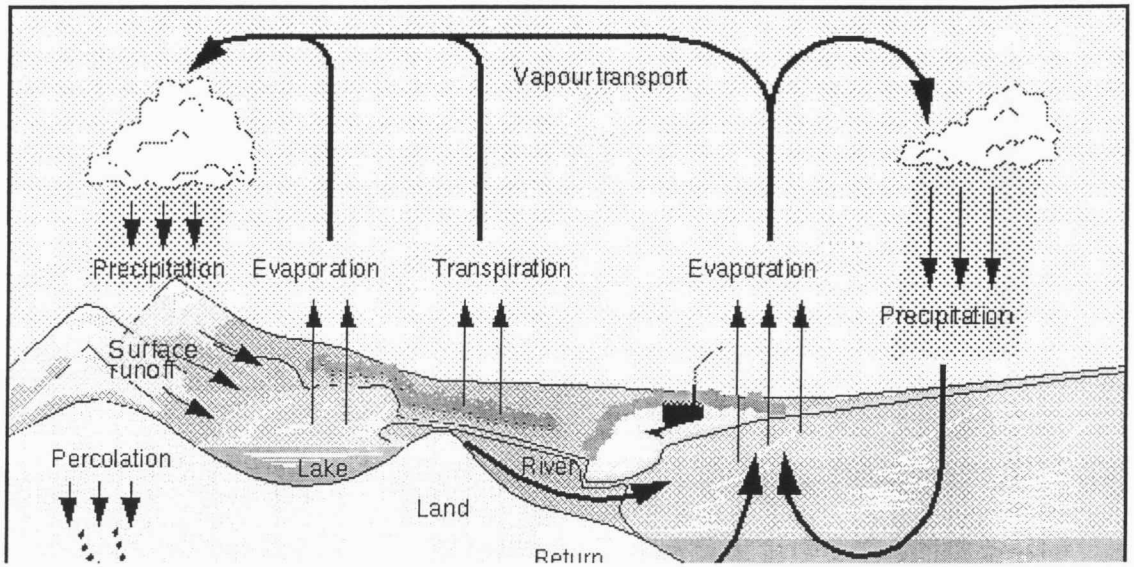

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View

To get started, three areas of background information are offered to help you develop a rich context of understanding of watershed and factors which contribute to the amount of runoff in watershed.

- **Precipitation**
- **Wetland**
- **Land Use**

One way watershed managers study drainage basins is by measuring streamflow. Determining how much water a watershed discharges involves measuring the amount of water (volume) that flows past a certain point over a period of time (velocity). Streamflow is measured in cubic feet per second (cfs) or cubic meters per second (cms).

Scientist calculates average streamflow by measuring the amount of water flowing through a stream channel over a period of years. Watershed managers investigate reasons for abnormality when streamflow changes significantly from its normal quantities. The amount of water discharged by a watershed is influenced by **land use** such as, soil conditions, vegetation coverings, and human settlement patterns. **Wetlands**, forests, and prairies capture and store more water than paved roads and parking lots. Consequently, urban areas will have more runoff than areas covered with vegetation.

Click on a link to read the information that others have found or type in new information below.

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Keyword [ ] Search in Title Search in Text

I have a research idea to submit.

My Name [ ]

Title [ ]

My Research Idea and My Comments About it - separate paragraphs with <p>

Optional Related Link URL: (include the http://)

Link Title:

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Source of graphic (give credit):

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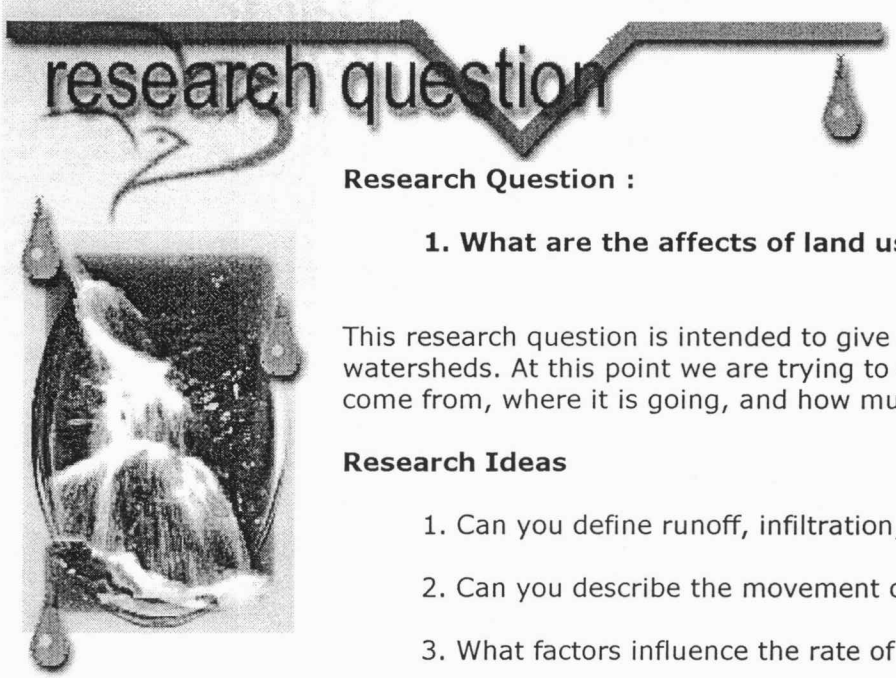
As you have reviewed additional information you have developed, an even deeper understanding of the context from which the research question comes from has developed. It is important to go back to your research question and review it. Is it asking what you really want to know? The research question directs your work and you should refer back to it often.



Research Question :

1. What are the affects of land use on our watershed system?

This research question is intended to give directions to your study of surface water occurring in streams and watersheds. At this point we are trying to develop a deep understanding of the stream ecosystem. Where it has come from, where it is going, and how much land use influences the overall health of the watershed ecosystem.

Research Ideas

1. Can you define runoff, infiltration, runoff/infiltration ratio, and watershed?
2. Can you describe the movement of water into and through the ground using the above terms?
3. What factors influence the rate of runoff in a watershed?
4. Why is it important to measure and monitor the streamflow?
5. How likely is it for a stream draining a forested watershed to flood during rain and why?
6. How likely is it for a stream draining a forested watershed to flow during a dry period and why?
7. What are the impacts of land use development on nature?
8. What are the effects of increasing runoff? Or decreasing infiltration?
8. How might the water quality of the water be affected by changes in the watershed?
9. What problems could arise if water runs quickly over surface material, rather than moving slowly or soaking in?

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Student

Land use changes can have significant impact on a region's water resources. Streams, lakes. and other bodies of water collect water drained from the surrounding land area, called watershed or drainage basin. After periods of precipitation or during snowmelt, surface water is captured by the soil and vegetation, stored in ground water and

Research
Publish
View

in plants, and slowly released into collection site. (E.g., a stream) If the **watershed** is covered by natural forest or grassland with rich topsoil, most of the precipitation will infiltrate and serve to recharge the groundwater. Only exceptionally heavy or prolonged storms are sufficient to saturate the ground and cause significant runoff. In turn, groundwater "leaks" out through springs and seeps. The water leaks out at about the same rate regardless of fluctuations in the amount of water in the reservoir. Thus, a stream draining a forested watershed is prevented from flooding during rains because water is being taken to groundwater, and it continues to flow during dry periods because water continues to leak out. Such a stream is able to support not only a rich aquatic ecosystem; it also serves to support much of the surrounding terrestrial ecosystem as many species depend on the water directly for drinking or indirectly through various food chains.

The nature of the land surface is changed by many human activities so that the infiltration/runoff ratio is shifted to cause less infiltration and more runoff. Most conspicuously, urban and suburban development greatly increases runoff by creating innumerable hard impervious surfaces such as roadways, parking lots, and rooftops. Even the soil of the suburban lawn is generally compacted so that infiltration decrease and runoff increased. Agricultural practices that cause the soil to become puddled and/or compacted, as well as clearcutting of forest and overgrazing by livestock, also lead to increased runoff. Whatever its cause, shifting the infiltration/runoff ratio in this way has numerous and far-reaching effects. On one side are the **effects of increasing runoff;** on the side the **effects of decreasing infiltration.**

Working to answer this research question will help you learn a lot about watersheds. This information combined with the provided background information and information that you find on your own, should help you develop a rich understanding of stream and watershed ecosystem. While you are developing this understanding, additional questions will come up. It is these questions that derive research.

With this research question guiding your work, proceed to the background information on Land Use in Watershed.

RESEARCH IDEAS (READ, SUBMIT, AND COMMENT)

View the Next 20 Submissions | View the Best 20 Submissions

Keyword [ ] Search in Title Search in Text

I have a research idea to submit.

My Name [ ]

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My Research Idea and My Comments About it - separate paragraphs with <p>

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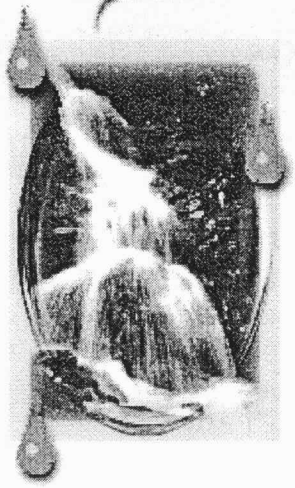
top

research question



Effects of Increasing Runoff:

Stream Bank Erosion

A natural process which normally occurs very slowly, therefore, regrowth of vegetation restores the bank. With additional runoff, the erosion becomes an ongoing process since restorative balance is upset.

Flooding

With increased runoff, even a very modest storm may lead to flood. Many communities, suburban developments, have experienced flooding with increasing severity and frequency as explanding development has paved more of upstream watershed.

Increased Pollution

Runoff carries all kinds of polluting materials from the surface into streams and rivers, in contrast to high-quality water from springs.

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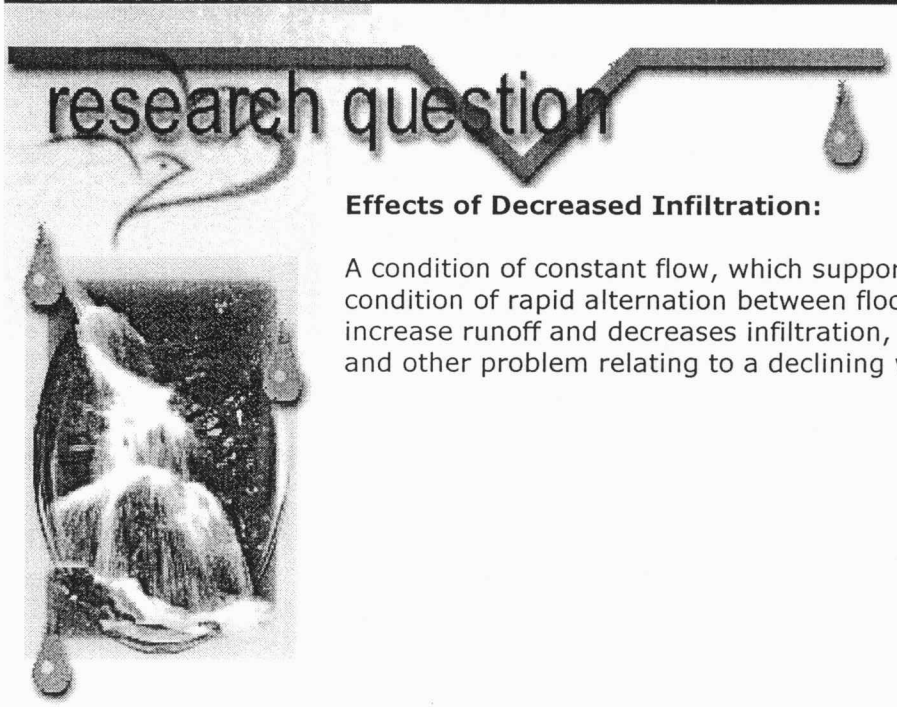


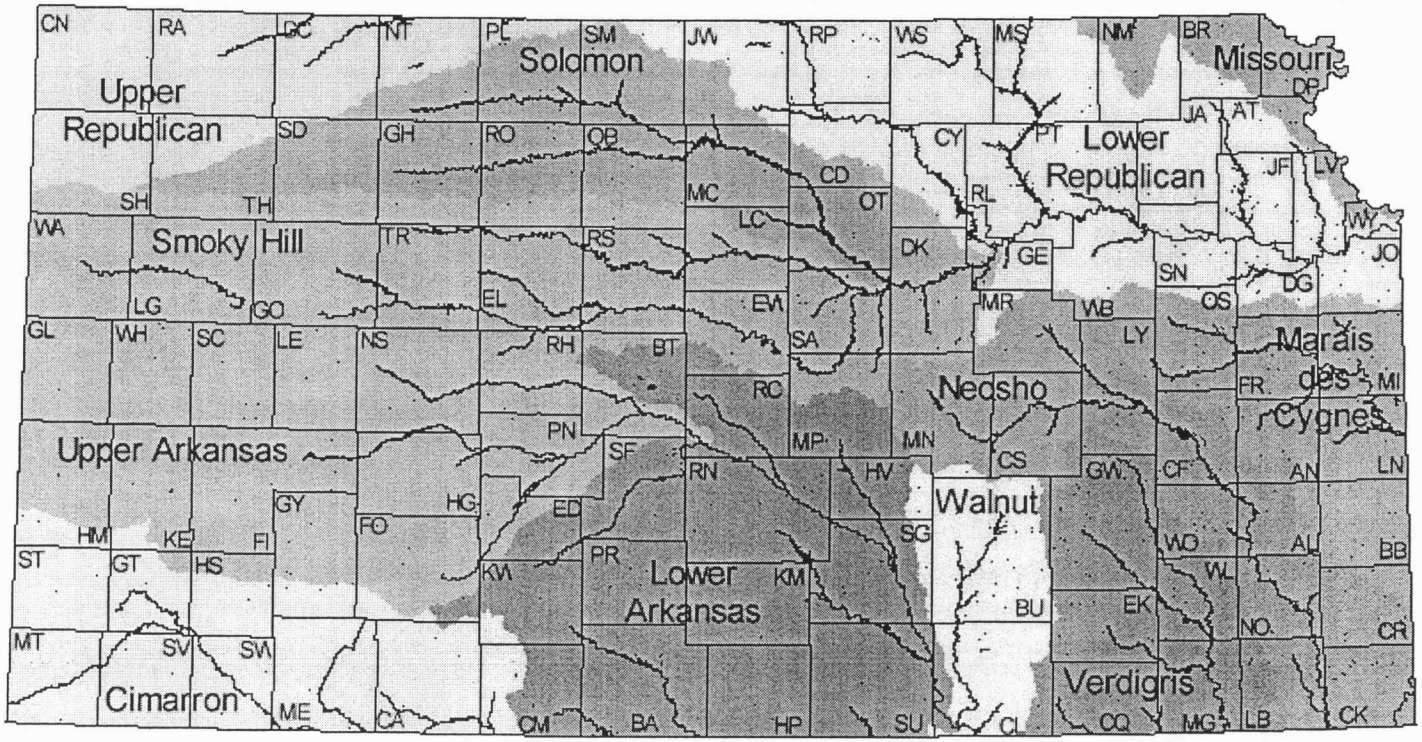
Effects of Decreased Infiltration:

A condition of constant flow, which supports a rich ecosystem for a stream, is changed to an ecologically destitute condition of rapid alternation between flood-producing surges and dryness by hard surfacing. Development, which increase runoff and decreases infiltration, intensifies the problems of saltwater encroachment, land subsidence, and other problem relating to a declining water table.

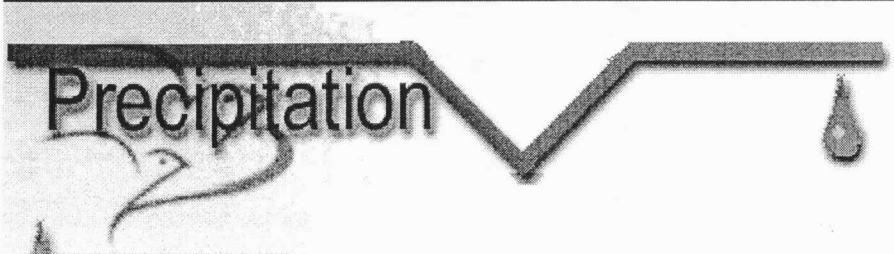
Surface Water Information Management System (SWIMS)

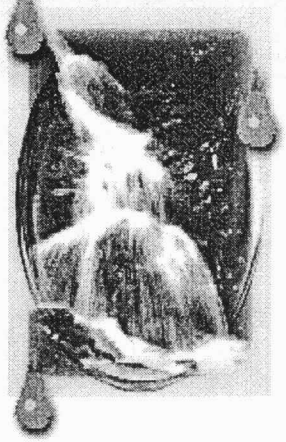
Database created by: Kansas Department of Health and Environment (KDHE) & Geographic Research, Analysis, and Information Laboratory (GRAIL)

Click on a watershed to view a more detailed map of that watershed.



Or choose a watershed by name: Upper Republican | Missouri | Lower Republican | Solomon | Smoky Hill | Marais des Cygnes | Neosho | Upper Arkansas | Lower Arkansas | Verdigris | Walnut | Cimarron

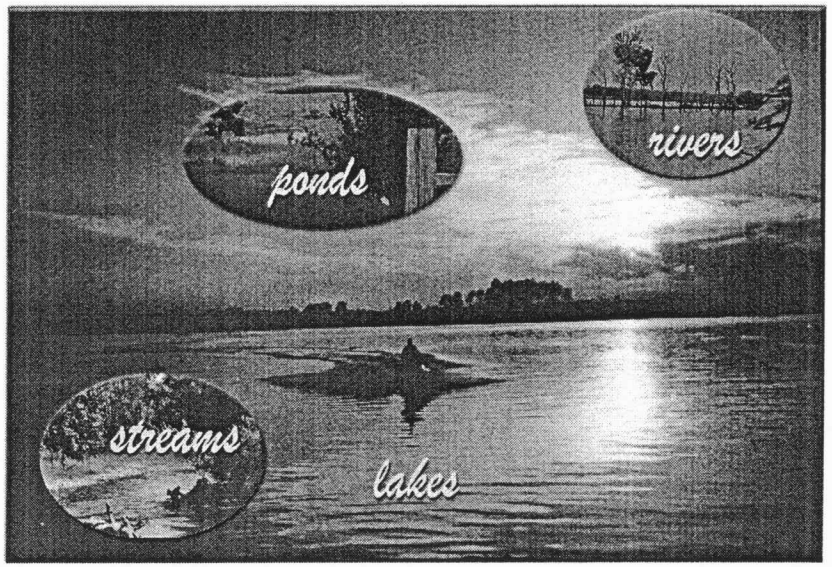




Precipitation

Water from precipitation landing on the ground may follow two alternative pathways. It may soak into the ground, **infiltration**, or it may run off the surface, **runoff**. The amount that soaks in compared to the amount that runs off can be referred to as the infiltration/runoff ratio. Runoff flows over the surface into streams and rivers which make their way to the ocean, or other point of evaporation. All ponds, lakes, streams, rivers, and other waters on the surface are referred to as.....

surface water.



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Sooner or later, however, gravitational water comes to an impervious layer of rock or dense clay. Free water accumulates, completely filling all the cracks, pores, and spaces above such an impervious layer. This accumulated water is called groundwater, and its upper surface is the water table.

Wetland

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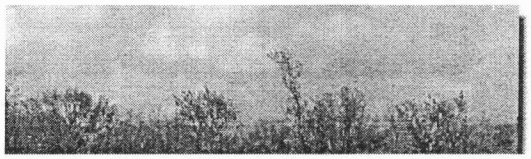
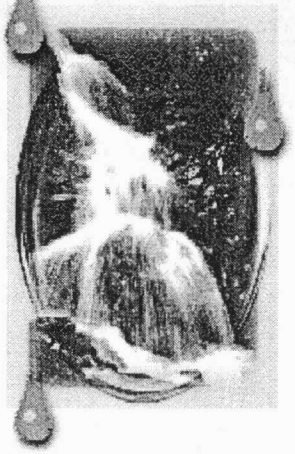
Surface water, ground water and precipitation can each contribute water to wetlands. When it rains much of the water that hits the ground runs over the surface of the land, until it eventually collects in low spots (e.g., ponds, rivers, or lakes). If it saturates the surrounding lands, wetlands may form. Ground water seepage from uplands and from waterways form and feed wetlands. Wetlands are valuable for the watershed management because of their ability to hold water.

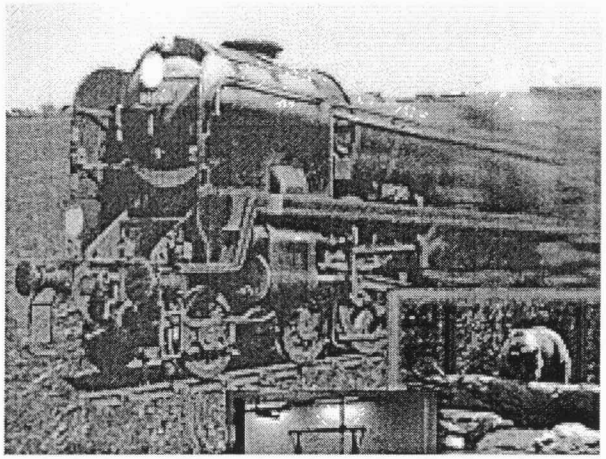
Many wetlands store water and slowly release it over time. Significant differences exist among wetlands. One of the primary variables is soil type. If a wetland forms on sand, water moves into the soil at a rapid pace, and unless the ground-water level is above the surface, most of the water will filter underground.



At the other extreme is a wetland located in clay ground, a small

Land Use





Graphic created by Roxy Malone
Grizzly Bear picture courtesy of Travel Montana

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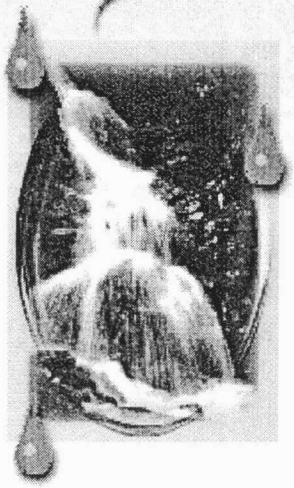
The ***shape of the land*** and the ***type of the land*** material affect runoff. Plant's slow down the water movement, so more water soaks into the ground. As a result, runoff decreases in areas with extensive plant growth. Some types of soil can also reduce the amount of runoff. If soil is loosely packed or has a large humus content, water can more easily soak into the ground. On the other hand, runoff increases when the water can not get into the ground, or when rain falls on ground that is already saturated with water. Large cemented areas, such as those that are presented in cities, provided little opportunity for water to get into the ground. In addition, the steeper the slope, the greater the speed of the runoff.

Land use changes that could contribute to increased amounts of runoff flowing into a river can be monitored by resource managers and policymakers. Extensive amounts of public and private time, money and energy, have been invested in research projects specifically designed to collect **land use** data.

research methodology



Careful observation and precise measurement is the key to any successful research.

Research Question: How does change in land use in a watershed influence the rate of runoff?

The models that you are going to create represent the types of surfaces found in cities. Some of the ground is covered with cement, houses and sidewalks that prevent any rain from soaking into the soil and being carried through the ground. Other places have expanses of soil covered with grasses, trees and flowers. Here, much of the rain can be absorbed and provide water for the plant growth and the excess can enter the underground layers that feed the aquifers that wells tap into. Excess water may not be absorbed into the ground. It flows across the surface, moving down slopes toward small creeks and ditches. Eventually, this run off collects into larger streams and continues to flow toward the ocean.

In this model you will compare the rate of run off between two types of surfaces, one that absorbs like the soil and one that is not able to absorb any moisture like the surface of a parking lot. The sponge will represent soil and the cardboard will represent the non-permeable surface.

Materials:

1. 2 Large, light colored sponges. Two sponges per group
2. Strips of cardboard
3. 2 Measuring cups (250 ml)
4. Stopwatch
5. Aluminum pans
6. Blade
7. Rack

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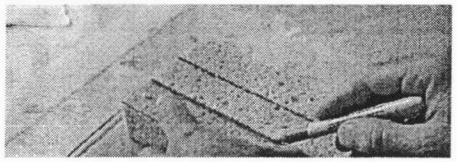
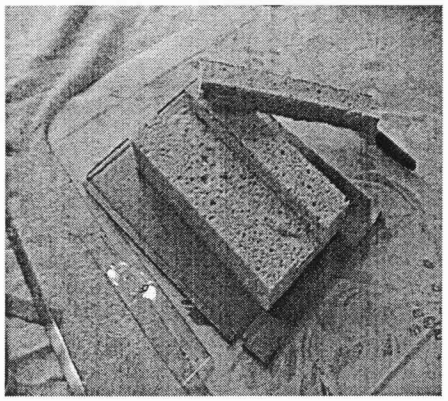
Building A Watershed Model

Draw two lines in the middle of the sponge so that it divides the width into



View

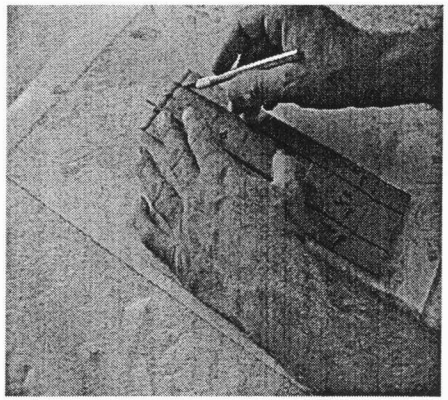
three equal parts. (Approximately, 4 cm each).

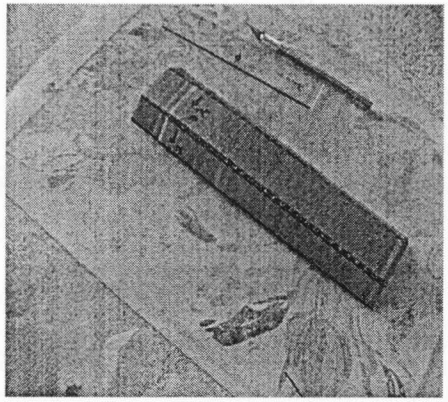


Fold the sponge lengthwise and cut along the lines about 2 cm deep, cut to remove the strip to make a channel in the middle of the sponge.

***Prepare the second sponge as above.**

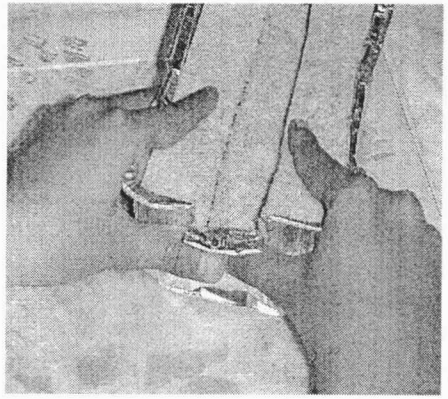
Cut a strip of a cardboard (22cm X 8 cm) that fits into the sponge channel so that it covers the walls of the channel. (The width of the cardboard is equal to the width of the sponge channel plus 4 cm to cover the sides, the length of the cardboard should be 4 cm longer than the channel for directing the flow better, Fig. 3)

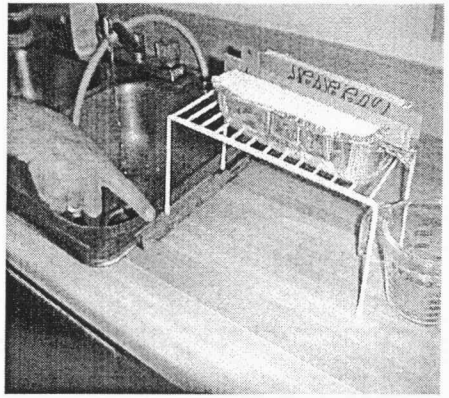




Make two shallow cuts to the cardboard (2 cm from each edge) to make it more flexible to fit in the channel. (Do not cut all the way through the cardboard. You should cut only through one layer. Fig, 4)

Place the sponge in an aluminum pan and cut an opening on both sides of the pan as illustrated in the Fig. 5





Place the model on the top of the rack on a slightly slant surface. (Remark: to make a slight incline surface, place an object under one side of the rack to lift it about 1 inch as illustrate it in Fig.6)

Insert the cardboard in one of the sponge's channel and label it model #1. Use the

second sponge as it is, without the cardboard and label it model #2. (Fig. 7)

Methodology:

Form groups of three people. Setup the model, which represents a part of a watershed as was described above to illustrate the runoff/infiltration process. **Read the instructions carefully and completely before conducting the experiment.** Discuss the role and responsibilities of each person in conducting the experiment within your group.

In order to compare you will first practice your skill at delivering a steady stream of water so that each investigation has a constant rate of incoming water.

You will hook up a hose and adjustable clamp to a water source or use a spray faucet to create this steady stream of water. You will know when you have a rate similar to others conducting this experiment because every 3 to 9 seconds you will collect 50 mls in the measuring cup.

Once you achieve this rate, you keep this constant rate of water and record the time and corresponding volume in the provided data sheet.

Measuring Inflow: Inflow Data Sheet

1. Turn on the faucet and measure the time t (s) that it takes to fill up 50, 100, 150, 200, and 250 ml in a measuring cup. (Remark: Do not turn the time back to zero in between readings)
2. Repeat step 1 until you obtain consistent reading in time t (s) for at least three 50-ml volumes. This will be your actual Inflow reading time.
3. The ideal inflow rate should be within the range of 5.5-16.7 (ml/s) that is filling up 50-ml volume within 3 to 9 seconds. Compare your Time t (the actual Inflow reading time) with ideal reading time (3 to 9 second), if not within the range adjust the flow rate of the faucet and repeat the experiment to approximate the ideal inflow rate.
4. Record the time t (s) and volume v (ml) in provided Inflow Data Sheet.
5. Once the inflow rate is obtained, **DO NOT TURN THE FAUCET OFF UNTIL THE END OF THE EXPERIMENT.** (Hint: For reading precisely, the measurement lines should be at the eye level)

Now that you can provide a constant rate of water flow, you are ready to apply it to the model you created. In the first trial, you will set up the cardboard model (model #1).

When it is time to begin, you will let the steady flow of water run from the top of the cardboard slope to the bottom where the run off will be collected in a measure. Once again, as 50 mls, then 100 mls, and so on collected, you will be recording the time that the volume is reached. One person will control the flow of the water. One team member will call out each time 50 milliliters of water has been collected in the measure. The third person will call out the time in seconds and another will record the time in seconds. In this experiment you will collect the time intervals represented as a t. The beginning time is t0 (read as time zero). It is recorded in

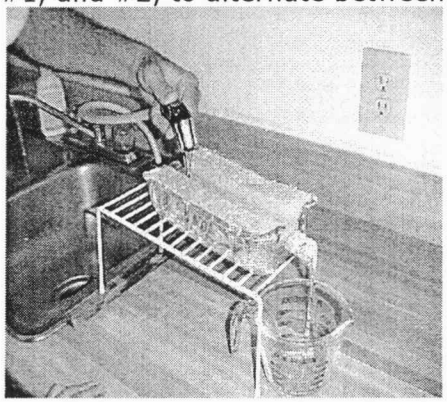
seconds represented in the data chart as (sec). The volume of water is represented as a v and is measured in milliliters(mls).

Time t0 is when the water begins to flow down the slope and time t1 is the time of the first drop flows off the edge of the cardboard into the measure. This time is VERY QUICK! Time t2 is the time of the first 50 mls, then t3 is the reading at 100 mls, and so on. To review you will be recording the volume of water (represented in the data chart as v(mls) and the time intervals (represented as t0 (sec) and so on.

You do the exact same procedure for the sponge model (model #2).

Measuring Outflow: Outflow Data Sheet

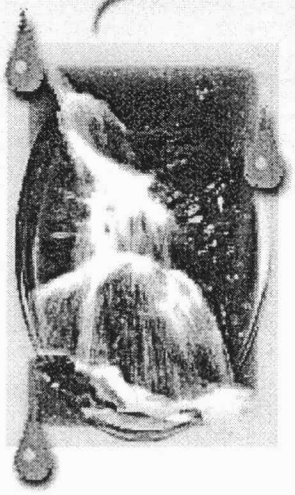
Obtain two measuring cups, label them #1, and #2, to alternate between outflow measurement.



1. Secure the model #1 (with cardboard) near the sink.
2. have your partner hold the measuring cup #1 at the other end of the cardboard to collect the water.
3. When ready, direct the water to flow through one side of the cardboard and promptly start the stopwatch to run the time (initial time t0 = 0).
4. Read and record the time that water reaches the other end of the cardboard right before it pours into the measuring cup #1 (t1). (Do not stop the time, simply read the time and record it)
5. Collect respectively 50, 100, 150, 200, and 250 ml. Read and record the time at each collection.
6. Replace second measuring cup immediately and repeat step 5. (Note: Care must be taken at the time of switching cups. It is important to recollect all the outflow water)
7. Record the time t(s) and corresponding volume v (ml) in provided Outflow Data Sheet. (Remark: you can read volume of 50, 75, 125, …if you like)
8. Start with the model #2 (without cardboard) and repeat from step 2.
9. Calculate the rate of Inflow and Outflow, R, as described below.

Ideal Inflow Rate = 5.5 ml/s to 16.7 ml/s t0 = 0.0

research methodology



Print this page in order to record your data.

Inflow Data Sheet

Time t (sec)	Volume v (ml)
t1=	v1=50
t2	v2
t3	v3
t4	v4
t5	v5
t6	v6

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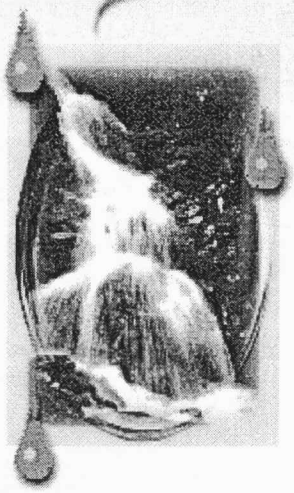

Outflow Data Sheet

Time t (sec)	Volume v (ml)
t1=	v1=0
t2	v2=50
t3=	v3=
t4=	v4=
t5=	v5=
t6=	v6=
t7=	v7=
t8=	v8=
t9=	v9=
t10=	v10=
t11=	v11=
t12=	v12=

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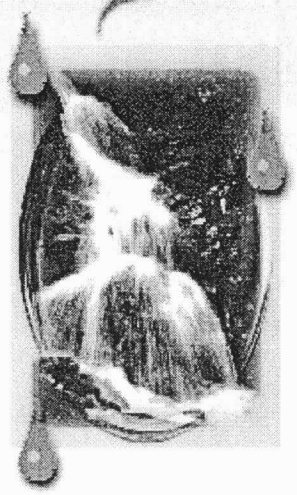
data analysis



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In your experiment, you recorded the time that elapsed from the very beginning of the experiment. But for analysis, you will want to know how much time was needed to add the next 50-ml volume of water.

To determine the individual amounts of time you will do the following: To find the amount of time, find the difference between the recorded times. For example, you began at 0(zero) time. In 2 seconds the water reached the lower edge of the cardboard channel. This is t1. You can subtract 2 - 0 = 2 seconds time (The formula is t1 - t0 = time interval called Delta t. Scientist use the Greek word Delta or the triangle symbols for Delta to mean change in what ever is being measured. In this example it is time.)

The next time in our example was 6 seconds, it occurs when 50mls had been collected in the measure. How would you find the Delta time for this interval?

You would use the formula t2 - t1 = Delta t (Dt)

6 - 2 = 4 seconds

You will find the Delta time intervals and record them in the chart below.

Inflow Data Sheet

DO THE SAME THING FOR VOLUME JUST LIKE ABOVE PARAGRAPH AND OBTAIN Delta V (DV).

Visualizing Data

Calculating Flow Rate: Graphs

1- Calculate Dt at each step by subtracting the reading time at each collection from the previous reading.

2- Calculate Dv at each collection by subtracting each volume from previous volume reading.

3- Obtain Rate, R, by dividing Dv by corresponding Dt at each collection (e.g. DV1/D t1).

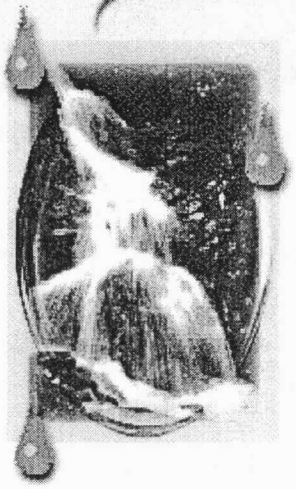
View

4- record R in the provided space in Data Sheets. (if you have done enough repetition, you should expect the same outflow rate for at least the last two steps in measuring outflow rate)

Outflow Data Sheet

Collaboration

1. Did you reach the constant outflow? Why?
2. Is the outflow rate the same as inflow at the end of the experiment? How do you explain this phenomenon?
3. How do you explain the difference in time t1 in the two cases (Model #1 and model #2)?
4. How would you predict the time t1 changes as you increase the inflow rate? 1-Increases; 2-Decreases
5. Calculate how much water will be collected after 2 minutes in model #1 compare to model #2? Discuss this result in terms of watershed, land use, runoff, infiltration, and reservoir instead of Sponge/cardboard, inflow, and measuring cups.
6. Press both sponges firmly with the palm of your hand and discuss your observation in terms of real watershed system? (i.e. is it possible for the ground water to flow out to surface? Under what condition these phenomena takes place? What is this process called?)
7. Calculate the amount of water stored in the sponge at the time t1?
8. Do you predict the stored water in sponge increases/decreases at the time t1, as the inflow rate decreases? Verify your response by viewing other students' data in the **data submission** (this is a link to result of study page) in this project.
9. Can you conclude from above questions that during heavy rain the runoff increases because there is not enough time for water to soak in?



This is where you would insert the "conclusion" information for your research project.

To continue your work, proceed to Guided Research, if you would like some guidance working out a research question and with the process of finding possible answers. If you have done some work on the Land Use in Watershed Project on your own that you would like to share with the KanCRN community, you can go ahead to Publish My Research.

Submitting Your Conclusions

View the Next 20 Submissions | View the Best 20 Submissions

Keyword [ ] Search in Title Search in Text

I have a conclusion to submit.

My Name [ ]

Title [ ]

My Conclusion and My Comments About it - separate paragraphs with <p>

[ ]

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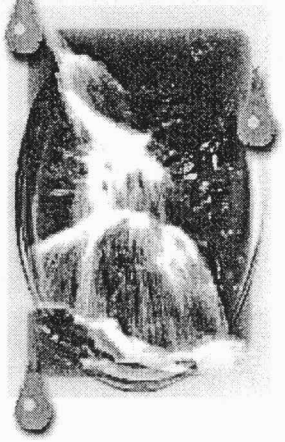

Further Research Questions:

What is the impact of dams, irrigation, and land use in our environment?

Why is it important to know water system connectivity or waste of water?

How important it is to use water carefully at home?

How to maintain the water supply for semi-arid areas for people or animals?

Are precipitation and evaporation the only main factors in our regional water supply?

Does humans have any impact on regional water supply?

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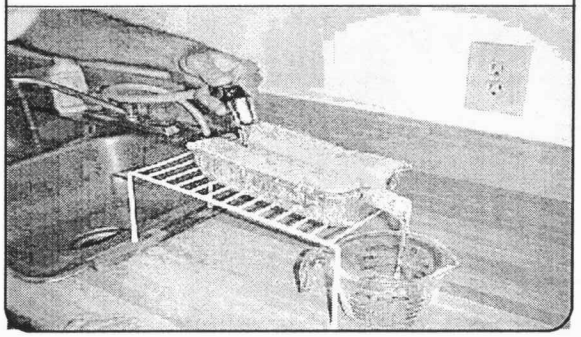
APPENDIX B

STELLA Models

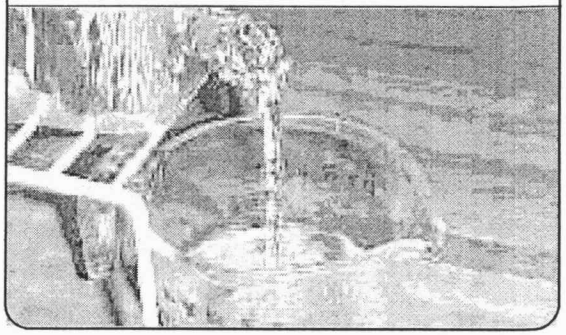
STELLA Unit #1
Sponge Simulation

Go "To Control Panel" and familiar yourself with the tools such as inflow slider, switches, and other buttons. Through this simulation you can experiment different rates of inflow into the Sponge/Cardboard models and observe its effect on stored water in the sponge, stored water in the cup and the time t1 at which outflow starts. Play with the model. Sit back, relax and enjoy your exploration.

water on sponge



water in the cup

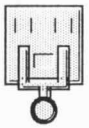


To Control Panel

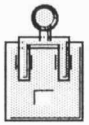
inflow

5.50 ? 10.50 16.70

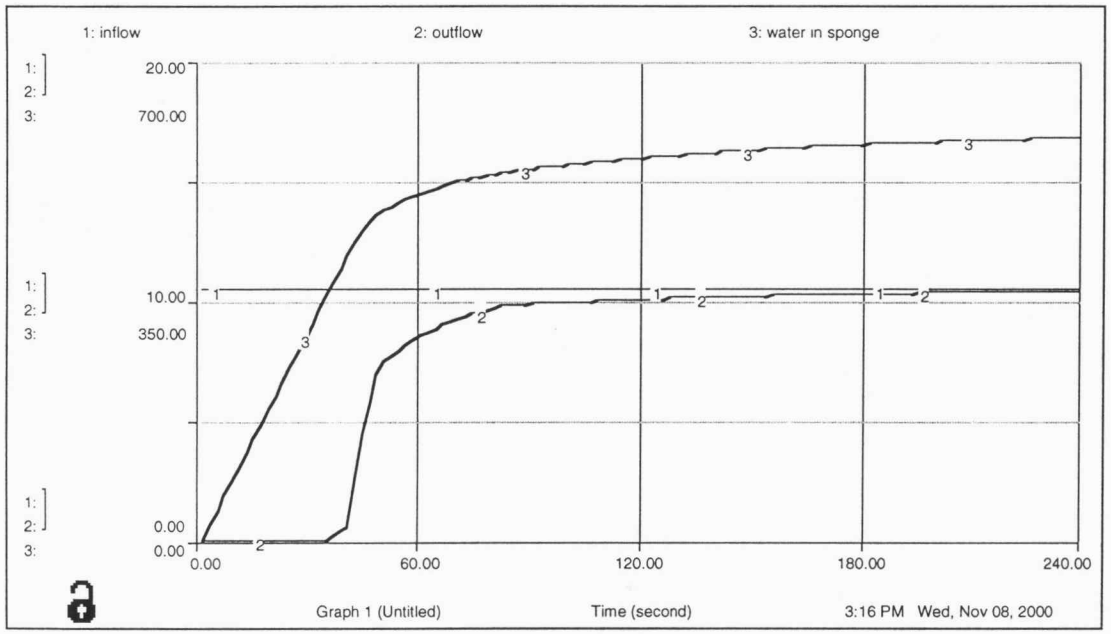
cardboard



sponge



water collected in cup	1,930.0
water in sponge	590.0
inflow	10.5
outflow	10.4



To get more information on the inflow slider, click on "?"

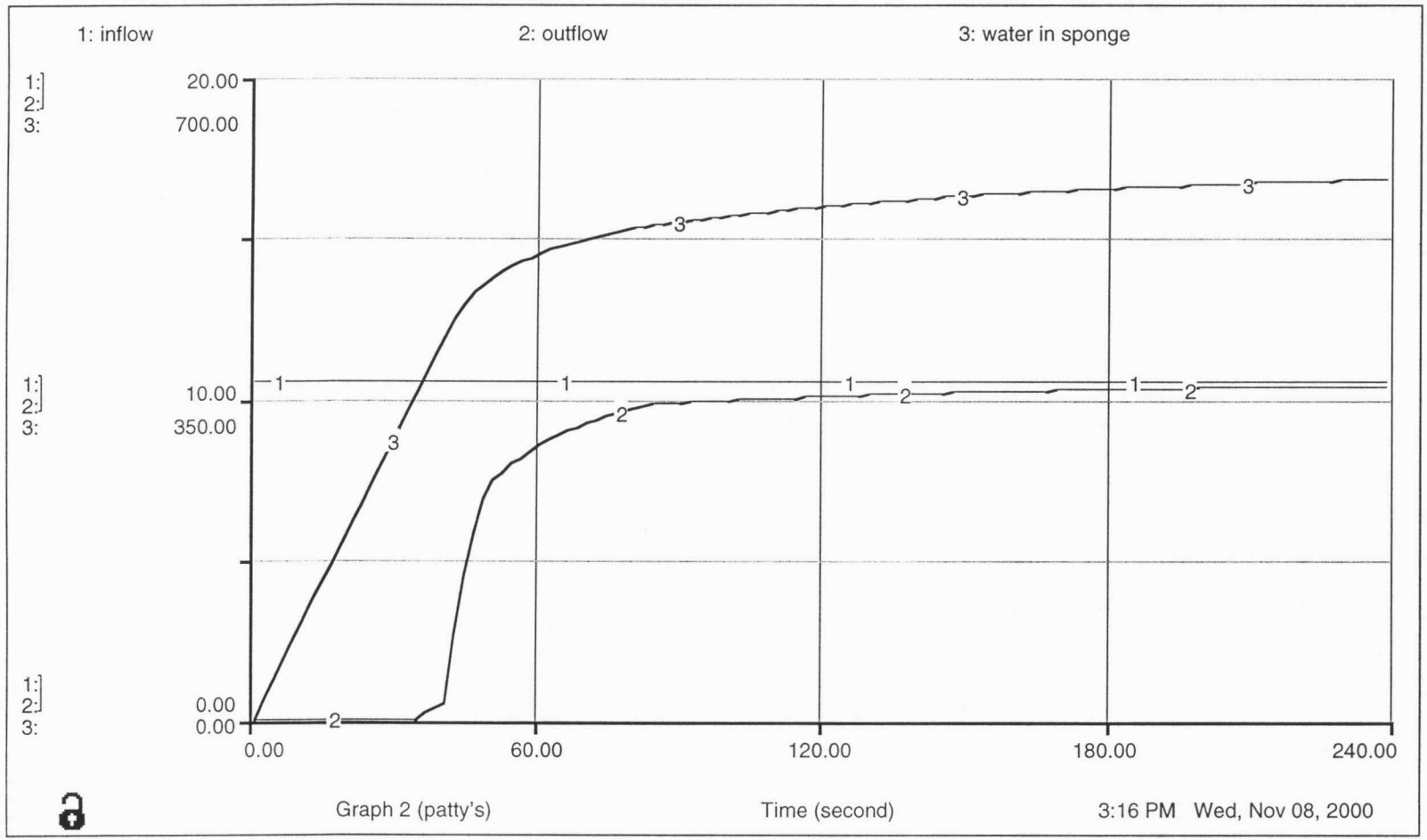
* **Click on the "Reset" button.**
* **Which model is on, Cardboard or Sponge?**
* **Click on "Run" and observe the graph.**
* **How much water is collected in Sponge, record the value in "water in sponge"?**
* **How much water is collected in the cup, record the value in the "water collected in Cup"?**
* **Double click on the table icon and read the last entry in the column Time. For how m**
* **Close the table by pressing the**

Table 1

Return to Map | Pause | Stop | Reset | Run | Zoom to Graph

cardboard	0
water in sponge	590.0

inflow	10.5
outflow	10.4



Discuss the behavior of the outflow graph in terms of time.

In other words, Interpret different portions of the graph with regard to time.

To Control Panel

STELLA 1
written text in Stella box #1

To get more information on
the inflow slider, click on "?"

Record your answers in Student Worksheet #1.

1- Click on the "Reset" button.
2- Which model is on, Cardboard or Sponge?
3- Click on "Run" and observe the graph.
4- How much water is collected in Sponge?
5- How much water is collected in the cup?

6- Double click on the table icon
7- What is the outflow after 20, 40, and 60 second?
8- Close the table by pressing the "x" in the upper right corner.
9- Zoom to graph, print (only page 3) and label it A

Sponge Case

1- Turn the Sponge switch on and cardboard off, (to do that, You have to see a hand when you point on the switch).

2- Run the model.
3- Record the water in Sponge.
4 - Record the water in the cup.
5- Open tha table and record the outflow value after 20, 40, 60 second?
6- Explain the difference between "Water in Sponge" in cardboard case with "Water in Sponge" in Sponge case?

7- Explain the differences between "Water in cup" in cardboard case with "Water in cup" in Sponge case?

8- Explain the difference between outflow rate in cardboard case and Sponge case?

9- Zoom to graph, print the graph and label it B
10- Compare graph A with graph B.
11- Explain the difference between outflow graph in A and outflow in B?
12- Explain the difference between "Water in Sponge" graph in A and " Water in Sponge" in B?

Now we want to see the effect of slow inflow versus fast inflow on the amount of water in sponge. This might explain the difference between heavy rain and slight rain on the soil absorbency.

1- Change inflow to the lowest point by sliding

the inflow bar.

2- Run the model.

3- Open the table and find the time t1, this is the last time that "Outflow" is zero.

4- How many seconds is passed at the time t1?

5- Print the table, label it Slow Inflow.

6- What is the value for "water in sponge" at time t1, Call it W1?

7- Close the table and change the inflow to the highest point.

8- Run the model.

9- Open the table, find the time t1, How many seconds is passed at t1?

10- Print the table and label it FAST INFLOW.

11- What is the value for the water in sponge at t1, call it W2?

12- Explain the difference between W1 with W2?

13- Which inflow slow or fast, produced more water in sponge at time t1?

14- Can we conclude that soil can absorb more water in light rain than in heavy rain?

Student Worksheet # 1

Group #:
Record your answers from STELLA.

1- Click on the "Reset" button.
2- Which model is on, Cardboard or Sponge?
3- Click on "Run" and observe the graph.
4- How much water is collected in Sponge?
5- How much water is collected in the cup?

6- Double click on the table icon.
7- What is the outflow after 20, 40, 60 seconds? At 20:_____at 40: _____ at 60:_____
8- Close the table by pressing the "x" in the upper right corner.
9- Zoom to graph, print (only page 3) and label it A.

Sponge Case

1- Turn the Sponge switch on and cardboard off, (To do that, You have to see a hand when you point on the switch).

2- Run the model.
3- How much water is collected in Sponge?
4- How much water is collected in the cup?

5- Open the table and record
the outflow value after 20, 40, 60 second? At 20:_____at 40:_____ at 60:_____

6- Why is there a difference in how much water the sponge soaked up in the two experiments? Explain your reasoning.

7- Why is there a difference in how much water collected in the cup in the two experiments? Explain your reasoning.

8- Why is there a difference between the outflow rate in the two experiments? Explain your reasoning.

9- Zoom to graph, print the graph and label it B.
10- Compare graph A with graph B.
11- Explain the difference between Outflow graph in A and Outflow graph in B?
12- Explain the difference between "Water in Sponge" graph in A and "Water in Sponge" graph in B?

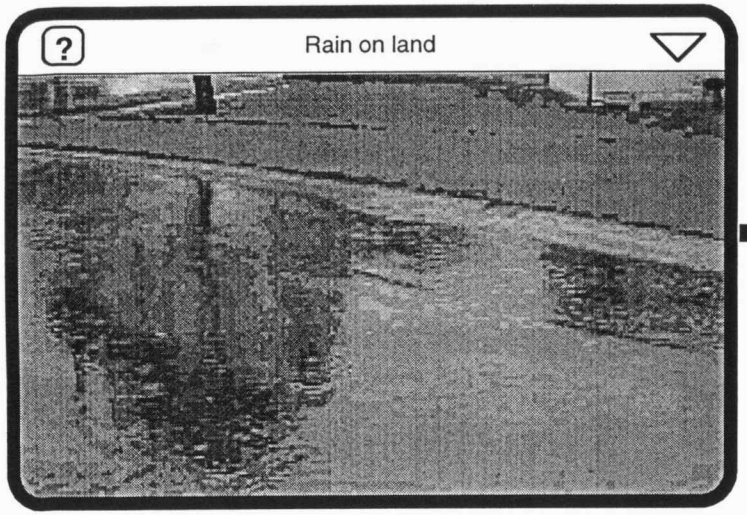
Now we want to see the effect of slow inflow versus fast inflow on the amount of water in sponge. This might explain the difference between heavy rain and slight rain on the soil absorbency.

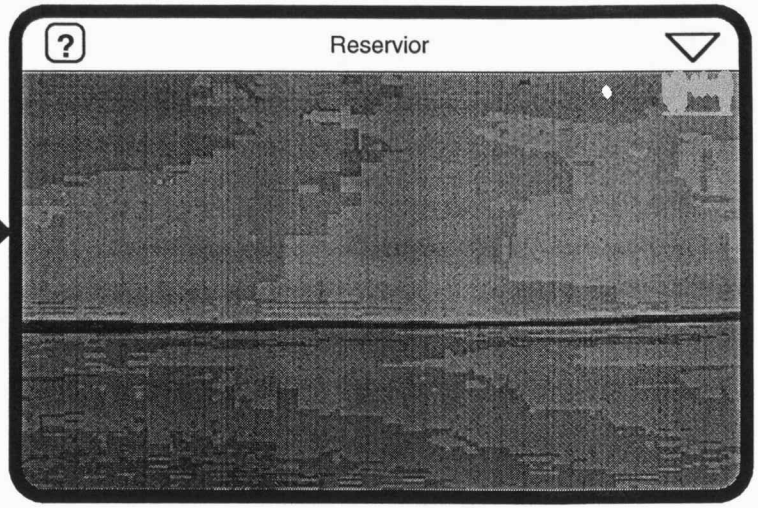
1- Change inflow to the lowest point by sliding the inflow bar.
2- Run the model.
3- Open the table and find the time t1, this is the last time that "Outflow" is zero.
(**RECALL,** t1 is the time that outflow started to flow in your Sponge experiment).

4- How many seconds is passed at the time t1?
5- Print the table, label it Slow Inflow in Sponge.

6- What is the value for "water in sponge" at time t1, Call it W1?
7- Close the table and change the inflow to the highest point.
8- Run the model.
9- Open the table, find the time t1, How many seconds is passed at t1?
10- Print the table and label it Fast Inflow in Sponge.
11- What is the value for the water in sponge at t1, call it W2?
12- Explain the difference between W1 with W2?
13- Which inflow, slow or fast, produced more water in sponge at time t1?
14- Can we conclude that soil can absorb more water in light rain than in heavy rain?

STELLA Unit #2
Flood Simulation





To Control Panel

Your town is going through some new development. There is a 200-acre farmland that is been negotiated for development of a shopping mall.
The citizens of your town, including you, are very concerned about this. Your town has experienced flooding in the past. Since you know expanding development has a major effect on the watershed system, increases runoff and decreases infiltration, you are off to investigate this change in terms of flood possibility.
We are assuming that all the precipitation on this area eventually drains into the nearby reservoir, which has a limited capacity.
Go "To Control Panel", and get yourself familiar with the tools such as slider, for setting precipitation range, switches, for setting the land use, and other tools.

Imagine it is a stormy day!

You have the power to simulate what happens to your town if the Shopping Mall takes place of the Farm

rainfall

1.000 — 3.000

? 2.000

Runoff	378.3
Absorbed water in gr...	5,819,506.0
Lake	29,028,514.0

Lake

0.000 x 10^7

2.500

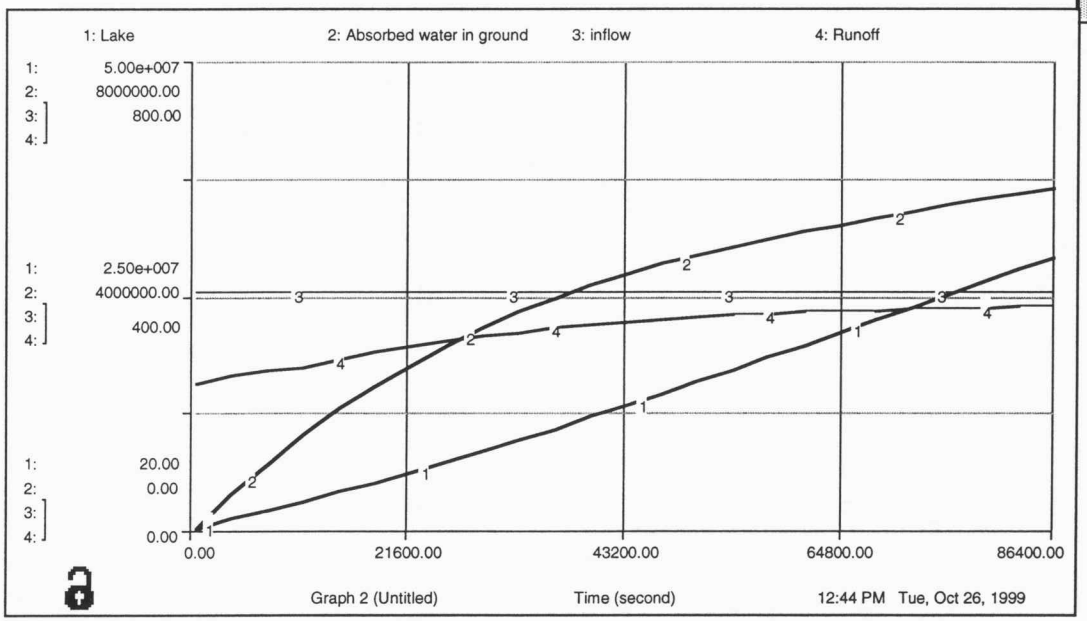
? 0.000 5.000

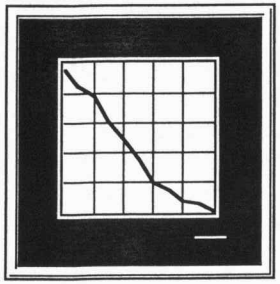
land angle

0.600

0.300

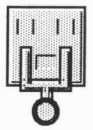
? U 0.000 0.600

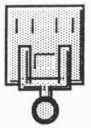




Farm Land

Shopping Mall





Return to Map | Pause | Run | Restore | Stop | Set Time | Zoom to Graph

rainfall	2.0
inflow	403.3
Runoff	378.3

FIgure #1: This graph represent Runoff, inflow and absorbed water in ground.

Absorbed water in gr...	5,819,506.0
land angle	0.6
Lake	29,028,514.0

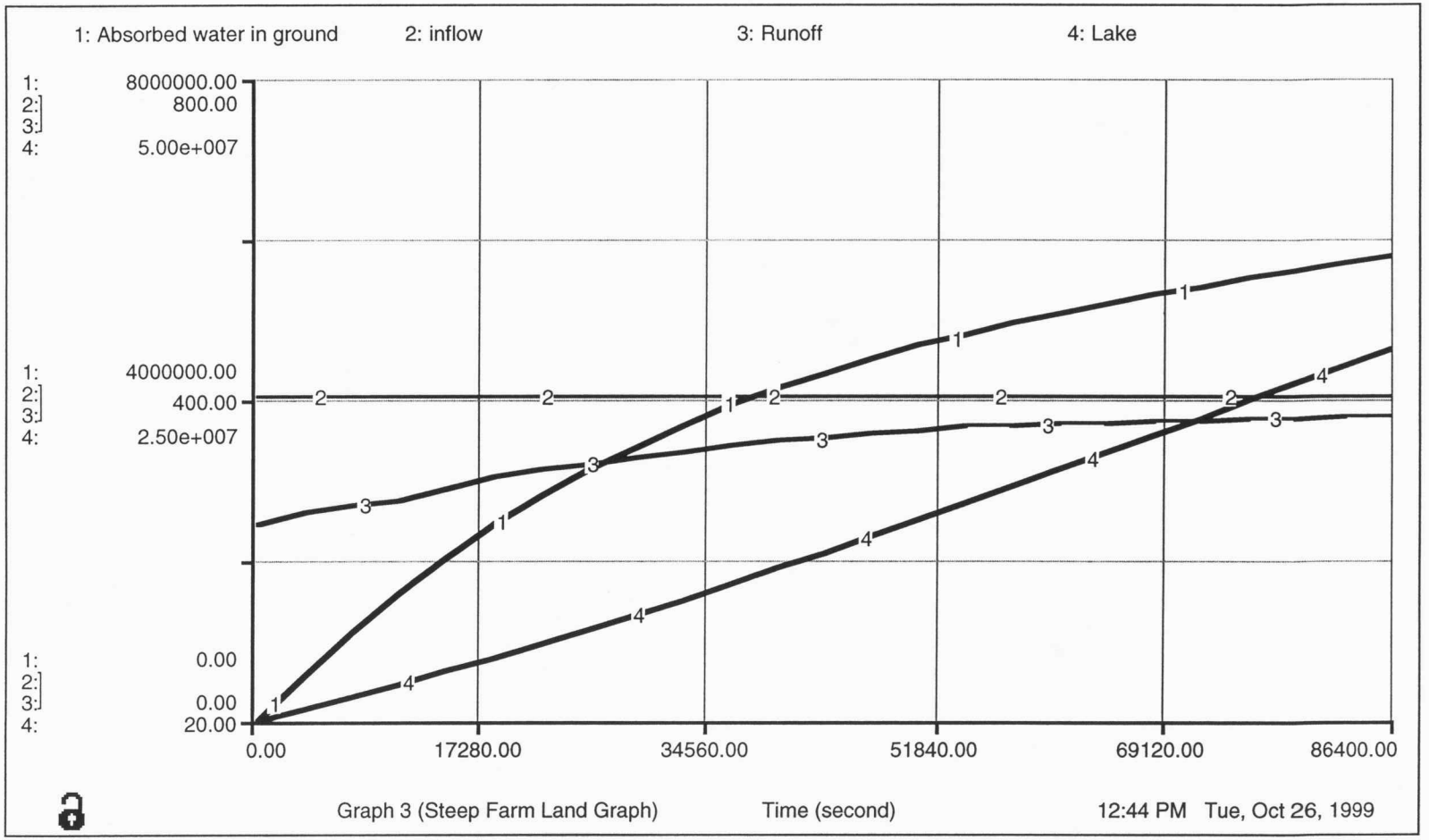
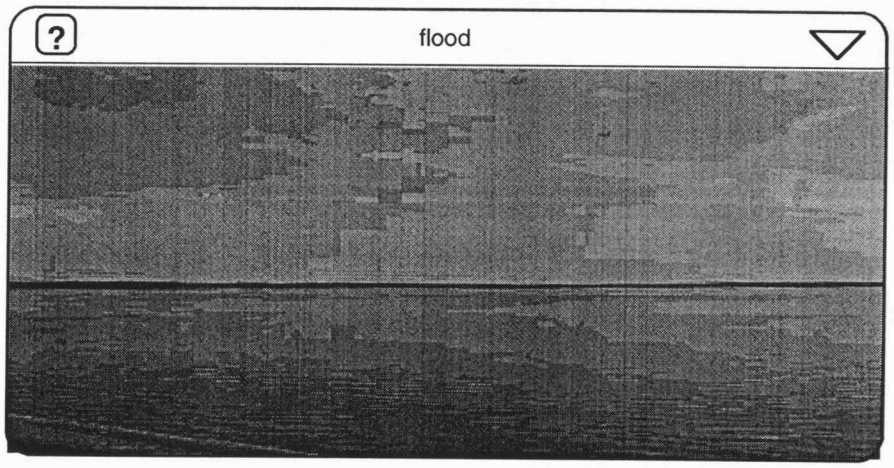


Table 1

Return to Control Panel



Return

Graph 4

STELLA 2
Written text in Stella box #1

Your town is going through some new development. There is a 200-acre farmland that is been negotiated for development of a shopping mall.

The citizens of your town, including you, are very concerned about this. Your town has experienced flooding in the past. Since you know expanding development has a major effect on the watershed system, increases runoff and decreases infiltration, you are off to investigate this change in terms of flood possibility.

We are assuming that all the precipitation on this area eventually drains into the nearby reservoir, which has a limited capacity.

Go "To Control Panel", and get yourself familiar with the tools such as slider, for setting precipitation range, switches, for setting the land use, and other tools.

STELLA 2
Written text in Stella box #2

Imagine it is a stormy day!

You have the power to simulate what happens to your town if the Shopping Mall takes place of the Farm.

* Take a few minutes and explore available objects on screen.
* Click on the Restore button to restore original values.
* Run the simulation by clicking on "Run" button.

QUESTIONS

1- Do you have Farm land or Shopping Mall case?
2- What is the amount of absorbed water in the ground?
3- What is the amount of water in the Lake?
4- "Zoom to graph" and identify the graph of runoff, absorbed water in ground, and lake.
5- Double click on Table icon. Examine the values in the table
6- Print the graph (only page 5) label it Farm Land.

Now, Imagine the Shopping Mall is built.

* Set the Farm Land off and shopping Mall on.
* Run the model and observe!

1- Did you get flood warning when you had your Farmland in place?
2- What is the amount of absorbed water in the ground?
3- What is the amount of water in the Lake?

4- Click on Run again to complete the Shopping Mall scenario.
5- Zoom to graph and print the graph again (Page 5), label it Shopping Mall.
6- Compare the two printed graphs, explain the difference in "Runoff", and "Absorbed water in ground" in Farm Land Graph Versus Shopping Mall graph?

SLOPE OF THE LAND (ANGLE)

· Repeat Farmland scenario. Click on "Restore".
· Change "land angle to 0.600, BY HOLDING THE DOT AND TURNING IT CLOCKWISE
· Run the model,

1- Did you get flood warning even though you have your farm land?
2- Can you explain why?
3- Zoom to graph and print it, label it Steep Farm Land.
4- What is the slope (angle) of the land?
5- What is the absorbed water in ground?
6- Compare Steep Farm Land with the previous Farm Land, explain the difference?

Now, Set the rainfall to have different values

Increase the rainfall value. Adjust the time of simulation by "Set Time" below and explore how long it takes for your town to be flooded in the Shopping Mall case but not in the farmland case. (I.e. if you have a storm for

so long, you eventually approach a flood situation in any case, so adjust the time so that flooding occurs only in the shopping mall scenarios).

You could also change the Farm absorbency graph, or initial value of the Reservoir.
You can use the buttons below to return to the original page, pause the simulation, reset the values, or change the length of simulation time.

* Click on the "?" to get more information on the lake, rainfall, or land angle options.

Student Worksheet #2

Group #:

1- Do you have Farm land or Shopping Mall case?
2- What is the amount of absorbed water in the ground?
3- What is the amount of water in the Lake?

4- "Zoom to graph" and identify the graph of runoff, absorbed water in ground, and lake.
5- Double click on Table icon. Examine the values in the table
6- Print the graph (only page 5) label it Farm Land.

Click on "Return to Control Panel"

Now, Imagine the Shopping Mall is built.

* Set the Farm Land off and shopping Mall on.
* Run the model and observe!

1- Did you get flood warning when you had your Farmland in place?
2- What is the amount of absorbed water in the ground?
3- What is the amount of water in the Lake?

4- Click on Run again to complete the Shopping Mall scenario.
5- Zoom to graph and print the graph again (Page 5), label it Shopping Mall.
6- Compare the two printed graphs, explain the difference in "Runoff", and "Absorbed water in ground" in Farm Land graph Versus Shopping Mall graph?

SLOPE OF THE LAND (ANGLE)

- Repeat Farmland scenario. Click on "Restore".
- Change "land angle to 0.600, BY HOLDING THE DOT AND TURNING IT CLOCKWISE
- Run the model,

1- Did you get flood warning even though you have your farm land?
2- Can you explain why?
3- Zoom to graph and print it, label it Steep Farm Land.
4- What is the slope (angle) of the land?
5- What is the Absorbed water in ground?
6- Compare Steep Farm Land with the previous Farm Land, explain the difference?

Appendix C

Questionnaire

Student Questionnaire

Name:

Grade:

Gender: Male female

PART A

In this section there are 10 questions to measure what you have learned.

Read the questions carefully and circle the right answer.

1) More water would infiltrate the ground on a street rather than the side of the road.
1-True 2-False

2) A stream draining a forested watershed is likely to flood during a heavy rain.
1-True 2-False

3 A stream draining a forested watershed is likely to flow during a dry period.

1-True 2-False

4) There is less runoff in a sandy watershed than in a clay watershed.
1-True 2-False

5) The ability of the soil to absorb water increases during heavy rain.
1-True 2-False

6) The amount of runoff decreases if rain falls on saturated ground.
1-True 2-False

7) Runoff increases during a heavy storm because there is not enough time for much water to soak in.
1-True 2-False

8) The amount of runoff is not affected by the type of land-use in its watershed.
1-True 2-False

9) The amount of water that soaks into the soil decreases with the sharper slope of the land.
1-True 2-False

10) The amount of runoff depends on all of these factors: a) type of the soil, b) rate of rain, c) slope of the land, and d) water saturation of the soil.
1-True 2-False

PART B

This section measures your understanding of the watershed concept.

Read the following questions carefully and write your response in 2 to 4 lines for each question.

Look at both graphs--each provides data about the same rain on 2 different surfaces. Both surfaces were dry before the rain. The data in these graphs were collected over 24 hours period (86400 seconds).

Look at figure #1 graph. The **pink line** is the steady rain coming down on a surface. You can see that it is steady because the line is straight. The **blue line** indicates the amount of rain (inflow) that being absorbed by the surface is falls on. **The green** line is the amount of runoff.

Explain why the data that created a blue line increases quickly and then levels on it?

Explain where the water was going in the 1st section of the green line graph?

When does the runoff rate level off, why?

What is the type of the surface, Permeable or non-permeable? Explain how you know this?

Now, look at figure #2.

Why the green line (runoff) is straight and at the same level as pink line (rain)?

Why the blue line (absorbed water in ground) is straight and near the bottom?

What is the type of the surface, Permeable or non-permeable? Explain how you know this?

PART C

In this section there are 23 questions to measure how well you liked this project. **Circle** the answer that most describe your experience.

1) I liked the "Collaboration" part of the project Where I discussed the questions with my teammates.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

2) I feel like I learned something whenever there was a discussion within our group.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

3) I would like to have more projects like this.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

4) I found it particularly useful to work with partners.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

5) Participation in discussion often lead our group to new questions.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

6) The written instructions in Methodology Page for doing sponge experiment was difficult to follow.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

7) I had enough time to complete the reading part of the project.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

8) The reading part of the project was too difficult.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

9) I liked the STELLA simulation activity.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

10) I found the STELLA simulation an interesting way to learn about watershed concept.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

11) The STELLA simulation aroused my curiosity.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

12) I enjoyed exploring "What if scenarios" with STELLA modeling.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

13) The STELLA simulation helped me understand how runoff affects the watershed.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

14) The written instructions in STELLA modeling were not clear.
a) Moderately agree
b) Agree

c) Moderately disagree
d) Disagree

15) After working with the simulation model, I would like to learn to create my own Stella models.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

16) Not enough time was given to complete the STELLA activity.
a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

17) I enjoyed exploring Kansas Watershed link in the project.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

18) I would like to do more research on water runoff.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

19) This project increased my interest in the land use subject.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

20) I think the topic of this project, land use in watershed, is a very important topic.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

21) The Internet speeds were very slow when we had to browse to the next page
a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

22) I enjoyed exploring Kansas Watershed link in the project.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

23) I understand how different types of surfaces (ex: dirt or pavement) change the amount of rain runoff in watershed.

a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

PART D

In this section you are asked about your experience with computers **Circle** the answer that most describe your experience with computers.

1) I have never worked with STELLA simulation before.

True False

2) I have never used any computer simulation before.

True False

16) I never had a project on-line before this one.

True False

17) I have never used computer before.

True False

18) I use a computer at home.

True False

Write any comments you may have:

Part C (control group)

1) The reading part of the project was too difficult
a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

2) This project increased my interest in the land use subject.
a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

3) I understand how different types of surfaces (ex: dirt or pavement) change the amount of rain runoff in the watershed.
a) Moderately agree
b) Agree
c) Moderately disagree
d) Disagree

4) I think the topic of this project, land use in watershed, is a very important topic.

a) Moderately agree

b) Agree
c) Moderately disagree
d) Disagree

Write any comments you may have:

APPENDIX D

Observational Sheet

Observational Sheet

GROUP

Activity Observation	1	2	3	4	5
**Sponge operation	xxx	x		xx	
Time spent on exp.					
Everyone actively participating in Sponge exp.					
#of time ask for help in Sponge exp.					
Everyone actively participating in on-line reading					
Time spent on on-line project					
#of time ask for help in project on-line					
*Everyone actively participate in STELLA					
Time spent on STELLA					
# of time ask for help in STELLA					

*Sponge operation, xxx, organization, cooperation, accuracy, any one of these missing one less mark (xx, x)

**Everyone actively involve in a time sampling of 5minutes. Fill in the number of students involved in each cell, if all 5 involved, put 5.