

The Pennsylvania State University
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**EXPLORING UNDERGRADUATE STUDENTS' ACTIVE LEARNING FOR
ENHANCING THEIR CRITICAL THINKING AND LEARNING IN A LARGE CLASS**

A Dissertation in
Instructional Systems

by

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ABSTRACT

Although theories and practice in education have emphasized learners' active role in their learning, undergraduate large-enrollment courses (e.g., general education courses) pose challenges for providing students with a learning environment conducive to developing critical thinking skills through their engagements in active learning. This study investigated the effect of incorporating active learning strategies such as small-group learning with authentic tasks, scaffolding, and individual reports, which were employed to enhance students' learning and critical thinking in a large undergraduate, general science education class.

Two active learning modules on natural disaster content were implemented over the semester. Pre and post-tests were developed and implemented to examine effects of active learning on student learning of geoscience concepts and reasoning skills, and two sets of individual reports were analyzed to investigate levels of critical thinking exhibited in student reports over the semester. Data were collected from 155 students enrolled in the class.

Results indicate that the active learning strategies had a positive significant effect on undergraduate students' learning of geoscience concepts, from pretest to posttest, as well as students' critical thinking displayed in written reports, which suggests that the use of active learning strategies in a large class were useful to enhance student learning.

With regards to students' critical thinking, the findings of this study revealed students' average critical thinking levels fell in the category of "developing" for all subcategories (e.g., identifying problems while considering social context, developing a perspective, justifying own decisions, presenting evidence/data, and integrating issues, etc.). The quantitative results revealed that the use of the active learning strategies was

associated with a statistically significant gain in student scores on Individual reports. Thus, the finding of this study from the quantitative and qualitative analysis confirmed that the active learning strategies were useful in enhancing students' critical thinking as well as engaging their critical thinking process: (i) The result from students' scores on Individual reports revealed a statistically significant increase, and (ii) the results from students' perception survey and interview identified specific areas of the critical thinking process students perceived as being supportive (e.g., approaching the problem from various perspectives, applying scientific concepts/ ideas to real-world problems, and so on.).

From the qualitative results regarding students' perception, in general, the use of active learning strategies reportedly had a positive effect on students' engagement in the learning experience. The three active learning strategies employed in the course were perceived as being supportive for student learning and critical thinking. Overall, students perceived positive impacts or values of the active learning strategies on the following: 1) their active engagement in their learning, 2) receiving external support and input from group discussion and scaffolding as well as for applying knowledge to real-life problems, and 3) individual writing opportunities.

With regards to the relationships between student learning, critical thinking, and other demographic data, a correlation study identified several major relationships as follows: i) there was fair degree of positive relationship between GPA and student learning as well as between GPA and critical thinking. ii) there was also a positive relationship between student learning and the number of science courses taken in high school, and iii) there was a slight positive relationship between student learning and critical thinking.

TABLE OF CONTENTS

LIST OF TABLES	viii
LIST OF FIGURES.....	x
ACKNOWLEDGEMENTS	xi
Chapter 1. INTRODUCTION.....	1
Background of the Problem.....	1
Problem Statement.....	2
Research Questions.....	5
Need for the Study.....	6
Active Learning for Critical Thinking Development.....	8
Group-based Learning in Authentic Problems.....	10
Scaffolding Thinking in Active Learning.....	12
Individual Thinking Engaged in Active Learning.....	13
Definitions of Terms.....	14
Methodology Overview.....	16
Chapter 2. LITERATURE REVIEW.....	18
Critical Thinking.....	18
Defining Critical Thinking for This Study.....	18
Approaches to CT within large classroom.....	21
Implications for the Present Study.....	24
Background to the Study Context.....	24
Designing Active Learning for Enhancing Student Learning and Critical Thinking	
.....	27
Defining Active Learning for This Study.....	27
Prior Studies on Active Learning.....	28
Three Supporting Mechanisms of Active Learning.....	30
Chapter 3. RESEARCH METHOD.....	41
Participants.....	41
Research Context.....	41
Materials and Instruments.....	42

The Active Learning Modules I & II.....	43
Pre-test and Post-test.....	46
Scoring Rubric of Critical Thinking.....	48
Student Perception Questionnaire.....	49
Research Design.....	50
Quantitative Study.....	51
Qualitative Study.....	51
Descriptive Study.....	52
Data Collection and Analysis.....	52
Procedure.....	52
Data Analysis.....	54
Chapter 4. RESULTS.....	57
Introduction.....	57
Research Question 1: Effect of Active Learning Strategies on Student Learning.....	58
Demographic Information.....	58
Descriptive statistics for average performance on pretest and posttest.....	59
Results of paired t-test.....	60
Gender Difference on Pretest and Posttest.....	64
Summary.....	64
Research Question 2: Evidence of Critical Thinking in Students' Individual reports.....	66
Levels of critical thinking students displayed in two Individual reports.....	66
Statistics for Mean Performance on Two Individual Reports.....	68
Critical Thinking Level Changes Over Time.....	69
Research Question 3: Student Perceptions of the Learning Environment and Active Learning Strategies.....	72
Results.....	73
Students' Overall Learning Experience in the Course.....	73
Students' 'Active' Engagement in their Learning.....	77
Perceived Effectiveness of the Active Learning Strategies on Student Learning and Critical Thinking.....	80
Summary.....	88
Research Question 4: Relationships between Student Learning, Critical Thinking, and Other Demographic Data.....	89
Correlations between Student Learning and Critical Thinking.....	89
Relationships between Student Learning and GPA.....	90
Relationships between Student Learning and Previous Science Courses Taken in	

High School.....	91
Interaction between Students' Initial Knowledge and Improvement.....	93
Interaction between Gender and Academic Standing.....	93
Summary.....	96
Chapter 5. DISCUSSION.....	97
A Brief Summary of the Results.....	98
Effects of Active Learning Strategies on Student Learning and Critical Thinking..	101
Implications.....	103
Implications for Instructional Design.....	103
Implication for Curriculum Development.....	109
Limitations and Implications for Further Research.....	109
Implications for Educators.....	112
Conclusions.....	118
REFERENCES.....	121
APPENDIXES.....	127
Appendix A. Class Observation Protocol & Observation Record Template.....	128
Appendix B. Active Learning Module I: Instructional Materials (Sample).....	131
Appendix C. Active Learning Module II: Instructional Materials (Sample).....	143
Appendix D. Sample Scoring Rubric for Critical Thinking (Sample).....	150
Appendix E. Pre & Post-test on Students Learning.....	156
Appendix F. Structured Interview Questions.....	166
Appendix G. Student Perception Questionnaire (Sample).....	170

LIST OF TABLES

Table 3-1. Overall Study Questions, Data Collection Techniques, Instruments, and Data Sources	56
Table 4-1. Description of the Study Participants.....	59
Table 4-2. Student Performance Means and Standard Deviation for the Pretest and Posttest	60
Table 4-3. Descriptive Statistics by Academic Standing and Gender for Pretest and Posttest.....	60
Table 4-4. Difficulty index of Items in the Quantitative Reasoning Section for the Pretest and Posttest.....	63
Table 4-5. Paired Comparison Data from Pretest to Posttest of Geoscience Assessment.....	63
Table 4-6. Gender Differences on Pre-and Post-test.....	64
Table 4-7. Mean Scores for the Subcategories in Individual report I.....	67
Table 4-8. Mean Scores for the Subcategories in Individual report II.....	68
Table 4-9. Student Percentage Means and Standard Deviations for Individual Reports I & II.....	69
Table 4-10. Paired Comparison Results from Individual report I to Individual report II.....	69
Table 4-11. Cross tabulation of Three Critical Thinking Level Groups for Two Individual reports.....	70
Table 4-12. Student Perception of Their Learning Experience in the Course.....	75
Table 4-13. Examples of Student Responses regarding Unique Characteristic of the Course.....	76

Table 4-14. The Extent of Students' Engaging in the Learning Activities.....	77
Table 4-15. Students' Responses to Reasons for their Engagement.....	77
Table 4-16. Summary of the Results and Themes Found from the Students' Written Responses to the Open-Ended Question.....	79
Table 4-17. Students' Written Response Examples: Perceived Effects of the Small-Group Problem Solving Activities.....	82
Table 4-18. Perceived Effects of Collaborative Learning Activities on Critical Thinking	83
Table 4-19. Interview Excerpts Regarding the Effects of Scaffolding.....	87
Table 4-20. Comparison of the distribution between self-reported GPA and actual GPA..	91
Table 4-21. Correlations (Pearson's r) Among Student Learning, Critical Thinking, Number of Science courses taken in High School, Academic Year and GPA	92
Table 4-22. Case summaries of the students who changed in pretest and posttest Case Summaries.....	94

LIST OF FIGURES

Figure 4-1. Mean Scores for the Subcategories in Individual report I.....	67
Figure 4-2. Mean Scores for the Subcategories in Individual report II.....	68
Figure 4-3. Graph of the interaction of gender and academic year on posttest.....	95

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Chapter 1

INTRODUCTION

Background of the Problem

Recent research emphasizes developing student competency to deal with complex problems in real-life contexts (Bransford, Brown, & Cocking, 1999; Chinn & Malhotra, 2001; Donovan, Bransford, & Pellegrino, 1999) as well as ‘the need for instructional methodologies that support students [to effectively] function in complex problem-solving environments’ (Roth, 1995, as cited in Toth, Suthers, and Lesgold, 2002, p. 265). Dealing with complex problems requires students to engage in critical thinking, which can be enhanced by appropriate instructional support mechanisms. Although various definitions have been offered, some underlying principles of critical thinking include a process of purposeful, reasoned, and goal-directed higher-order thinking (Halpern, 1999), which involves the process of analyzing the arguments presented, making inferences, drawing logical conclusions, and critically evaluating all relevant elements, including the possible consequences of each decision (King, 1994). In higher education, critical thinking can be displayed through students’ mastery of intellectual skills and abilities, however the teaching and evaluation of critical thinking in current college classrooms and curricula is insufficient (Gupta, 2005).

Despite the calls for instructional methodologies that improve students’ critical thinking, little work has been done to investigate these processes in the context of undergraduate large-enrollment courses such as general education courses. It has been a

long-standing challenge to promote critical thinking in large lecture hall classes; specifically, the effectiveness of critical thinking instruction for the majority of students enrolled in introductory science courses has been questioned (Meltzer, 2002). Despite recent reform movements in undergraduate science education that focus on developing critical thinking skills (Chapman, 2001), there is a lack of research investigating students' critical thinking skill development within large classes.

Problem Statement

Undergraduate, introductory large-enrollment courses have presented some barriers for providing students with a learning environment in which they develop critical thinking skills through engaging in learning activities. Barriers include physical space, a focus on teaching and learning based on memorization of facts from lecture, and emphasis on passive learning. Active learning, an instructional strategy that employs collaborative work, problem solving, and reflection, shows significant promise for the development of students' critical thinking (Hager, Sleet, Logan & Hooper, 2003; Kronberg & Griffin, 2000; Yuretich, 2004).

Active learning focuses on student participation in their learning, allowing students to think critically while working on problem-solving activities, discussing issues with peers, and reflecting on what worked and what didn't work in their problem solving. The focus on learners' active learning in education is not a new idea, and can be traced back to John Dewey in the beginning of the 20th century (Barak, Lipson, and Lerman, 2006). Recent pedagogical strategies such as problem-based learning (Savery & Duffy, 1996), problem-solving, discovery learning (Mayer, 2004), and learning-by-

doing (Shank, Berman, Macpherson, 1999) are associated with exemplary efforts of active learning that emphasize learner's active role in their learning.

A significant question in active learning in undergraduate large classes is: "How can we implement active learning in the large classroom where more than 150 students are attending?" and "Despite the several practical barriers in place, how can we support learners' critical thinking through active learning in large class?"

In regards to the studies of active learning in higher education, many examine the effectiveness of active learning courses compared to conventional approaches (e.g., Trezini, et al., 2001; McConnell, 2003) for student learning. Research findings show that courses incorporating active learning strategies improved student retention, promoted deeper understanding of course materials, and increased students' logical thinking skills (McConnell, 2003). That is, many studies confirmed the benefits of active learning, including improvements in student attitudes about science (Gibbons, 1994; Ebert-May et al, 1997; Reynolds & Peacock, 1998) and increases in standardized test scores (Mazur, 1997; Hake, 1998).

However, it is rare to find research that examines the role of active learning in supporting students' critical thinking skill development in a large-enrollment undergraduate general science education classroom.

Some exemplary work of focusing on students' active learning for enhancing students' thinking can be found in science education, and one way to support active learning in science education is by providing students opportunities to be engaged in inquiry-based learning. For instance, in science education, students can be actively engaged in their learning by collecting and analyzing real-time weather data (Fisherman and D'Amico, 1994) or investigating the global greenhouse effect (e.g. Gordin et al.,

1986). Some exemplary work on active learning in undergraduate large classes were found in general science education courses (e.g., biology, chemistry, etc.). Some studies focused on employing instructional strategies such as small-group discussion and collaborative learning (Chapman, 2001; Rice-Snow & Fluegeman, 2004; Sutcliffe, et. al.), and others attempted to innovate within the classroom environment by incorporating technologies (Barak, Lipson, & Lerman, 2006; Dewey& Meyer, 2000; Oliver-Hoyo et. al., 2004). For instance, Rice-Snow and Fluegeman (2004) introduced a small-group discussion on international issues into a large classroom and gave special attention to the strategies for integrating extended small-group discussion in the large class setting. The primary concern in the current study was also the integration of promising instructional strategies such as small-group discussion into large class settings.

A study by Toth et. al (2002) presented the instructional framework for restructuring an environment into an active learning environment by providing “a non-traditional approach to three aspects of learning: *the activities* student are engaged in, *the tools* students use while constructing knowledge, and *the assessment* of learning outcomes” (p.264). This theme of restructuring classroom learning is similarly applied to the current study of undergraduate general science education, by focusing on providing students with ‘Active Learning Modules’ that have been developed for the course and investigating its influence on students’ critical thinking in the undergraduate course. The course context is Earth 101, an introductory geoscience course, which typically enrolls over 150 students per semester. The class takes place in a lecture hall environment, but its focus is on students’ active learning for enhancing students’ critical thinking and scientific reasoning. In this course, students are engaged in real-world

cases as part of their learning activities, which aim to enhance students' engagement in their learning and critical thinking. The in-class learning activities are presented with authentic problems associated with natural disasters (e.g., volcano, hurricane, global warming, etc.) and their social impact.

Active Learning Modules to support undergraduate students' thinking were designed with specific attention to *the activities* student are engaged in, *the learning materials* students use while constructing their reasoning skills, and *the assessment* of learning outcomes and individual critical thinking. The current study aims to investigate both process and outcomes resulting from students' engagement in Active Learning Modules through the course. Therefore, this study extends previous work in that it focuses (a) on investigating the effects of incorporating instructional interventions and practice of Active Learning Modules on student learning and perception, *and* (b) exploring what levels of critical thinking students displayed while engaging in active learning.

Research Questions

The purpose of this study is twofold: (1) to explore the effect of active learning on undergraduate students' learning, and (2) to examine what levels of critical thinking are exhibited in individual reports over the semester. The research goal and the research questions that will be examined in this study are as follow:

Research Goal:

Exploring the Effects of Active Learning in Support of Undergraduate Students' Learning and Critical Thinking

Overarching question:

How Does Active Learning Affect Undergraduate Students' Learning and Critical Thinking in an Undergraduate Introductory Geoscience Course?

Research Questions:

1. What was the effect of the active learning strategies on student learning?
2. What level of critical thinking did students display in individual reports? And did these change over time?
3. How did students perceive the active learning process and how it contributed to their understanding?
4. What are the relationships between student learning, critical thinking, and other demographic data?

Need for the Study

Higher education has been criticized for its inadequate preparation of students for lifelong learning and employment skills such as problem solving, critical analysis, teamwork and communication skills that are necessary in today's workplace (The Association of American Colleges, 1990; The Wingspread Group, 1993). Specifically, Seymour and Hewitt (1997) described undergraduate science education as being largely passive rather than active. For example, scalability issues associated with large undergraduate introductory courses are not typically supportive for instructors to create engaging collaborative activities, a supportive classroom culture, and physical space arrangements that support students' critical thinking and active learning.

In terms of the reality of undergraduate general science courses, another

important constraint for developing students' critical thinking skills is the predominance of teaching and learning that is based on memorization of facts from lecture (Chapman, 2001), and assessments that focus on testing students' knowledge and comprehension of scientific concepts. In regards to instructional methodology, lecturing is the most popular mode of instruction accounting for almost 89% of physical science and mathematics classes in U.S higher education (Chikering, & Gamson, 1987), which is a significant constraint in developing a student thinking skills.

Active learning processes provide students with an opportunity to engage in thinking that is active, critical, and collaborative. In referring to the analysis of the research literature (Chickering and Gamson, 1987), Bonwell and Eison (1991) proposed creating excitement in the classroom by incorporating active learning strategies that engage students in doing rather than just listening, incorporating instructional strategies that promote active learning such as dialog, debate, writing, and problem solving, and engaging students in such higher-order thinking tasks as analysis, synthesis, and evaluation. Examples of teaching practices relevant to active learning are those focusing on students' sense-making, self-assessment, and reflection on what worked and what needs to be improved (Bransford, et al., 2000).

Thus, learning activities that are appropriately designed for the realities of the large classroom (Furlong & Sharma, 2005) and that include active learning to improve critical thinking are sorely needed. This study was designed to investigate how students' critical thinking skills can be improved by incorporating active learning strategies such as small-group work, problem-solving, and reflection that are appropriately designed for an undergraduate large-enrollment course.

This study attempts to foster students' critical thinking skills as they solve

problems and make decisions about situations that resemble real-life natural disaster scenarios. A primary design principle of the Active Learning Modules is focusing on scaffolding students' more explicit thinking (Furlong & Sharma, 2005). By examining the current level of college students' thinking skills and their development through Active Learning Modules that incorporate scaffolding, it is hoped that further insight will be gained regarding college students' critical thinking skill development within active learning environments.

Active Learning for Critical Thinking Development

Active learning can be considered from two different perspectives: active learning from the student perspective and active learning as a design. From the student perspective, active learning has been discussed in learning theories that focus on learners' active role in their learning (e.g., constructivist learning, self-regulated learning, etc.), whereas active learning as a design places the emphasis on applying design principles and creating learning environments that foster students' active learning. This section will examine these two different aspects of active learning, by focusing on how active learning as a design helps to support critical thinking.

Active learning occurs when learners actively engage in their own meaning-making. The importance of a learner's own knowledge construction and meaning-making in learning has been emphasized in recent educational theories (e.g., constructivism, self-regulated learning, etc.), and various supportive instructional approaches have been increasingly implemented in education (e.g., Problem-Based Learning, problem-solving, active learning, etc.). The common feature of these theories

and practices is "a learner's active impact on learning and a learner's involvement in the learning process" (Neimi, et. al., 2002, p.764).

The term 'active learning' has no common definition (Bonwell & Eison, 1991). Rather, it has been used in some literature to refer to 'instructional strategies that promote students' active engagement in the learning activities' (e.g., Bonwell & Eison, 1991; Marbrouk, 2007). In other literature, it refers to 'the learner's active role in constructing meaning and thinking about their learning' (e.g., Bransford, 2004). This definition has also been used in many recent studies investigating a learner's active learning under the title of 'self-regulated learning'. The important characteristic of active learning is learners' ownership and responsibilities for their learning progress and that the active role may be manifested in individual and cooperative learning strategies (Simons, 1997; Slavin, 1997; Neimi, 1997 cited as in Neimi et. al. 2002). In this study, active learning refers to students' active engagement in their learning and thinking process while engaging in learning activities such as small-group work, writing, group discussion, and problem-solving. Further, as suggested by Mayer (2004), active learning in this study emphasizes students being not only behaviorally active but also being cognitively active during their learning.

Extensive research indicates that there is a significant association between what people tend to remember and their level of involvement (Finelli, Klinger, and Budny, 2001).

'Active learning' takes place when an instructor builds learner participation into classes (McConnell, 2003), and has characteristics such as:

- focusing on making content relevant to the intended audience
- increasing student-student interaction in class

– encouraging conceptual understanding rather than rote memorization of facts (Chickering and Gamson, 1987; Tobias, 1990, 1992; Angelo, 1993; Astin, 1993).

For example, by participating in many small-group problem solving activities, small-group discussions, class discussions, and individual write-ups, students are more actively engaged in their learning. In addition, active interaction among students as well as the teacher and the students are the characteristic of this active learning classroom.

Active learning is regarded as a design that helps to support students' critical thinking. Critical thinking can be fostered through many means, one of which involves students' active engagement with content. For example, learning activities that are designed to foster students' critical thinking require students to be involved with the process of understanding scientific concepts, applying them to real-life situations, critically evaluating relevant information and their peers' perspectives, and drawing logical conclusions. In this learning process, students are expected to utilize critical thinking actively, and emphasis is placed on developing students' cognitive skills (Keyser, 2000; Gupta, 2005) and higher-order thinking (Johnson, Johnson, & Smith, 1998) through active learning.

In this study of an undergraduate introductory geoscience course in a large-class setting, active learning is implemented by incorporating several supportive instructional mechanisms: group-based learning in authentic problems, scaffolding, and individual reflection, which will be discussed in detail in the following pages.

Group-based Learning in Authentic Problems

Active learning has the same theoretical background as constructivism in that it

emphasizes the importance of active learners interacting with various resources, engaging in their own meaning-making process.

The use of student-student interaction provides some benefits in students' thinking and learning, which helps deepen students' understanding through multiple perspectives (Jonassen, & Land, 2000). That is, while they are exploring, interpreting, and negotiating their ideas with other peers, students benefit through these processes. A multitude of research and theories address the intellectual benefits of students that are collaborating with their peers (e.g., Scardamalia & Bereiter, 1996; Vygotsky, 1978).

This premise is employed in this study so that undergraduates' thinking skills and learning can be enhanced through collaboration with peers, while engaging in several collaborative group learning activities that provide opportunities for students to understand concepts, integrate prior knowledge and processes of reasoning while dealing with the issues of a natural disaster.

For example, students are required to work in a group of 3-4 peers to solve authentic problems. In particular, two Active Learning Modules employed in the course are designed for engaging students in group-based learning activities while working on natural disaster problems—e.g., hurricane, flood, and global warming. Given that most undergraduate students' learning in large enrollment classes faces several constraints to be actively engaged in learning and thinking, it is meaningful to investigate how students engaged in active learning in this large class and what influence it had on college students' critical thinking and learning.

Two problems that were designed for the course were Hurricane Scenario and Global Warming and Bangladesh Flooding, which provided opportunities for students to engage in real-life natural disaster problem contexts. Students identify hurricane and

flooding problem in given situations, use real data, consider societal impacts, analyze hurricane and flooding impacts, and make decisions about how to deal with natural disaster problems.

Scaffolding Thinking in Active Learning

In group-based learning activities, the role of dialogue and social interaction that students would have with more capable peers is associated with the notion of scaffolding. That is students would help each other, which results in carrying out a task beyond their individual capability through these learning processes (Vygotsky, 1978). Peer interaction supports students' reflective social discourse and helps learners to consider various perspectives and to select the best decisions on the issues (Lin, Hmelo, Kinzer, & Secules, 1999), which can be an effective scaffolding strategy (e.g., King, 1991; Webb, 1989).

In particular, for the Earth 101 course, two of the Active Learning Modules that were designed to support students' thinking skills were implemented during the fall 2007 semester. To illustrate, the Active Learning Modules I & II contain complex natural disaster problems that require students' critical thinking and reasoning ability as well as engage students in active learning while solving the problems with other students through group discussion and writing.

In this study context, *procedural scaffolding*, a support that makes explicit the sequence of activities for complex tasks students are engaged in (Furlong & Sharma, 2005), was provided in the instructional materials that were intentionally designed to support students' critical thinking. For instance, the learning activities require students to engage in several separate tasks that lead to completing a complex task, which helps

them approach the problem in a manageable and ordered way.

Cognitive scaffolding is another type of scaffold employed in the Active Learning Modules. Hannafin, Land, & Oliver (1999) stated that conceptual scaffolding is provided to help learners reason through complex problems and guide learners in *what to consider*. One of the strategies is to create structures that provide problem-relevant perspectives related to the concepts and make relevant key concepts explicit (Hannafin, Land, & Oliver, 1999). In this study context, learning activities employed a structure to guide students' thinking to identify key concepts. For instance, students are asked to consider several perspectives that deal with the real-life natural disaster problems. In addition, students are required to respond to questions and provide reasoning for the decisions they make. Some examples of the questions embedded in the learning activities are 'What evidence supports your reasoning?', 'Why did you make that decision? List your reasons and the data that you used as evidence.' and so on. The integrated questions are intended to provoke students into critical thinking and reflection to help them think more explicitly, which is similar to the process of thinking used by scientists (Furlong & Sharma, 2005).

As a scaffolding mechanism that enhances peer interaction for the two Active Learning Modules, groupwork sheets were developed and employed as a part of group activity. While students discussing their ideas, the groupwork sheets were used for the students to focus on what should be discussed including what problems/situation they identify, what reasoning they can provide, and what evidence and data they have available to them.

Individual Thinking Engaged in Active Learning

In addition to group-based learning using authentic problems and scaffolding students' thinking, a series of individual assignments were designed that required students to engage in individual critical and reflective thinking. For instance, students were asked to write an individual report that provided their own decisions addressing the situation and their own reasoning behind the decisions, which were based on the findings and decisions of their group as well as their individual understanding of the situation. By engaging in this individual assignment after group work, students are engaged in reviewing their own thinking about the problem, which could help to synthesize group decisions.

In order to offer an opportunity for the individual student to engage in critical thinking processes, the individual report assignment was provided with an individual worksheet. For instance, Hurricane Smith learning activity involves a scenario where individual students are appointed as Special Aide for Disaster Management to the office of the Mayor of their specific community. The individual essay needed to include individual student's critical thinking process such as an analysis of the hurricane situation, suggestions about the evacuation decision with data and reasons, and own proposed decisions with justification.

Definitions of Terms

For purpose of this study, the major concepts discussed in this study are defined below.

Active Learning

In this study, active learning refers to the students' active engagement in their learning

and thinking process while engaging in learning activities such as small-group work, writing, group discussion, and solving problems. Further, the active learning in this study emphasizes not only students' being behaviorally active but also being cognitively active as well during their learning (Mayer, 2004), which leads us to focus more on students' critical thinking when dealing with natural disaster problems that are presented in the form of open-ended, contextual problems (Mabrouk, 2007).

A Large Class

“Frequently, large classes are defined operationally by researchers as those that contain 100 or more students” (Chism, 1989, p.1), although this definition would not fit for all large class situation.

Student Learning

Student learning is defined as changes in their performance on an assessment of their geoscience scientific reasoning skills (SRS), scientific thinking skills, and geoscience concepts of the problem under study.

Critical Thinking

In this study, critical thinking refers to students' ability not only to acquire knowledge of the natural disaster but also to use this knowledge and information while engaging in the active learning tasks of problem solving or decision making process. In this study, we define critical thinking skills as the ability to ‘identify the issues, analyze data and evidence, make judgments, critically and reflectively evaluate relevant elements, and draw conclusions, which includes critical and reflective thinking process.’ The students’

critical thinking skills will be explicated in the students' artifacts of individual and group work as they engage in two learning activities dealing with the natural disaster problems that can take place in real-life context. Critical thinking will be assessed by applying an assessment rubric to students' individual reports.

Scaffolding

Cognitive Scaffolding

Cognitive scaffolding is a type of scaffold employed in the Active Learning Modules. In this study, this conceptual scaffolding is provided to help learners reason through complex problems and it guides learners regarding *what to consider* (Hannafin, Land, & Oliver, 1999).

Procedural Scaffolding

In this study, procedural scaffolding is a support that makes explicit the sequence of activities for complex tasks students are engaged in (Furlong & Sharma, 2005). For instance, the learning activities students are engaging in require students to do several decomposed tasks that lead to completing a complex task, which helps them to approach the problem in manageable and ordered way.

Methodology

This study is a mixed study design, which integrates quantitative with qualitative methods. The quantitative method measures student learning that is defined as changes in their performance on an assessment of their quantitative reasoning skills, scientific

thinking skills, and scientific concepts of the problem under study. This outcome will help the researcher to investigate the effect of active learning strategies on student learning. The quantitative method is a quasi-experimental design that employs pre-test and post-test with no control group.

The qualitative method investigates students' level of critical thinking that was assessed by applying an assessment rubric to students' individual reports. This is triangulated with the data from observation and end-of-unit interviews.

In addition, through a survey that was distributed to all students at the end of the course, the researcher examines students' perceptions of the active learning process and its contribution to their learning (Research question 3).

For research question 4, a correlation study will be conducted to investigate the relationships between student learning, critical thinking, and other demographic data.

Chapter 2

LITERATURE REVIEW

This chapter includes literature reviews on theoretical concepts and empirical findings with regards to critical thinking and active learning. In addition, this section includes reviews of literature on three supporting mechanisms of designing active learning in large classrooms: small-group based learning with authentic tasks, scaffolding, and individual writing.

Critical Thinking

"Changes in technology and the workplace have made the ability to think critically more important than ever before. Instruction designed to help college students think critically focuses on skills that are widely applicable across domains of knowledge and the disposition to use these skills."(Halpern, 1999, p.69)

Defining Critical Thinking for This Study

The range of perspectives on critical thinking is quite broad, and the literature includes several different concepts and various definitions. For instance, Halpern (1999) stated that “critical thinking refers to the use of cognitive skills or strategies that increase the probability of a desirable outcome”, which is “purposeful, reasoned, and goal-directed” (p. 70). Also, critical thinking is defined as “the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/ or evaluating information gathered from, generated from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief

and action” (Scriven & Paul, 1996, cited in MacKnight, 2000, p.38). Some scholars have included the notion of reflection on one's own thinking and decision making and metacognition as part of critical thinking (e.g., Ennis, 1991).

In terms of general characteristics, Halpern (1999) characterized critical thinking as the following:

...the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions. ...When we think critically, we are evaluating the outcomes of our thought processes--how good a decision is or how well a problem is solved. Thus, critical thinking is associated with the concepts including ‘argument analysis, problem solving, decision making, or cognitive process’ (p.70).

Beyer (1995) identified six elements of critical thinking based on the literature, which include ‘dispositions, criteria to make judgments, argument, reasoning, point of view, and procedures for applying criteria and judging’ (p.10). (See also Ennis 1985; Lipman, 1991; Paul, 1990). For instance, dispositions describe expert critical thinkers’ habitual way of thinking such as being ‘skeptical’ and ‘open-minded,’ ‘respecting evidence, reasoning, and clarity,’ ‘considering different points of views’, and so on (Beyer, 1995, p.11, in referring to Ennis 1985; Paul 1990). Criteria describe certain standards or values that need to be applied for making judgments, which are part of critical thinking (Beyer, 1995, p.11, in referring to Lipman, 1991).

In introducing some of the debates in the field of critical thinking, Mason (2007) highlighted differences among thinkers including Ennis, Paul, and McPeck. According to Mason (2007), there are two primary positions regarding perspectives on teaching critical thinking: Ennis and Paul contended that critical thinking can be learned

independently of specific disciplines and transferred from one domain to another; McPeck, on the other hand, argues that critical thinking cannot be taught independently of a particular subject domain, as it is associated with a thorough knowledge of a discipline.

Moon (2008), in her recent book, also reviewed the literature and introduced critical thinking in relation to pedagogy. In particular, she likened critical thinking to activities such reflection and argument, while considering the progression of student learning in higher education. Given the learning context in higher education, she relates two terms --argument and reflection--to the concept of critical thinking as they are commonly practiced in education. For “argument”, she stated that critical thinking involves reflection, and reflection may likewise involve some critical thinking activities. Moon concluded that reflective learning and critical thinking have some commonalities. For argumentation, even though argument is not an alternative term for critical thinking, she acknowledged that sometimes the nature of argument can exactly fit the description of critical thinking.

Aligned with Moon’s considerations, King (1994)’s notion of critical thinking seems more practically applicable to the context of this study that involves students’ learning and enhancing students’ critical thinking. She noted that critical thinking involves the process of analyzing the arguments presented, making inferences, drawing logical conclusions, and critically evaluating all relevant elements, as well as the possible consequences of each decision.

Therefore, although various definitions and approaches have been used to explain critical thinking and its elements, given this study’s context involving an undergraduate general science course, a definition of critical thinking from a practical approach that

considers teaching and learning was modeled for this study. The context for this study relies upon learning activities that engage students in argumentation and reflective learning. Consequently, this study adapts both Moon's and King's notions of critical thinking, defining it as the type of reasoning skill that requires students not only to acquire knowledge of scientific phenomena (e.g., natural disasters) but also to apply this knowledge while engaging in active learning tasks of problem solving or decision making. Thus, in this study, critical thinking skills refers to the ability to identify issues, analyze data and evidence, make judgments, critically and reflectively evaluate relevant elements, and draw conclusions. The students' critical thinking skills will be articulated in the students' artifacts of individual and group work as they engage in several learning activities dealing with science-related problems that take place in a real-life context. The approach, in enhancing critical thinking, is to involve students in solving specific real-life natural disaster problems in small groups, and then having each individual student produce his or her own individual reports that analyze, synthesize, and evaluate critical-thinking processes engaged during their group work.

Approaches to critical thinking within large classrooms

Recent educational approaches advocate a constructivist view on learning, which emphasize learners' active role in the meaning-making process while engaging in rich learning environments anchored in real world contexts (Kirschner, 2001). This perspective calls for higher education to enable students to develop the ability think critically as a common objective of most disciplines in higher education (Chapman, 2001; Halpern, 1999; MacKnight, 2000; McConnell, et. al., 2005; Yuretich, 2004).

This section presents a review of the literature on the design of teaching strategies

to enhance students' critical thinking within large classrooms in higher education.

Hager, Sleet, Logan and Hooper (2003) designed and evaluated a project that aimed to promote the critical thinking abilities and dispositions of students at an Australian university. They developed critical-thinking tasks using open problems that required students to apply chemistry and physics concepts to everyday life problems. Open problems have multiple possible answers and provide students with more opportunity to engage in critical thinking activities such as seeking alternatives and considering other points of views. The researchers took an approach that employs group problem-solving processes, which adopted recommendations from previous research. For instance, the groups were formed with 3 persons with mixed-ability, same gender or 2 female/1male, and each student was assigned a specific role for each task (e.g., manager, checker, and recorder) and rotated the roles. Based on the data from discussions with groups of students and comments of tutors, they concluded that the approach of employing open problems and tasks in small cooperative groups were effective for enhancing students' thinking skills.

In introductory biology, Kronberg and Griffin (2000) selected analysis problems as a means for teaching critical thinking. They constructed the analysis problems in ways that required students to apply their knowledge and understanding of the situation and offered choices and alternatives depending on the justifications students made for their selections. One example of an anatomy and physiology question asked the following: "The pilot of a private plane takes off from the Wood County Airport and flies toward Dayton, Ohio. After 20 minutes, he faints. Which of the following would best explain why he fainted? State and explain any assumptions in your justifications." Even though the format is presented in multiple-choice answers, the choices are

reasonable alternatives students can justify with their choices. They noted that this approach that requires student to justify each response is designed to help them to analyze and synthesize information in an applied manner, which would develop students' critical thinking skills. They reported that the analysis question approach helped improve student achievement and retention.

Yuretich (2004) employed an 'in-class investigation' approach that was intended to introduce critical thinking skills into large classes. For instance, students were given questions that required them to synthesize and evaluate information from the lectures and readings and to engage in group discussion and cooperative learning activities. Students completed these investigations while discussing them with their peers and then reviewed the answers as a class. He asserted that this active learning strategy that required students to think about a question, to discuss it in groups, or to explain their answers to others would improve students' higher-order thinking skills. Thus, "having the opportunity to pause and reflect on, analyze, and discuss processes and concepts is the key" (p.44).

Even though Gupta's study (2005) context is not within a large classroom setting, it investigated the effects of employing a progressive questioning strategy on students learning in a senior-level course for environmental science majors. The major objective of the study was to improve students' critical thinking and problem solving skills through progressive questioning and instructor-facilitated discussion. The question types she asked were diverse, including recall, inference, synthesis, reflective questions, and so on. Also, some questions included research questions addressing local community environmental problems. She asserted that these types of questions prepare students to apply critical thinking skills to solve real-life problems related to environmental matters.

The researcher concluded that the progressive questioning approach improved students' test performance and overall interest in addressing real-life problems.

To summarize, approaches to promote critical thinking within large classes in higher education entail several major design components: (a) designing and developing tasks and problems that require students to engage in higher level thinking; (b) employing group learning activities that provide students opportunities to discuss the problem and work through together; and (c) instructor's facilitating strategies including questioning and instructor-facilitated discussion.

Implications for the Present Study

“Learning is not a spectator sport. Students do not learn much just sitting in classes listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write reflectively about it, relate it to past experiences, and apply it to their daily lives. They must make what they learn part of themselves. (Chickering & Gamson 1997,)”

Background to the Study Context

Instructional Problems of Undergraduate General Education Science Courses

College science students frequently fail to apply the concepts they have learned to understand real-life situations, presumably the result of limited opportunities in science classrooms to apply scientific concepts to real-life problems (Gupta, 2005).

With regards to college students' critical thinking development in introductory science courses, several instructional challenges to encourage student critical thinking have been raised. First, the educational setting of introductory science courses takes place in a lecture hall, which inherently encourages student passive learning including

listening and memorizing facts for multiple-choice exams (Pinet, 1992; Protheor, 2000, as cited in McConnell, et. al., 2005). Few introductory science courses provide students with learning environments where students are engaged in tasks and assignments that encourage their critical thinking (McConnell, et. al., 2005). In terms of the impact of lecture method on student learning and thinking, Mckeachie (1986) reviewed seventeen comparative studies and noted that the research is fairly consistent in supporting the idea that lecturing is less effective for long-term knowledge retention, transfer of knowledge to new situations, higher-order thinking, attitude, and motivation for further learning (cited as in Robinson, 2000). Second, many introductory science classes tend to focus on lower-level cognitive tasks, which offer fewer opportunities for students to engage in higher cognitive tasks including application, analysis, synthesis, and evaluation (Yuretich, 2004).

In these settings, students are not usually challenged to engage in much critical thinking and active learning. Third, many instructors are not aware of the possible teaching impact of these strategies on student thinking development, and many are ill-prepared to cultivate students' thinking skills (McConnell, 2005). Fourth, even when courses are well designed to meet the need for student critical thinking development, implementation issues such as appropriate assessment development are mitigating factors. Assessment tools need to be developed to measure student critical thinking and that monitor student development in the context of their learning (Harris, 2002).

Instructional Goal of the Course

Different concepts and thinking skills are used to describe the aim of science education. For example, National Science Education Standards (1996) used the term

scientific literacy to refer to a broad and general intellectual ability to “engage intelligently in public discourse and debate about important issues that involve science and technology.” Other researchers (e.g., Kuhn, 1988) used the term *scientific thinking* to refer to three major phases: hypothesis generation, experimentation, and inference. Also, *scientific inquiry* is used to refer to the systematic approaches scientists take when they answer to the question of interests (Lederman, 2003).

In higher education, a primary concern and teaching goal is to focus on students’ intellectual development, specifically higher-order thinking skills development including critical thinking, scientific reasoning and problem solving (McConnell, et. al., 2005; Yuretich, 2004). In terms of undergraduate general education science, it is important to develop students’ ability to understand concepts about the natural world, to use scientific information to make daily life choices, and to engage in public discourse about important issues involving science (National Research Council, 1996; www.project2061.org). One of the primary teaching goals is to promote students’ scientific thinking and critical thinking (Yuretich, 2004).

The course, which is the focus of this study, aims to develop student ability to think critically and scientifically. The instructional goal of the course is for students to understand how scientific thinking works and how science is relevant to their lives. The course uses excerpts from natural disaster movies, documentaries, and current newspaper articles, and students investigate various natural disasters using real data and authentic social situations as the bases for their learning of natural disaster and its impact on society. Thus, a primary teaching goal is to focus on active learning to enhance students’ critical thinking and scientific thinking in the natural disaster learning context.

In short, the domain of this study is an undergraduate introductory geoscience course, and the primary instructional goal of this course is to increase students' critical thinking ability needed for either problem solving or decision-making in natural disaster contexts.

Designing Active Learning for Enhancing Student Learning and Critical Thinking

This section discusses three supporting mechanisms for providing students with active learning opportunities in a large class. The present study involved two modules incorporating group-based learning activities, scaffolding, and individual reflective writing as supportive mechanisms to implement active learning in a large class. The purpose of this section is to identify design principles and rationales for employing these three supportive mechanisms. This study eventually aims to investigate whether a course incorporating active learning strategies where students work in small groups, are provided with scaffolds, and write individual reports would produce gains in learning and critical thinking development.

Defining Active Learning for This Study

In this study context, active learning refers to an instructional strategy that employs group-based learning using authentic tasks, scaffolding, and individual essay.

Within the literature, active learning (AL) is generally considered as either (a) a set of individual learning strategies (e.g., Bransford, 2004) or (b) teaching approaches in the classroom (e.g., Bonwell & Eison, 1991; Mabrouk, 2007; Meyers, 1993). Active learning accounts for individual learning strategies, which produced a large body of

research on metacognition and self-regulated learning (Bransford, 2004; Niemi, 2002). This perspective emphasizes learner's active role in their learning and knowledge construction, which includes learners' ability to construct their own knowledge by applying previous knowledge (Niemi, 2002). Another perspective on active learning found in the literature refers to teaching approaches that offer opportunities for students to be actively engaged in their learning in the classroom (e.g., Meyers, 1993; Babrouk, 2007), not passively receiving information. Some examples of these teaching methods employed for promoting active learning include small groups, cooperative work, problem solving, discussion, journal writing, or case studies (Meyers, 1993). In this regards, Meyers (1993) stated "active learning provides opportunities for students to *talk and listen, read, write, and reflect* as they approach course content through problem-solving exercises, informal small groups, simulations, case studies, role playing, and other activities—all of which require students to *apply* what they are learning" (p. xi).

Prior Studies on Active Learning

Even though it is complicated to apply active learning strategies to a large number of students in a class, some research has attempted to implement active learning in large undergraduate classes. Some exemplary work on active learning in undergraduate large classes were found in general science courses (e.g., biology, chemistry, etc.). Some studies focused on employing instructional strategies such as small-group discussion and collaborative learning (Chapman, 2001; Rice-Snow & Fluegeman, 2004; Sutcliffe, et. al., 1999), or designing innovative classroom environments incorporating technologies (Barak, Lipson, & Lerman, 2006; Dewey& Meyer, 2000; Oliver-Hoyo et.

al., 2004). Rice-Snow and Fluegeman (2004) maintained a small-group discussion on international issues in a large classroom.

Employing collaborative learning or co-operative group work is a promising instructional strategy in undergraduate courses. As a result, a growing body of research has investigated the effects of collaborative learning approaches on students' learning. Many of the early studies on collaborative learning focused on comparing the effects of this approach to more traditional methods of instruction that require students to work individually (Sharan, 1980; Savin, 1980), and focused on outcomes such as student achievement and interpersonal relations (Bossert, 1988).

With regards to studies of active learning in higher education, many examined the effectiveness of active learning courses compared to conventional approaches on students' learning (e.g., Treznini, et al., 2001; McConnell, 2003). Research findings show that courses incorporating active learning strategies can improve student retention, promote deeper understanding of course materials, and increase students' logical thinking skills (McConnell, 2003). Also, some studies confirmed the benefits of active learning, which can be seen in improvements in student attitudes about science (Gibbons, 1994; Ebert-May et al, 1997; Reynolds & Peacock, 1998) and increases in standardized test scores (Mazur, 1997; Hake, 1998). Some examples of active learning strategies that were effective for student learning include talking and interacting, opportunities for feedback, use of small-group discussion, problem posing (writing problems), and role playing (McKeachie, 1986).

In terms of the instructional and practice interventions and their influence on students' thinking, a substantial body of research focused on classroom-based interventions in science (Zimmerman, 2007). Regarding students' thinking,

Zimmerman's (2007) review of prior studies on scientific thinking concluded that the influence of instructional and practice intervention has a positive influence. For instance, some studies (e.g., Khun et al., 1995, 1992; Schauble et al., 1992) found that frequent engagement with an inquiry environment can lead to the development and modification of cognitive strategies. Wilhelm and Beishuizen (2004) reported no differences in learning *outcomes* but differences in learning *processes* were found between students with or without instruction or prompts. Based on the reviews of studies on the use of instruction or prompts (e.g., Chi, de Leeuw, Chiu, & Lavancher, 1994; Chinn & Malhotra, 2002a; Chi, 1996; Hausmann & Chi, 2002), Zimmerman (2007) concluded that incorporating such prompts in classroom-based inquiry could serve as a powerful teaching tool in terms of the effectiveness on students' scientific thinking.

Three Supporting Mechanisms of Active Learning:

In this section, literatures regarding three supporting mechanisms of active learning will be reviewed: Small-group learning with authentic tasks, scaffoldings, and individual writing. In particular, based on the theoretical concepts and empirical findings, how each strategy used in this study for active learning supports student learning and thinking will be discussed,

Small-group learning with Authentic Tasks

Vygotsky is most often associated with the notion of learning and thinking development through social interactions. Social constructivism, which advocates the influence of peer interaction on cognition and metacognition, provides one of the theoretical rationales for employing group-based learning in this study context.

When viewed as an effective instructional strategy to improve students' thinking skills, employing group-based learning activities is regarded as a type of active learning strategy in the college science classroom. Johnson, Johnson, and Smith (1991) noted that in small groups students are engaged in an active learning structure that may maximize their own and each other's learning. In other words, where a series of group-based learning activities are employed, students are more actively engaged in learning by discussing their ideas with other students. In terms of the thinking engaged in this learning process, Lipman (2004) claims that reasoning can become alive when, through dialogue, people interpret ideas in different ways on the basis of different assumptions and beliefs (cited as in Moseley, et al., 2005).

Discussion, as a part of the small-group learning process, can be beneficial to student learning and thinking. Brookfield (1995) identifies some of the following benefits of discussion;

- helps students explore diverse perspectives
- helps students become connected to a topic
- helps students engage in active knowledge co-construction
- encourages attentive, respectful listening
- develops habits of collaborative learning.

In particular, peer interaction during small-group learning activities brings several cognitive benefits to students' thinking as they work through problems together. Webb (1989) points out that learning in small groups provides learners with opportunities to explain their ideas to peers, which results in articulation and recognition of their understanding. Also, when students realized the gaps between new information and previous knowledge, they are motivated to search for new information and then

reconstruct their knowledge (Webb, 1989). In this sense, providing students with opportunities to express what they understand is important, thereby encouraging students to think upon their experience, to articulate and elaborate their own understanding, and to connect new knowledge to their previous knowledge. In particular, in small-group learning, students sometimes have disagreements and encounter conflicts with other perspectives to reach a consensus, and these “cognitive conflicts” trigger new knowledge construction. In this regard, King (2002) has shown that, based on the research on peer learning (Cohen, 1994; O’Donnell & King, 1999; Webb & Palincsar, 1996), the interaction between and among the learners in a group influences the cognitive activity that is occurring. She contended, as a result, that peer interaction influences cognitive processing (King, 2002). Previous research also suggests that peer interaction could be an effective scaffolding strategy (King, 1991; Palincsar et al., 1987; Webb, 1989).

Tien, Roth, and Kampmeier’s study (2002) confirmed the effect of small-group learning in an undergraduate science course by implementing peer-led team learning as an instructional approach, which resulted in statistically significant improvements in student performance, retention, and attitudes. They suggested this peer-led team learning model as a workable mechanism for effecting change in an undergraduate science course.

In the context of undergraduate introductory science courses, Sutcliffe, Cogdell, Hansell and McAteer (1999) employed resource-based project learning as an instructional strategy of active learning. They introduced a Study Project, AIDS in Science and Society, to their first year Biology students. Students worked in groups to prepare inter-group debate, and submitted an individual writing assignment, and no

lecture on AIDS was provided. They reported the students' written work quality was highly acceptable, and students' participation rate was high. Students also evaluated the project as a good way of learning.

In terms of the prior studies regarding the effects of small-group learning, Springer et. al (1999) noted that few investigations have focused on college students outside the psychology laboratory. Attending to this need, they conducted a meta-analysis of small-group learning focusing on undergraduates. Their analysis focused on cooperative, collaborative, and mixed forms of small-group learning of various duration in different settings, which included undergraduates' Science, Technology, Engineering, and Mathematics (STEM) courses and programs. In general, the results of the meta-analysis suggested that small-group learning has statistically significant and positive effects on undergraduates' increased academic achievements, persistence, and more favorable attitudes toward learning (Springer, et. al, 1999).

Various forms of small-group learning were employed in prior studies (e.g., Jigsaw (Aronson, Blaney, Stephan, Sikes, & Snapp, 1978), Student Team Learning (Slavin, 1995), Group Investigation (Sharan, 1990), and Learning Together (Johnson & Johnson, 1989, cited as in Springer, 1999). For instance, Aronson's 'jigsaw' approach is a well-known form of small-group learning. It utilizes student's cooperative role-taking by having each group member work as an 'expert' in one segment of the learning material and having them share their expertise when they return to their original groups. In terms of the undergraduate SMET education, Springer et. al's study identified that diverse and complex forms of small-group learning (e.g, collaborative, cooperative, or mixed forms of both processes) were employed into the classroom instruction as well as assignments (Springer, et. al., 1999).

As a way to ensure students' interaction and their active participation, assigning students particular roles is another way to get group members to take responsibility for active participation in the group (Cohen, 1994). With regards to the amount of structure that is appropriate for higher-order thinking, there is no consensus: some scholars advocate less structure on a task, while others suggest that more structure can result in high-level discussions leading to greater conceptual understanding (Springer, 1999). For instance, Cohen (1994, p.20) asserts that "too much structure on a task that involves higher-order thinking skills is dysfunctional because it impedes conceptually oriented interactions", where as Johnson & Johnson (1985) assert that having the instructor provide students with a structure (e.g., assign roles to group members, specify procedures, etc.) is beneficial to student learning. Given these issues regarding structuring the interaction, Cohen (1994) suggested focusing more on what conditions it is productive than on whether structuring interaction is productive.

In small-group learning, the nature of the task is another critical characteristic to be considered, which influences student interchanges and the opportunities for learning that result (Blumenfeld, Mars, Soloway, & Krajcik, 1996). While advocating the possible benefits for student learning (e.g., sharing ideas, accommodating others' perspectives, and giving and receiving help, etc.), Blumenfeld et. al (1996) suggested employing tasks entailing ill-structured problems with more than one right answer. They also noted that although there are desirable peer interactions resulting in benefits to student learning, in practice, students need considerable assistance in considering alternative explanations, offering justifications for their reasoning, and negotiating such complex tasks (Blumenfeld. et. al, 1996). In this regard, Cohen (1994) also noted that for students to be engaged in higher-level thinking while engaging in their small-group

learning, students will require specific development of skills for discourse, either in advance of cooperative learning or through direct assistance while doing group works.

In addition, the mix of students' achievement levels, race and ethnicity, and gender influences how students interact and who benefits (Blumenfeld, 1996). In terms of different group composition (e.g., achievement level, gender, ethnicity, etc.), Springer's meta-analysis (1999) reported that no significant difference in the positive effects of small-group learning on students' achievement was evident between predominantly female and heterogeneous or mixed gender groups, although the benefits of small-group learning on students' attitudes were greater for predominantly female groups than groups of mixed gender. Also, regarding the ethnic composition of the group, they reported that the positive effect of small-group learning on students' achievement was greater for groups composed primarily or exclusively of African Americans and Latinas/os compared with predominantly white and relatively heterogeneous groups, although they admitted that there were not sufficient data available. For students' different achievement levels (low, middle, high), it is suggested to employ heterogeneous groups, in that groups are more successful when members are mixed in different achievement levels (Blumenfeld, et. al, 1996; Springer, et. al., 1999).

Scaffolding

In addition to peer interaction, the affordance of externalized scaffoldings is another primary mechanism of supporting students' thinking through active learning in this study context, which is appropriately designed and embedded in learning activities.

Employing small-group learning in complex authentic problems does not guarantee that students will actively engage in their thinking critically or learn to apply

scientific concepts that they have learned to real-life contexts. Without appropriate scaffolds, students have difficulty engaging in complex thinking (Linn, 2000; Perkins & Simmons, 1988). For instance, students may fail to apply knowledge from one context to another (Gick, 1986; Gick & Holyoak, 1980) or have difficulties in ill-structured problem solving (Feltovich, Spiro, Coulson, & Feltovich, 1996). Thus, some recent researchers have raised questions regarding the efficacy of active instructional techniques and unguided learning situations (Mayer, 2004; Kirschner, Sweller, and Clark, 2006), which highlights the call for scaffolding students' active learning process. To meet this need, Active Learning materials in this study provide students with procedural scaffolds, cognitive scaffolds, metacognitive scaffolds.

The original concept of 'scaffolding' describes supports from interactions between individuals such as a child and a parent, or a tutor and a more capable person (Wood, Bruner, and Ross, 1976). In recent research, this concept has been expanded, which includes the notion of the support provided in tools and materials to help student learning (Puntambeker & Hubscher, 2005). In particular, in a classroom, a complex learning environment, tools and artifacts that are used for presenting relevant aspects of the task and for making processes visible are being described as scaffolds (Puntambekar, et al., 2005). Tabak (2004) also stated that "...various instructional materials and activities can be considered scaffolds and that intentionally designed 'packages'..." (p. 309) can support students' thinking. Structuring the task is one scaffolding mechanism, which "...involves providing students with tools and workspaces that provide the structure necessary to make an open-ended task more manageable" (Reiser, 2002, as cited in Puntambekar & Hubscher, 2005, p.5).

This current notion of scaffolding is embedded in the Active Learning Modules

for this course, in that the active learning activities and materials are intentionally designed for undergraduate critical thinking in large classes and incorporated into the course. To illustrate, the Active Learning Modules were designed to provide visible scaffolds for student thinking in the materials and learning activities, which includes thought-provoking questions for cognitive scaffolding and structuring a task as a metacognitive scaffold.

Cognitive scaffolding supports learners in identifying important aspects of the problem task defined (Hannafin, Land, and Oliver, 1999). For cognitive scaffolding, using question prompts is suggested to enhance students' learning and thinking. For instance, King (1995) suggested using thought-provoking questions (critical questions) to enhance students' critical thinking. Thought-provoking questions (e.g., how do schemas differ from scripts, and explain how a schema would facilitate problem solving in the following scenario) require students not only to memorize the facts but to activate critical thinking. These critical-thinking questions induce high-level cognitive processes including analysis, inference, evaluation, and synthesis.

In this study, these thought-provoking questions are provided in the materials for students' group and individual activity.

The questions help students to identify key concepts and guide their thinking on 'what to consider,' in the natural disaster problem situation. For instance, the Active Learning Module I learning materials that students use for the first group activity requires students to provide their reasoning for the decisions they make by responding to questions such as 'What evidence supports your reasoning?', 'Why did you make that decision? List your reasons and the data you used as evidence', and the like. This strategy of providing students with problem-relevant perspectives related concepts and

making relevant key concepts is to help learners identify what is important and focus on reasoning through complex problems. Therefore, students engage in activating their critical thinking through the process of answering those thought-provoking questions, which will presumably enhance students' critical thinking and learning.

Metacognitive scaffolding is a support that “guides students how to think during learning” (Hannafin et. al., 1999, p.131). For metacognitive scaffolding, one suggested strategy is to support students to plan ahead and to evaluate progress (Hannafin et. al., 1999). Another strategy is to make student thinking explicit (Lin, 1999). For instance, in this study, to help students make their reasoning explicit, visible, and available for revision, students record what decisions they made regarding a hurricane evacuation plan in three different evaluation points and link evidence/ reasoning with their decisions. This approach supports students to explicitly explain and justify their reason for decisions and monitor their decision process. In particular, the record of the group decision process is used for the follow-up individual writing. Thus, this scaffolding is expected to trigger students' thinking by having them focus on the reasoning process in practice while dealing with real-life complex tasks, which can enhance their learning and thinking.

In the Active Learning Modules, a structured sequence of activities is created for student to engage in doing several decomposed tasks that eventually leads to completing a complex task. This approach helps students to organize actions and thinking around activities while engaging in a complex task, as they approach the problem in a manageable and ordered way. In other words, the overall structure of the Active Learning Modules is set up using complex authentic tasks, but in a way that learners can more fully engage in their learning. To illustrate, at the beginning of the learning

modules, students individually are engaged in the process of having a shared understanding of a common goal of the task, while each individual student is working on the individual worksheet that is designed to help them to be prepared for the following in-class group activity. After this individual activity, students engage in the in-class group activity, which is followed by individual reflective writing activity. This structure of the learning activities offers students to do several separate tasks that lead to completing a complex task. In addition, this strategy not only helps them approach the problem in a manageable and ordered way but also offers an opportunity to assume ownership of the task. Puntamberkar et al. (2005) introduced this shared understanding of the goal as an important concept of scaffolding that can be provided in the classroom learning context. They stated that “Although this shared understanding of the goal was achieved between the adult and the child in the original notion of scaffolding, it is now important for the whole class or a group of learners to share the goal and have ownership of the task so that they are motivated to learn” (p.4).

Individual Writing

The third aspect of active learning support is individual writing. Writing is one of the key elements of active learning that involves cognitive activities that allow learners to clarify, question, consolidate their thinking and appropriate new knowledge (Meyers, 1993). However, Meyers and Jones (1993) pointed out that college writing assignments often require summarizing and rewriting, and instead called for using writing as a powerful means for students’ active learning.

With regards to the type of writing, the Bereiter and Scardamalia (1987) model compared summarizing and reflective writing in association with a ‘knowledge telling

model' and 'knowledge transformation model'. To illustrate, summarizing provides students with opportunities for retrieving content information relevant to the topic, while reflective writing / freewriting in a knowledge transformation model can be used to reflect on the concepts students understand or do not understand.

In application of this model to enhancing student learning, Kalman (2007) suggested 'reflective writing' as a successful science and engineering teaching strategy. For instance, students read materials and respond to what they read, which helps them internalize concepts and understand relationships. Kalman stated that reflective writing is "a process that allows students to engage metacognitively with some given material" (p. 12), and this helps student gather their thoughts on a chosen topic and rethink to develop knowledge. He described reflective writing as a 'self-dialogue about what they understand' (p.16).

Providing learners with an opportunity to think upon what worked and what didn't work during the learning process is important to enhance their critical thinking, as it provides learners with an opportunity to reflect on their learning by monitoring and evaluating their progress. In this sense, individual writing functions as a tool to develop students' critical thinking. In particular, in this study context, individual writing opportunity can be considered as a metacognitive tool in students' learning process. While engaging in the writing process, students go through a process of activating critical thinking such as identifying the issues presented, analyzing and synthesizing what they discuss with other students, and evaluating the decisions they made during group activities.

Chapter 3

RESEARCH METHOD

Participants

The research participants were undergraduate students from Earth 101, an introductory geoscience course, which was offered in the fall 2007 semester as a basic science course at The Pennsylvania State University; One hundred seventy-three (173) students were enrolled, and 155 students agreed to participate in the study. The participants consisted of 83 males and 72 females, and about 85% of the students were Caucasian. They were in different majors and years: The great majority of the participants (95%) were non-science major students (e.g., Business, Accounting, Journalism, Communication, etc.), and were in the 18-23 year age (4 First year; 49 Sophomore; 19 Junior; 78 Senior, respectively.)

Research Context

This study is part of an ongoing educational study of an introductory geoscience course at a large northeastern public university. This project has been funded by The National Science Foundation (NSF) (Furlong, & Sharma, 2005). The scope of the research context involves developing Active Learning Modules and assessment techniques for students' reasoning skills that would be effective in large classes. The course context is Earth 101, an introductory geoscience course, which typically enrolls over 150 students per semester. I chose to study this particular course because of its emphasis on students' thinking skill development through active learning strategies in a

large-enrollment classroom. Students are required to be involved with a series of small-group activities, class discussion, collaborative problem-solving activities, and working with real-life data. This course focuses on improving students' quantitative reasoning, scientific thinking and critical thinking in association with natural disasters. In-class activities require students to solve real-life problems related to natural disasters, while working with supporting data, charts, maps, and graphs. For example, students watch a video clip of a Hollywood-produced movie that shows volcanic eruptions with a rescue team trying to cool down lava by pouring water out of helicopters and water hoses. Students are asked to think critically about the correspondence of the movie depiction to scientific evidence about natural disasters and to engage in a collaborative problem-solving activity.

The study context involved two multifaceted and intentionally designed instructional modules –Active Learning Module I & II—on natural disasters. The study consisted of two Active Learning Modules composed of three 1.5 hour sessions for each module as a part of hurricane and global warming units that focused on critical thinking through active learning. These sessions were conducted during class time. This course met weekly on Tuesdays and Thursdays.

Since the focus of this course is not on lectures but on the students' active learning, the professor attempted to focus minimally on lectures and more on student activities. Also, to facilitate small-group activities and problem-solving tasks, three teaching assistants walked around the classroom to facilitate students while they engaged in these group activities.

Materials and Instruments

The materials and instruments used for this study included the material for active learning module I & II (Appendix B, and Appendix C); the pre & post-test material (Appendix E), and scoring rubric (Appendix D); the structured interview questions (Appendix F); and the students' perception questionnaire (Appendix G).

The Active Learning Modules I & II

The two Active Learning Modules used for this study share the following design elements:

- use current events and situations that students might encounter in the news and daily lives as a context for the activities (Furlong & Sharma, 2005),
- provide visible supports, or scaffolds, for student thinking: cognitive scaffolding and procedural scaffolds (Furlong & Sharma, 2005),
- provide opportunities in which students engage in peer discussions and collaborative activities
- provide opportunities for writing individual reflective essays after small-group activities

The Active Learning module I. The Active Learning module I material (Appendix B) is a real-life complex problem related to natural disasters (hurricanes) developed by a research team including experts from the fields of Instructional Systems and Earth Sciences. This scenario is entitled “Hurricane Smith” and revolves around decision-making processes for an evacuation plan.

The learning modules were designed using established research in the area of pedagogy dealing with complex thinking and reasoning (Furlong & Sharma, 2005). Ill-structured problems using authentic events and genuinely complex problems were employed in the learning activity to elicit students' answers and justification for the

answers.

Group and Community chart materials. The material developed for the *Active Learning Module I: Hurricane Smith Exercise* (Appendix B) includes both a small-group activity and an individual activity. The group activity consists of a group discussion chart with a three-point evacuation plan and requires explicit reasoning about the decisions made. For each point of the evacuation, 3-5 questions were provided that asked students to think about and list what was important and why they made the decisions provided in the group and community decision charts.

Individual report materials. After the group activity is completed, each student is asked to write an individual report (Appendix B). It presents a scenario that appoints the student as a Special Aide for Disaster management of the office of the Mayor for the community that students were assigned to in the group activity in class. Each student is asked to write an individual report that provides their own proposed decision to address the situation and their reasoning behind the decision for their Hurricane Smith evacuation plan, which should be based on the findings and decisions of their group and community members. This report should include an analysis of the hurricane situation and suggestions about evacuation decisions.

The Active Learning Module II. Similar to Active Learning Module I, the Active Learning module II also employs an authentic event and genuine complex problems regarding a natural disaster, which requires students' critical thinking skills and justifications. The Active Learning module II material (Appendix C) is composed of a similar structure which presents a real-life complex problem associated with natural disaster and asks students to engage in a small-group activity followed by an individual

reflection report. The Active Learning module II was designed for a global warming unit, which includes three phases of learning requiring students to use three instructional materials designed for this module: (a) *Individual Worksheet*, (b) *National Geographic Creative Team Documentary Storyboard*, and (c) *Bangladesh Global Warming Individual News Report*.

Before engaging in the team documentary storyboard activity, students were provided with an *individual worksheet* to help them understand and prepare for the group activity and final paper on the impact of Global warming in Bangladesh. The purpose of providing the worksheet was to help students think about the socio-cultural context of Bangladesh and the impact of global warming on Bangladesh. The worksheet includes questions for students to consider and the instructions for the team storyboarding activity. To complete the individual worksheet, students should (a) read the information provided on the course management system carefully, and (b) write down answers to each question, based on their understanding of the material. This activity was planned to be completed by the individual student before coming to the class session for the following group activities.

A document entitled '*National Geographic Creative Team Documentary Storyboard*' and an actual '*storyboard*' were designed to be used when students were engaged in the group activity in class. It asked the subjects to work in a team to make a documentary for National Geographic on the effects of global warming on Bangladesh flooding. The activity is composed of two parts: In the first part, it requires student teams to consider the question presented and come up with a set of information about Bangladesh that they would like to present in the documentary. The second part of the activity asks students to create a storyboard for the documentary. Overall, the

documentary should be split into two parts: (a) Background information on Bangladesh and (b) the impacts that global warming can have on Bangladesh.

Bangladesh Global Warming Individual News Report. After completing the two preceding learning activities--some background research on flooding and global warming (individual worksheet) and a creative meeting with the documentary team where students discussed impacts of flooding and global warming in Bangladesh with their peers (group activity)--an individual activity was designed to provide students with an opportunity to write an in-depth report on the impact of global warming on Bangladesh. This new task requires students to show clear links to research and data and to provide vivid descriptions of global warming trends and their impacts on Bangladesh, which was to be considered for inclusion in National Geographic's special issue on climate change.

Pre-test and Post-test

Item Development. In the geosciences field, the Geoscience Concept Inventory (GCI), a valid and reliable assessment instrument, was recently developed (Libarkin & Anderson, 2005) for assessing students' understanding of entry-level geoscience course material. However, the question items in the GCI did not meet our goal of examining students' ability to employ scientific reasoning skills with supportive data to deal with questions regarding natural disaster data (e.g., quantitative reasoning, scientific thinking skills, geoscience concepts). Consequently, additional items covering these areas were developed.

A research team— including a specialist in assessment development from Instructional Systems, the professor of the Earth 101 course, a subject-matter expert

from the Geoscience department, and the researcher—wrote a set of questions. Given the goals of major geoscience skills and Bloom’s taxonomic levels, subsections (e.g., ‘nature of science,’ ‘data analysis,’ ‘people & geoscience process,’ etc.) were extracted in association with the assessment criteria that were being targeted. Each question presented a scenario of natural disaster events (e.g., hurricane, earthquake, etc.) and then asked students to justify their choice of answers. Given target skills, items were developed for three categories, which are associated with different areas of thinking skills and concepts: *scientific reasoning skills*, *quantitative reasoning skills*, and *geoscience concepts* (Total 25 questions: 2, 13, 9 items, respectively.)

The *scientific reasoning skills* category tapped the student’s ability to generate questions about a situation and turn the questions into researchable hypotheses (Stillings & Ramirez, 1999), which targeted the students’ scientific thinking skills. The *quantitative reasoning skills* category presented some data related to natural disaster scenarios and asked the student to plot the data on a graph based on the relationship between the X and Y data presented in the table, analyze the relationship between two variables, predict the time of earthquake and evacuation, and to provide reasoning for the decisions they made. Such questions allowed students to be engaged in the logic of the qualitative properties of quantitative data (Stillings & Ramirez, 1999). The items within the *geoscience concepts* category presented questions asking basic facts and concepts relevant to natural disasters, which were presented as multiple-choice items. Sample items from these three categories appear in Appendix E.

All items of the pre-test were pilot-tested with undergraduate students, who were randomly selected from different majors and years but attending the same university. Items that failed to elicit clear understanding and targeted reasoning skills were

reworded.

The internal consistency reliability was estimated for the pretest and posttest using the Cronbach α coefficient. The internal consistency reliability coefficients, Cronbach's alpha, for this version of the instrument that includes 25 items was .67 (n = 128).

Development of a Scoring Rubric. A set of scoring rubrics for the pre-tests and post-tests were developed, which included multiple-choice answers and ratings of the quality of students' scientific reasoning. For instance, a question asked students to make a decision on the latest time at which a hurricane evacuation can start, and is followed by a question that asked the students to explain their reasoning in determining their prediction. In such a case, answers were awarded points both for the exactness of the calculation and for the reasoning associated with their prediction. For the *scientific thinking skills* category, two questions asked the students to analyze an event of testing hypotheses and to generate a testable well-formulated hypothesis. Answers were awarded points for each question.

Scoring Rubric of Critical Thinking

A set of scoring rubrics for each learning activity students engaged in class were developed. These rubrics rated the level and quality of the subjects' critical thinking. An analytical rubric (Appendix D) was modified based on the guide to rate critical thinking skills developed by Washington State University (WSU) (www.ctlt.wsu.edu, 2006). The modified WSU rubric was used to score the result of the students' level of critical thinking from the Hurricane Smith activity. This rubric is divided into three sections; (a) Rubric for Community in Geo Class, (b) Rubric for Group in Geo Class, (c) Scoring

Rubric for Individual Essays. The set of rubrics for Active Learning module II (Global Warming activity) follows a similar framework and includes group activities and individual reports.

Student Perception Questionnaire

A student perception questionnaire of their experiences of active learning in a large class (Appendix G) was developed by the researcher. It was designed to investigate how students experienced active learning and what elements and components of the Active Learning Modules students perceived as effective for learning and critical thinking. It is composed of three categories: (a) Learning Experience in the Course, (b) Effects of collaborative learning activities, (c) Open-ended questions regarding the general effectiveness of active learning. Some of the statements regarding student perception of the effect of collaborative learning in the survey were adapted from the Student Survey (Mourtos and Allen, 2001). The questionnaire includes 18 Likert-scale statements and 6 open-ended questions on the student's learning experience in regards to such things as small-group activities and the learning activities they engaged in during the course. 18 statements are to be scored on a 5-point Likert scale from strongly disagree (1) to strongly agree (5). The format used for each statement is as follows: "I enjoyed..." and "I found X was helpful for Y", and "The collaborative learning activities used in this course helped me develop my ability to X". For example, "*The collaborative learning activities used in this course helped me develop my ability to consider other people's perspectives while making decisions.*"

The questionnaire was reviewed by a team of seven other researchers for construct validity. The team was asked to review and evaluate the nature of survey items

including students' learning experience in the course and perceived effects of collaborative learning activities. Each item was individually examined, and only items that were approved by the entire team were selected as survey questions. Other suggestions included rewording of some items and only including one construct in each item, which were revised and reordered based on the suggestions.

Research Design

A mixed-methods study is employed, which combines a quantitative study to investigate research questions 1, 3, & 4 and a qualitative study to investigate research questions 2 & 3. In this context, a mixed-method study provided a better understanding of research problems and the best opportunities for answering the research questions (Creswell, 2007; Johnson & Onwuegbuzie, 2004)

Quantitative Study

The quantitative method empirically measures (a) student learning gains from pre-and-post test (Research Question 1), and (b) individual student's critical thinking skills on assessments developed to evaluate them (Research Question 2). The independent variable is instructional materials that were incorporated in the Active Learning Modules I & II as students' class activities. The dependent variable is (a) student learning and (b) critical thinking skills, measured by pre –and-post test and analysis of student's individual assessment.

Qualitative Study

The qualitative method investigates student learning within the actual context of the classroom, in particular, focused on improvements in undergraduate students' critical thinking skills while they are working in collaborative activities, and individual

reflection represented in the student's individual essay. Data was collected through participant observations, interviews, and written document analysis from the assessments that were designed to evaluate student's thinking skills. In regards to improvements in students' critical thinking, two in-class exercises were designed to examine students' thinking skills and are used as data.

Observation and interview

For the qualitative part of the study, several observations were used. Participants and their in-class activities were observed as they engaged in their learning activities. Observations provided information on how subjects interact with other students in group activities and with the instructional materials provided for their activities. Based on the observation protocol (Appendix A), the researcher observed class and student activities, which were used to derive discussion points for a structured interview (Appendix F) at the end of the course, following the completion of the two Active Learning Modules.

The structured interview (Appendix F) allowed the researcher to discover contextual information about the students' engagement in their learning, such as how the Active Learning Modules and instructional materials affected their engagement in learning and how they facilitated their engagement in critical thinking. It provided supplementary data to confirm the result of the subject's perception of the learning activity and instructional materials.

Descriptive Study

For the descriptive study, data collected from students' survey questionnaire were used to investigate students' perception of their learning environments where the Active Learning Modules were employed. For Research Question 3, a descriptive study

provided more focused information on how students perceived the active learning process and how it contributed to their understanding. To answer the Research Question 4, a correlation study was employed to investigate if there was any more statistically significant relationship among related variables that include student learning, critical thinking, and other demographic data.

Data Collection and Analysis

Procedure

The study was conducted during the fall 2007 semester at the Pennsylvania State University. At the beginning of the semester, the professor of the Earth 101 course introduced this study to the students. Prior to the study, the researcher met with the Earth 101 class, explained the purpose of the study, and requested participation for the study that includes two assessments and two Active Learning Modules as in-class activities. Students were informed that they were being asked to participate in an ongoing study of active learning in large classes and that they would participate in in-class activities that will take place as a part of the course. They were also informed that they had the right not to participate, and that their data would be kept anonymous. Informed consent was obtained from all subjects who agreed to participate. All subjects were added into a group within Penn State's Course Management System, ANGEL. Some copies for the learning activities and associated materials were available for all subjects through ANGEL, also a drop box was set up for students to submit individual reports and other assignments.

The pre-test was administered at the fourth session of the course. Students were

given 50 minutes to complete the pre-test.

During the course, two Active Learning Modules I & II were implemented as part of the students' class activities. The instructional materials and associated handouts were distributed to all subjects via a handout at the appropriate point in the course. Subjects were randomly divided into groups for the in-class learning activities, which were designed for groups of four or five subjects. Students were randomly arranged into the groups, which varied depending on the characteristic of the activity. For example, in the Active Learning module I: Hurricane Smith, four students were assigned in each *group* (six groups working on commerce, disability, emergency, infrastructure, media and school group), and then students from each group were gathered within the larger *community* of groups to discuss their decisions.

The post-test was administered to the participants at the last session after all activities were completed. A self-report questionnaire on students' perception of their learning and Active Learning Modules (Appendix G) was administered when students took the post-test at the last session of the course after all learning activities were completed. Students were given 40 minutes to complete the post-test and a perception questionnaire.

For the further study that includes a structured interview with students, the researcher contacted students through ANGEL's class email and recruited volunteer students. The interviews were conducted with two voluntary students at the convenience of each individual student. Each interview lasted approximately 1 hour.

Data Analysis

In this study, to examine the changes in student learning and their critical thinking

through active learning, I applied two methods of analysis: qualitative method and quantitative method. Overall study questions, data collection techniques, instruments, and data sources are presented in Table 3-1.

In regards to the answer for research question 1, the effect of the active learning strategies on student learning, the quantitative method was employed. A data set collected from the students' pre and post-test was analyzed and compared to gauge students' learning gains. Student learning is defined as changes in their performance on an assessment of their quantitative reasoning skills and scientific concepts of the problem under study.

To answer for research question 2, 'What level of critical thinking did students display in both group work and in individual reports?', students' critical thinking level was determined based on the rubrics that were developed for evaluating students' Individual reports I & II employed in Active Learning Modules (Refer to the Appendix D). A collaborative research team who has been working together for a larger on-going study was involved in the analysis phase, which included developing a coding scheme for critical thinking and rating of students' work. In addition, the qualitative analysis was used for analyzing data from the students' perception questionnaires, with specific focus on the questions regarding effects of active learning strategies on students' critical thinking.

In an effort to ensure the raters' scoring reliability, each of four researchers assessed the same two sets of students' Individual report at the beginning ($n=15$; 10 % of total N). After ensuring inter-rater reliability ($.97$) between the raters, four raters worked on the scoring job separately, which included two raters assessing the set of Individual report I and two other raters assessing the set of Individual report II.

In addition, another qualitative analysis was included to answer research question 3, i.e., how did students perceive the active learning process and how it contributed to their understanding? This procedure included an analysis of the students' perception survey, interview and observation data. The analysis of the students' perception questionnaire provided fundamental data for the researcher to answer this question. In addition, the data collected from the researchers' participant observation and a follow-up interview with volunteering students provided supplementary data to confirm the findings for research question 3. This informed the research team about the culture that active learning strategies engender within the classroom such as teacher-student and student-student interactions and the dynamics of group work problem-solving activities in the entire class, which was used to ascertain contextual information about students' critical thinking skills through active learning while engaging in the learning activities.

Table 3-1. Overall Study Questions, Data Collection Techniques, Instruments, and Data Sources

Research Question	Data Collection Techniques	Tasks/Materials/Instruments	Data Sources
1. What was the effect of the active learning strategies on student learning*?	Quantitative study	Pre-test & Post-test Scoring rubrics	-Students' performance on pre-& post-test
2. What level of critical thinking** did students display in individual reports? And did this change over time?	Qualitative analysis of data	-Samples of Students' activity worksheet & Individual reports -Rubrics on critical thinking	-Students' activity worksheet & (Active Learning Module I, II) -Individual report
3. How did students perceive the active learning process and how it contributed to their understanding?	Descriptive study confirming with qualitative data: Students perception survey Interview Observation	-Survey Questionnaire -Interview Protocol -Observation protocol	-a survey (data from interviews : supplementary) -Observation Document
4. What are the relationships between student learning, critical thinking, and other demographic data?	Correlation Study	-pre-test & post-test -Individual reports -Demographic data	-Demographic data -scores from pre & post-test -level of critical thinking

Note. *Student learning is defined as changes in their performance on an assessment of their quantitative reasoning skills and scientific concepts of the problem under study.

**Critical thinking will be assessed by applying an assessment rubric to students' individual reports.

Chapter 4

RESULTS

Introduction

Chapter 3 presented a delineation of the methods responding to the research questions posed for the study. In brief, four research questions were posed:

1: What was the effect of active learning strategies on student learning?

2: What level of critical thinking did students display in individual reports? Did these levels change over time?

3: How do undergraduate students describe their learning environment that employed active learning strategies to support their learning and critical thinking?

4: What are the relationships between student learning, critical thinking, and other demographic data?

To answer the four questions posed, a mixed methodology that employs quantitative analysis and qualitative analysis was proposed, which provides a better understanding of research problems than either approach alone (Cresswell, 2007). For the research question 1, 2, and 4, quantitative analysis was employed, and for the research question 3, according to the data collected, both quantitative analysis and qualitative analysis were conducted.

The purpose of Chapter 4 is to present results from the data analysis that addresses the four research questions presented above. The sequence follows the order of the four research questions, and includes four separate sections presenting the results responding to each research question and discussion addressing the findings from the results.

Research Question 1: Effect of Active Learning Strategies on Student Learning

Question 1: What was the effect of active learning strategies on student learning?

In order to answer research question 1, students' performance scores on the pretest and the posttest were collected and analyzed. To identify if there were any effects of active learning strategies on student learning, a paired-t test for the pretest and

posttest was employed, and included data from the students who participated in both tests.

In this section, demographic information for the students who participated in both pretest and posttest is presented along with descriptive statistics for average performance on pretest and posttest, results from the paired t-test, and follow-up analyses for identifying gender differences in the pre and post-tests.

Demographic information for the students who participated in both pretest and posttest

Table 4-1 presents a summary of the students who participated in both the pretest and posttest. Of the total of 176 enrolled, only 129 were able to complete both tests. Of these 129 students, 60 were male and 52 were female, representing a roughly even split between the genders. Table 4-1 also shows the students' distribution by academic year, which includes First year (4), Junior (35), Sophomore (17), and Senior (53). Data on students' college affiliations indicate that only six students (5%) reported belonging to the College of Science, and the rest were from a variety of colleges, the most prevalent of which were the College of Communications (21%), and the College of Business (19%). The distribution of students' class standing and the presence of a majority of non-science major students is congruent with general demographics of undergraduate general science education courses.

Table 4-1. Description of the Study Participants

Variable	N	Percentage
Gender (data missing=17)		
Male	60	46.5%
Female	52	40.3 %
Class Standing (data missing=20)		
First Year	4	3.1%
Junior	35	27.1%
Sophomore	17	13.2%
Senior	53	41.1%
Race		
White	96	74.4 %
African-American	5	3.9 %
Hispanic	2	1.6 %
Asian	2	1.6 %
Others	5	3.9 %
Majors by College		
Arts	2	2%
Business	25	19%
Communications	27	21%
Education	4	3%
Engineering	6	5%
Health and Human Developments	12	9%
Liberal Arts	19	15%
Science	6	5%
IST	3	2%
un-identified	25	19%

Note. Total N = 129.

Descriptive statistics for average performance on pretest and posttest

Descriptive statistics for average performance on pretest and posttest are summarized in Table 4-2. The results show a minor difference in students' means in pretest (M=10.25) and posttest (M=10.28), and the range of scores varies from 2 to 17.5 in both pre-and posttest.

In addition, to provide general descriptive statistics of students' performance in pretest and post test, Table 4-3 presents mean scores and standard deviation by student academic standing and gender. These results indicate that in general senior students performed better than the students who belong to other academic standings in both pretest (M=11.32) and posttest (M=11.38). Also, female students performed better in both pretest (M=11.36) and posttest (M=11.42), than male students (M= 9.66, M=9.65,

respectively for pretest and posttest).

Table 4-2.

Student Performance Means and Standard Deviation for the Pretest and Posttest

Test	M	SD	Range	
			Low	High
Pretest ^{α°}	10.25	3.75	2.0	17.5
Posttest	10.28	3.79	2.0	17.5

Note. Total score = 25. α° n=128: participants for each test

Table 4-3.

Descriptive Statistics by Academic Standing and Gender for Pretest and Posttest

	N	Pretest		Posttest	
		M	SD	M	SD
Academic Standing					
First Year	4	9.13	5.66	9.13	5.66
Sophomore	34	10.63	4.19	10.68	4.23
Junior	16	8.44	3.76	8.44	3.77
Senior	51	11.32	3.02	11.38	3.06
Gender					
Male	57	9.66	3.98	9.65	4.01
Female	48	11.36	3.61	11.42	3.63

Results of paired t-test

In order to analyze the effect of active learning strategies on student learning, learning gains from pretest to posttest were compared through a paired t-test. Student learning was defined as changes in their performance on an assessment of quantitative reasoning skills, scientific reasoning skills, and geoscience concepts for the problem under study.

The distribution of participant scores were along a normal distribution, thus, a paired-t test using total pretest and posttest scores for students was used. Some students did not answer any questions on a page, which indicated that they completely skipped that section, and those items were treated as missing data.

The result of the paired t-test was a slight gain in mean scores from pretest (M=10.25) to posttest (M=10.28), with a p-value of .21, which was not significant at the .05 level (Table 4-5). In terms of Cohen-d values presented in the table, all are less

than .2, which is a fairly small effect size. This indicates that there was non-overlap in the distribution ranging from 0% ~15%.

In addition, to identify if there were any changes in student performance on the three different sections of the tests, including quantitative reasoning skills, scientific reasoning skills, and geoscience concepts, a follow-up analysis using paired-T test was conducted, and the results are also reported in Table 4-5.

a. Scores on the geoscience concept section:

On average, participants performed significantly higher on the posttest ($M=4.18$, $SE=.15$) in the geoscience concept section, than on the pretest ($M=3.76$, $SE=.18$, $t(126)=-2.2$, $p < .05$, $r=.22$), with an effect size of approximately 0.2, which represents small effect size (0.0~0.2). This result indicates that the active learning strategies employed had a fairly small effect on undergraduate students' learning of geoscience concepts, from pretest to posttest, which means there was a non-overlap of 17.4 % in the two distributions; although, the paired t-test showed that the means were significantly different between pretest and posttest ($p < .05$) (<http://web.uccs.edu/lbecker/Psy590/es.htm>).

b. Scores on quantitative reasoning skills section:

As presented in Table 4-5, student performance was slightly poorer on the posttest, which was significant at the .05 level, with a p-value of .02. To investigate if this result was influenced by the test difficulty difference between pretest and posttest, a follow-up analysis using difficulty index was conducted.

The pretest and the posttest had a total of 25 items with 11 identical questions for geoscience concepts and scientific reasoning and 14 non-identical question items in the Quantitative Reasoning section. The two versions of the quantitative reasoning section were attempting to measure the same constructs, such as plotting the data on the graph (e.g., Q6 in the pretest, Q10 in the posttest), data interpretation, and reasoning, and so on. Also, both versions were equally matched on the proportion of the question types; both pretest and posttest were composed of 8 multiple-choice questions and 6 open-ended questions (including providing reasoning for calculations and plotting data on the graph). For the content, the quantitative reasoning section on pretest dealt with

hurricane and earthquake; whereas, the section in the posttest dealt with plate tectonics, volcanic eruptions, and global change.

The difficulty index was calculated for the 14 non-identical question items used in the pre- and post-test. Even though the term ‘difficulty index’ is used for the measure that determines the difficulty level of the test items, conceptually the difficulty index is calculated based on the proportion of students who answered the test item accurately. Thus, a higher number for the difficulty index indicates that a greater proportion of students answered an item correctly. The difficulty index ranges from 0.0 to 1.0, and test items that range from 0.3 to 0.7 indicate moderate difficulty, which is to be taken into consideration when generating the test items. The difficulty indices for the pretest and posttest are presented in Table 4-4. The result showed that out of total 14 questions, 9 questions (items 1, 2, 3, 4, 6, 7, 8, 9, 10) on the pretest had a greater percentage of students who answered correctly as compared to the posttest. There were 5 questions (items 5, 11, 12, 13, 15) where a greater percentage of students answered correctly on the posttest as compared to the pretest. That would indicate that students generally had more difficulty in answering correctly on the posttest as compared to the pretest. Therefore, in addition to the differences in the topic covered in the Quantitative Reasoning section, this difficulty level difference might explain the students’ slightly lower scores in the quantitative reasoning section.

c. Scores on the scientific reasoning section:

Students performed slightly better on the posttest ($M= 0.76$, $SE= .06$) on the scientific reasoning section, than pretest ($M=0.70$), which was not significant at the .05 level with a p-value of .45.

Table 4-4.

Difficulty index of Items in the Quantitative Reasoning Section for the Pretest and Posttest

Item	Pretest	Difficulty Index	Posttest	Difficulty Index
Item 1	Q1	0.59	Q10	0.63
Item 2	Q2	0.46	Q11	0.19
Item 3	Q3	0.39	Q12	0.24
Item 4	Q4	0.41	Q13	0.31
Item 5	Q5	0.23	Q14	0.25
Item 6	Q6	0.41	Q15	0.32
Item 7	Q7	0.52	Q16	0.35
Item 8	Q8	0.51	Q17	0.31
Item 9	Q9	0.69	Q18	0.15
Item 10	Q10	0.63	Q19	0.59
Item 11	Q11	0.19	Q20	0.79
Item 12	Q12	0.24	Q21	0.5
Item 13	Q13	0.31	Q22	0.38
Item 14	Q14	0.24	Q23	0.41

Table 4-5.

Paired Comparison Data from Pretest to Posttest of Geoscience Assessment

Subtest	Test	M	SD	t	df	Sig. (2-tailed)	Cohen d
Geoscience concept section (n=127)	Pretest	3.76	2.01	-2.15	126	(.03*)	0.22
	Posttest	4.17	1.73				
Quantitative Reasoning section (n=128)	Pretest	5.78	2.10	2.35	127	(.02*)	0.19
	Posttest	5.34	2.48				
Scientific Reasoning section (n=128)	Pretest	0.70	0.74	-.76	127	.45	0.08
	Posttest	0.76	0.72				
Total score (n=128)	Pretest	10.25	3.75	-1.23	127	.21	0.01
	Posttest	10.28	3.79				

Note. Sub-total score for Geoscience concept section, Quantitative Reasoning section, and Scientific Reasoning section = 9, 15, 2, respectively. * $p < .05$ level

Gender Difference on Pretest and Posttest

In order to investigate if there is any significant difference in performance between male and female students, Univariate Analysis of Variance between genders

was conducted for the pretest and posttest. On average, female students performed significantly higher ($M=11.40$, $SE=.49$) on the pretest, than male students ($M=9.75$, $SE=.51$, $t(110)=-2.3$, $p<.05$) in pretest. Also, in posttest, female students performed significantly higher ($M=11.50$, $SE=.49$) than male students ($M=9.47$, $SE=.53$, $t(110)=-2.79$, $p<.05$). The effect size is around 0.5, which represents medium effect size (0.3~0.5). This result indicates that although the ANOVA showed that the means were significantly different between male and female students in both pretest and posttest, the effect size was modest, which means there was a non-overlap of 33.0 % in the two distributions (<http://web.uccs.edu/lbecker/Psy590/es.htm>).

Table 4-6.
Gender Differences on Pre-and Post-test

Test		n	M	SD	t	p	Cohen d
Pretest	Male	60	9.75	3.99	-2.32	.02*	0.44
	Female	52	11.40	3.50			
Posttest	Male	60	9.47	4.10	-2.79	.01*	0.53
	Female	52	11.50	3.52			

Note. Total score= 25. * $p < .05$ level

Summary

This section presented the results from the data analysis of the students' performance on the geoscience assessments (pretest and posttest) in terms of the effects of active learning strategies on student learning. The results identified from the data were: (1) overall, the result of the paired t-test was a slight gain in mean scores from pretest ($M=10.25$) to posttest ($M=10.28$), which indicates a slight improvement in student learning measured by the geoscience assessments. (2) More specifically, for the geoscience concept learning, the result indicates that the active learning strategies employed had a positive effect on undergraduate students' learning of geoscience concepts. For the quantitative reasoning section, there was an actual decrease in means, but findings from the further investigation on difficulty difference between pre-and post-test might provide a possible reason for this result. (3) For the gender difference, on average, female students performed significantly higher ($M=11.40$, $SE=.49$), than male students ($M=9.75$, $SE=.51$, $t(110)=-2.3$, $p<.05$) in pretest. Also, in posttest, female

students performed significantly higher ($M=11.50$, $SE=.49$) than male students ($M=9.47$, $SE=.53$, $t(110)=-2.79$, $p<.05$). Although the means were significantly different between male and female students in both pretest and posttest, the effect size was modest (0.44 in pretest, 0.53 in posttest, respectively).

In the next section, students' critical thinking level displayed in Individual reports and the level change over time from the data analysis results will be presented, which would answer the second research about the level of individual critical thinking.

Research Question 2: Evidence of Critical Thinking in Students' Individual reports

The second research question posed was: What level of critical thinking did students display in individual reports? And did these change over time?

For evaluating students' critical thinking level, individual reports from both Active Learning Modules (i.e., Hurricane Smith and Bangladesh Global Warming) were analyzed. Students' critical thinking level was scored based on rubrics that we developed. Individual report I (Hurricane Smith activity) included four major subcategories in the rubric to evaluate students' ability in 1) identifying problems while considering social context, 2) evaluating group & community decisions, 3) developing a perspective by justifying own decisions, presenting evidence/data, and integrating issues, and 4) communicating effectively. For the Individual report II (Global Warming activity), the rubrics included six subcategories: (1) selection of impacts; (2) selection of supporting material; (3) presentation of data; (4) quality of integration; (5) self-reflection; and (6) language & mechanics. For each subcategory, the rubric was further broken down into three levels of critical thinking that were termed 'emerging,' 'developing,' and 'mastering' (Refer to the Appendix D.)

Levels of critical thinking students displayed in two Individual reports

For the Active Learning module I (Hurricane Smith Individual reports), 131 students participated, and the mean score of performance on the Individual reports was 27.74 out of a total of 30. This shows that students' average critical thinking level fell in the category of "developing" for all four subcategories. Mean scores for the four subcategories are presented in Table 4-7 / Figure 4-1. The category for "Developing own perspective by justifying decisions..." was low compared to other three subcategories (Mean=3.66), even though this score is rated at the same 'developing' level.

Figure 4-1. Mean Scores for the Subcategories in Individual report I

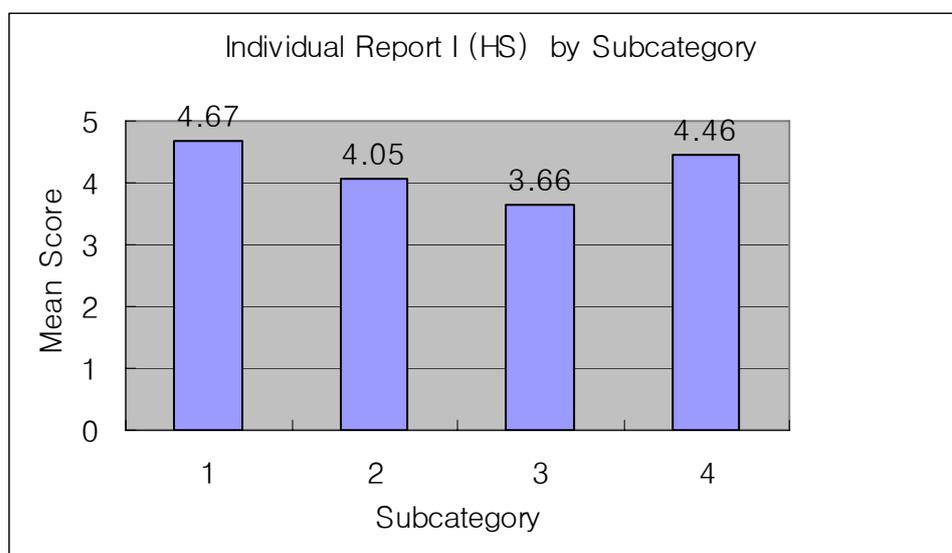


Table 4-7.

Mean Scores for the Subcategories in Individual report I

1. Identifying problems	2. Evaluating decisions	3. Developing and justifying own decisions	4. Communication
4.67	4.05	3.66	4.46

Note. Total score for each subcategory = 6. N = 131

For the Active Learning module II (Global Warming Individual report), 125 students participated and the mean performance score on the individual reports was 27.30 out of total 36. This shows that students' average critical thinking level fell in the category of "developing" for all six subcategories. Mean scores for each of the six subcategories are presented in Figure 4-2 (Table 4-8). Six points were given to each of the six categories according to the rubric developed for this Individual report activity. Even though there was not much difference among the mean scores for the six subcategories, the score for the second category for selection of supporting material was slightly low (Mean = 4.06) compared to the other five subcategories, even though this score is rated at the same 'developing' level.

Figure 4-2. Mean Scores for the Subcategories in Individual report II.

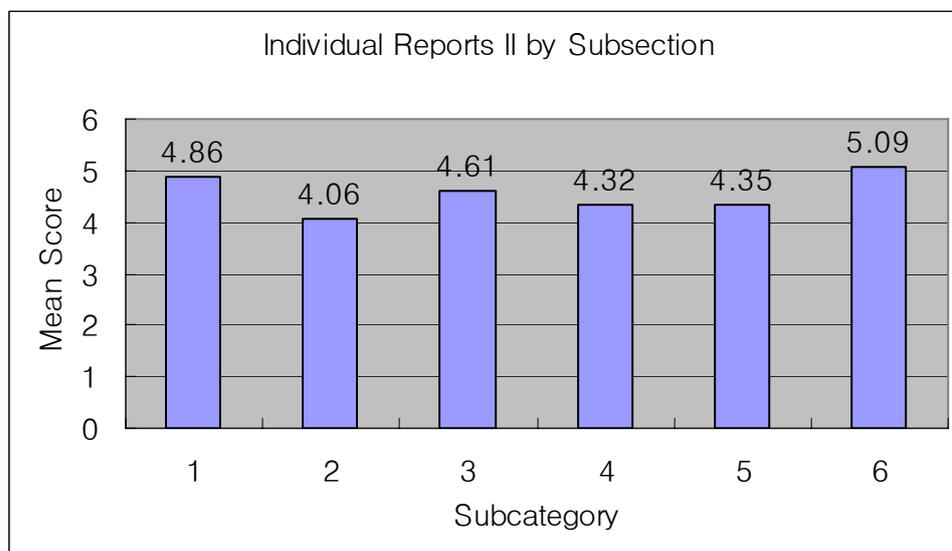


Table 4-8. Mean Scores for the Subcategories in Individual report II.

1. Selection of impacts	2. Selection of supporting material	3. Presentation of data	4. Quality of integration	5. Self-reflection	6. Language & Mechanics
4.86	4.06	4.61	4.32	4.35	5.09

Note. Total score for each subcategory = 6. Total = 36.

Statistics for Mean Performance on Two Individual Reports

In an attempt to see if there was any significant difference for the students' average performance between the two Individual reports, raw scores based on each rubric were converted to percentage mean scores, as their total scores were different (Total = 30 and 36, respectively). These converted percentage mean scores from the students who submitted two Individual reports were analyzed with a paired-t test (N = 105). Table 4-9 presents the converted percentage mean scores and standard deviations for the Individual report I and II. The range of scores is from 16.7 to 100 in Individual report I and from 36.1 to 100 in Individual report II.

On average, participants performed higher on Individual report II (M= 75.66, SE= 1.20, $t(104)=-3.53$, $p =.001$, $r=.45$) than Individual report I (M= 68.34, SE= 1.89), which is presented in Table 4-9. The result shows that there was a gain in students' percentage mean scores from Individual reports I (M= 68.34) to Individual report II (M= 75.66), which was significant at the .05 level with a p-value of .001.

The result shows that there were improvements (7.31 points) in students' percentage mean scores from Individual report I (M= 68.34) to Individual report II (M= 75.66), which was significant at the .05 level with a medium effect size (0.45).

Table 4-9.

Student Percentage Means and Standard Deviations for Individual Reports I &II

Individual reports	Percentage Mean score	SD	Range	
			Low	High
Individual reports I (HS)	68.34	19.36	16.7	100
Individual Reports II (GW)	75.66	12.28	36.1	100

Note. Total score = 100. α ° n=105: participants for both reports

Table 4-10

Paired Comparison Results from Individual report I to Individual report II

Individual reports	Mean difference	SD	t	df	Sig. (2-tailed)	Cohen <i>d</i>
I II	7.31	21.20	3.53	104	(.00*)	0.45

Note. Total score= 25. N = 105. $p < .05$

Critical Thinking Level Changes Over Time

In order to investigate if there was a significant association between the students' critical thinking level changes and the two assigned Individual reports, the three critical thinking levels of 105 students who submitted both Individual reports were used to conduct a Chisquare analysis. To assign each of two Individual report scores into three critical thinking levels, a median split technique was employed. For Individual report I (Hurricane Smith activity), scores ranging from 1 to 70 were assigned to the 'Low' level (1), from 71 to 82 to the 'Medium' level, and from 83 to 100 to the 'High' level. For Individual report II (Global Warming activity), 1~75 (Low), 76~82 (Medium), 83~100 (High) levels were assigned. Then, these two levels were used for Chi-square analysis, and the result is presented in Table 4-11.

Table 4-11 presents students' category of critical thinking level for each

Individual report I & II. Overall, for Individual report I, out of a total of 105 students, almost 50% (n=56) students belonged to ‘Low’ level for their critical thinking level. 21 students (20%) belonged to ‘Medium’ level, and 28 students (27%) were in ‘High’ level. For the Individual report II, 53 (51%), 21 (20%), 31 (30%) students belonged to Low, Medium, High level respectively. This result indicates that almost 50% of the students belonged to ‘Low’ critical thinking level for both of the Individual reports and the other 50% of students belonged to either ‘Medium’ or ‘High’ critical thinking level.

Table 4-11.

Cross tabulation of Three Critical Thinking Level Groups for Two Individual reports

			GROUP_G W			Total
			Low	Medium	High	
GROUP HS	Low	Count	30	13	13	56
		% within GROUP_HS	53.6%	23.2%	23.2%	100.0%
		% within GROUP_GW	56.6%	61.9%	41.9%	53.3%
		% of Total	28.6%	12.4%	12.4%	53.3%
	Medium	Count	12	4	5	21
		% within GROUP_HS	57.1%	19.0%	23.8%	100.0%
		% within GROUP_GW	22.6%	19.0%	16.1%	20.0%
		% of Total	11.4%	3.8%	4.8%	20.0%
	High	Count	11	4	13	28
		% within GROUP_HS	39.3%	14.3%	46.4%	100.0%
		% within GROUP_GW	20.8%	19.0%	41.9%	26.7%
		% of Total	10.5%	3.8%	12.4%	26.7%
Total		Count	53	21	31	105
		% within GROUP_HS	50.5%	20.0%	29.5%	100.0%
		% within GROUP_GW	100.0%	100.0%	100.0%	100.0%
		% of Total	50.5%	20.0%	29.5%	100.0%

Note. Total N=105

In terms of students’ critical thinking level changes over time, we can report as follows:

- Out of 105 students, overall almost 50% of students (n=47) stayed in the same level of CT.
- Students’ critical thinking level for 31 students (30%) went up from Individual report I to Individual report II, which includes 13 students from ‘Low (L)’ level to ‘medium (M)’, 13 students from level (L) to level ‘High (H)’, and 5 students from level (M) to level (H).
- 11 students’ critical thinking level (10%) went down, which includes 12

students from level (M) to level (L) and 11 students from level (H) to level (L). Those 11 students who dropped down from level (H) to level (L) would be of particular interest for further examination to explain what might have happened.

- As both variables have more than two categories (three levels for each variable) Cramer's V statistic (.16) was attained to determine the significance for these students' critical thinking level changes between two Individual reports.

Although the students were volunteers into the class and inferential test like Chi-square has an assumption that it is an experimental design or a random sample, the approach of using an accessible group of individuals to infer about the larger population enabled the researcher to perform this analysis, as a comparison of demographic data of the participants to the larger population at a university level indicated a similar distribution on gender, ethnicity, major (Huck, 2008). Overall, there was no significant association between students' critical thinking levels for the Individual report I and II $\chi^2(4) = .16, p = .25$. Therefore, this result indicates that there was no significant change between two critical thinking level changes made over time, even though there were some changes in students' critical levels between the two Individual reports.

Research Question 3: Student Perceptions of the Learning Environment and Active Learning Strategies

The third question posed was: How do undergraduate students describe their learning environment that employed active learning strategies to support their learning and critical thinking?

In order to answer this question, data were collected primarily from the student perception survey questionnaire (Appendix G), and the results were supported with data from the interviews (Appendix F) and observations. The survey was designed to investigate how students perceived their learning experience within the EARTH 101 course, which incorporated active learning strategies such as small-group work, problem-solving, and reflection. To illustrate, the survey questionnaire is composed of three categories: (a) Learning experience in the course, (b) Effects of collaborative learning activities, (c) General effectiveness of active learning. The questionnaire includes 34 Likert-scale statements and 6 open-ended questions on the subject's learning experience with regard to small-group and other learning activities they engaged in during the course. This survey questionnaire was distributed while implementing the post-test during the last session of the course.

One hundred thirty-one students completed the survey out of the 169 students who submitted their consent forms at the beginning of the semester. Also, two students volunteered for a follow-up interview and were interviewed individually. All the interviews were recorded and transcribed verbatim. For this transcription procedure, the software "Transana" (www.transana.org) was used to facilitate the transcription and qualitative analysis of audio data. After transcribing the interview data, the researcher focused on identifying the recurring themes regarding students' perceptions of their learning environments.

Observation data were used to triangulate and to inform the results from students' perception survey questionnaire and interviews, which increases credibility of the assertions (Rossman & Rallis, 2003). However, there is a limitation to the observations, since they only provide a general frame of reference for the entire class, and we cannot link individual students' perceptions to the observations.

Results

To answer research question 3 more effectively, three specific sub-questions were generated as follows:

- (i) How did students describe their overall learning experience in the course?
- (ii) How did students' 'active' engagement in their learning take place in the course?
- (iii) How did students perceive the effectiveness of the active learning strategies on their learning and critical thinking?

Every question on the survey was used once to answer only one question. However, data collected from both subsections (i.e, Likert-scale and open-ended questions) of the student perception survey were grouped and presented to answer the three sub-questions. To illustrate, to answer sub-question (i) students' overall learning experience in the course, survey section I (Likert-scale statements 1~12) and open-ended questions Q3 were used. For sub-question (ii) students' 'active' engagement in their learning, data collected from open-ended question 1 and 2 were used. To answer the sub-question (iii), data collected from the survey section II (Likert-scale statements 1~18) and open-ended question 4~6 were used.

Thus, the results are grouped in three sets of thematic categories related to active learning in support of student learning and critical thinking, which will be presented in detail in the following sections.

I. Students' Overall Learning Experience in the Course

In this section, the results with regards to students' overall learning experience in the course will be presented, which includes sub-categories such as 'overall learning experience in the course,' and 'the unique characteristic of the course compared to other large classes.'

Overall Learning Experience in the Course

Students' responses to 12 statements on a five-point Likert scale were used to measure student perceptions of their learning experience in the overall course. Response categories for each item ranged from (1) strongly disagree to (5) strongly agree. Of the

12 items, no greater than two responses for each item were missing.

A profile of responses to the statements from the questionnaire is presented in Table 4-12. The percentages for each statement for each point on the Likert scale are noted as well as the mean (M) and standard deviation (SD).

Table 4-12 shows the mean scores of students' perceptions of learning experience in the course, which includes overall satisfaction with the course learning environment. These data show that the majority of students were satisfied with their learning experience, including the course topics, overall course structure, and collaborative class activities (i.e., item 1, 3, 4, 7, 9). In addition, students perceived in-class group activities and the learning materials used in the course as supportive in their learning (i.e., item 2, 5, 11). In terms of engagement in their learning, students perceived that they were actively engaged in their learning and group activities (i.e., item 6, 8, 10, 12). With regard to students' engagement in their learning, more specific data collected from students' responses to open-ended questions (question 1 & 2) were analyzed and are presented with the factors that encouraged students to be more actively engaged in their learning.

The Unique Characteristic of the Course Compared to Other Large Classes

Students were also asked about what they found to be the most unique characteristic of this course compared to other large classes. The student's written responses were analyzed and several common themes were found: (a) active engagement in learning including large amount of group work opportunities & hands-on activities (n=64), and emphasis on participation opportunities (n=23); (b) interesting topic and material (n=24); and (c) interactive and facilitating learning environment (n=8). This result suggests that major design components of active learning environments (e.g., group work activities with authentic tasks) have been perceived as unique characteristics of the course compared to other course large classes. This result is summarized in Table 4-13. In addition, Table 4-13 presents some examples of student responses, grouped according to themes.

In particular, one interviewee explained the value of the student participation-focused approach, which placed more values in the quality learning process as follows:

A: ...I think exams, when you have exams, your main purpose is just to pass

exams just to take exams, so basically you are just cramming information just for the exams, you are not learning for life outside of college. I think taking the exam portion out, and it comprising mainly of projects, I think that's a lot more helpful cause you're learning a lot.

Table 4-12.
Students Perception of Their Learning Experience in the Course

Item No.	Statement	Strongly Disagree-----Strongly Agree					M	SD
		1	2	3	4	5		
1	I enjoyed learning about the topic of this class.	1.5%	5.4%	24.6%	42.3%	26.2%	3.86	.92
2	The learning materials used in this class were helpful for learning.	4.6%	10.8%	29.2%	36.9%	18.5%	3.54	1.06
3	I am satisfied with overall structure of the course.	4.6%	11.5%	26.9%	40.0%	16.9%	3.53	1.05
4	I enjoyed the class activities.	7.7%	16.2%	35.4%	30.0%	9.2%	3.12	1.13
5	I found the class activities useful to my understanding of natural disasters.	5.4%	15.4%	26.9%	34.6%	17.7%	3.44	1.11
6	I found that the emphasis on the group activities and participation encouraged me to be active in learning.	10.8%	13.8%	29.2%	30.0%	16.2%	3.27	1.21
7	I enjoyed working with others in the classroom (solving problems & working on the activities together).	8.5%	10.0%	23.8%	39.2%	17.7%	3.45	1.19
8	I actively engaged with in-class exercises.	1.5%	1.5%	23.8%	46.9%	26.2%	3.95	.84
9	I found working with others to be less stressful than doing similar tasks alone.	.8%	13.8%	23.8%	30.0%	26.2%	3.55	1.21
10	I feel that my teammates collaborated in solving the in-class exercises.	3.1%	3.1%	23.1%	43.8%	24.6%	3.82	.97
11	I found that working with others improved my understanding of the course material.	6.9%	12.3%	26.9%	33.8%	20.0%	3.48	1.15
12	I was able to help my teammates learn the course content.	.8%	9.2%	33.8%	32.3%	21.5%	3.59	1.05

Note. Total N = 131.

Table 4-13.

Examples of Student Responses regarding Unique Characteristic of the Course

Open-ended Question 3: Compared to other course in large classes, what did you find most unique (/characteristic) in this course?
Examples of Student Written Responses:
(a) <i>active engagement in learning</i>: Large amount of group work opportunities & hands-on activities (n=64), and emphasis on participation opportunities (n=23)
<ul style="list-style-type: none"> -“most unique was the amount of group work. Much more group work compared to other classes” -“we actually did active learning and not all lecture, Active is much better” -geared toward participation, not exams - small group work every week, “All of the group work, a lot or writing assignments” -“Other large classes do not give you the opportunity to work in small groups”-“The breaking down into groups constant group work & assignments” ‘How often we worked in groups, Emphasis on small group activity -the group discussion / group work were great -The group work was unique. - “a lot of actual discussion & activities. Not just a lecture” -“The amount of in-class activities FAR exceeds that in any class I've had.” -“Projects and assignments were completely different and unique.” -“The class activities were more effective compared to others.”
(b) <i>Interesting topic and material</i> (n=24):
<ul style="list-style-type: none"> - “The way that movies are compared to real-life.” - “The intermingling of Hollywood movies with scientific documentaries” - “watching movies and analyzing them. Haven't done this in other courses”
(c) <i>Interactive & facilitating learning environment</i> (n = 8):
<ul style="list-style-type: none"> - “That we actually did group work with such a large class. Instructor came around and talked with group” -“I found that although this was a large class I felt like I belonged here.” - “The attitude of the teacher, environments and the topic and it all covered.” - “it was not treated like most large classes. Everyone got independent help” -“It is more personal & not lecture-style.”

II. Students’ ‘Active’ Engagement in their Learning

The aim of this section is to present student perceptions of the extent of engaging in learning activities and the factors that enhanced student engagement, including subcategories such as: (1) student engagement in their learning, (2) the reasons for engagement in learning activities, and (3) the perceived value of opportunities created for students’ active learning.

Student Engagement in Their Learning

On the survey question which asked to what extent students actively engaged in the learning activities, sixty-two students responded ‘a lot’ and sixty-one students responded ‘somewhat’. This result corroborates that the majority of students (92%) in the class were actively engaged in their learning in the course as presented in Table (4-14).

Table 4-14.

The Extent of Students’ Engaging in the Learning Activities

Question	n (%)
How <i>actively</i> were you engaged in learning of natural disaster in the course?	
A lot	62 (46%)
Somewhat	61 (46%)
Not at all	0
No response	10 (8%)
Total	131 (100%)

The Reasons for Engagement in Learning Activities

On the follow-up question that asked why students thought they were engaged or not engaged in the activities, students reported various reasons, as summarized in Table 4-15. Primary factors that facilitated students’ active engagement in their learning were i) interesting topics and visual materials, (ii) useful and applicable activities that were pertinent to real-life and group-work, (iii) numerous participation/engagement opportunities created through the course (e.g.: participation-based grade, series of problem-solving activities, video-clip analysis). This result indicates that the major focus of designed active strategies was perceived as important in facilitating students’ engagement in learning activities.

Table 4-15.

Students’ Responses to Reasons for their Engagement

Question	Q2: <i>Why</i> do you think you were engaged or not engaged in the activities?
Themes found from the Student Written Responses (N=131)	• Interesting (n=37) : topic (real-life info)/ visual material /activity
	• Characteristic of activities (n = 36): (1) useful & applicable: hands-on & real-life,(2) group-work based
	• A lot of participation/engagements opportunities (n = 13): participation-based course, series of problem-solving activities, video-clip analysis
	• Grade and others (n = 11): grade, professor, guidance in the material.
	• Not engaged (n =15): not interesting
	• No answer (n = 17)

The Perceived Value of Opportunities Created for Students' Active Learning

The aim of this section is to present how students perceived the value of engaging in the active learning process. In particular, it focuses on how the participation opportunities help students to be actively engaged in their learning and thinking in a large class, which was identified in chapter 2 as one of the barriers to implementing active learning.

As presented in the survey results (Table 4-16), the majority of students characterized the course as including 'a great deal of group-work and assignments opportunities,' which provided opportunities for students to engage in their learning. In the following section, more in-depth information from interview data will be presented to support the survey results.

In terms of the active learning process that was perceived as effective for their thinking, the interviewees explained their learning process in detail. For instance, Angel (alias), one of the interview participants, noted that doing video-clip analysis activities was more effective for her to relate the movie to science and more effective in keeping her attention. The second interviewee, Kay (alias), articulated that this process was beneficial in her learning and thinking, and she felt that she was more actively engaged while watching the movies and thinking through the questions the worksheet.

Angel: "...Yeah. I think when you're writing down notes from a movie, I think it's a lot more effective, because you know when you watch a movie, you just watched a movie. You don't really think about the science part, but when you're writing down notes, you're actually thinking about how it relates to science. So, it's a lot more effective ...more attentive."

Kay: "...I probably remembered more from watching them. Just because when you have to write something down while you're watching, you're both writing and listening. So there's a lot of it's coming in concrete....so I feel like probably anything that would've remembered course, remembered learning from the course, was when I had to write down while I was listening or watching something. So, that probably...As far as thinking is concerned, that would be just what I remembered most, learn most...."

Table 4-16. Summary of the Results and Themes Found from the Students' Written Responses to the Open-Ended Question (Q3--6)

Open-ended Questions (Q3~6)	Results and themes found from the students' written responses
Q3: Compared to other course in large classes, what did you find most unique (/characteristic) in this course?	<ul style="list-style-type: none"> • Active engagement in learning (n=64) : Large amount of group work opportunities & hands-on activities • Interesting topic and material (n=24):(e.g., analysis activity using visualized material, comparison of Hollywood to real life disasters) • Completely different course structures (n=23): (e.g., emphasis on participation opportunities /projects, write-up assignments & average amounts of lecture) • Interactive & facilitating learning environment (n=8): (e.g., more personal& interaction, facilitating role of instructor, large class, etc.) • No response (n=17)
Q4: which activity did you like <i>most</i> ? How did it help your understanding natural disaster?	<ul style="list-style-type: none"> • Video clip analysis activities (comparing hollywood to reality& follow-up small-group discussion) (n = 63) • Group activities (n =40) : -students who specifically mentioned two Active Learning modules (HS&GW): (n = 22) • Others (final projects, individual reports, etc.) (n = 9) • No response (n = 19)
Q5: As you engaged with the learning activities, how did <i>the group discussion</i> help you make decisions?	<ul style="list-style-type: none"> • Facilitated individuals engaging in CT process and support sense-making (n = 56) • enable me to hear/ consider multiple perspectives (MP) (n = 34) • Facilitated group decision-making process: collaborative & constructive (n = 34) • Not that helpful/ prefer individual or class discussion (n = 7)
Q6: How did the small-group problem-solving activities help you apply scientific concepts / ideas to real problems / situations?	<ul style="list-style-type: none"> • affective factors (n = 4): (e.g, to get excited; enhanced interesting and awareness, etc.) • cognitive factors (n = 25): (e.g., enhanced understanding; clarified what's confusing; enhanced perspectives & impacts; offered new perspectives) • procedural & metacognitive factors (n = 41): (e.g., engaging in step-by-step process; staying on the problem; performing tasks as scientists; facilitated ability to apply the concepts to real-life problem • general comments(e.g., 'helpful' (n= 7) & 'not helpful' (n= 13), & no answers (n = 38)

III. Perceived Effectiveness of the Active Learning Strategies on Student learning and Critical Thinking: Small-group Activities, Scaffolding, Individual write-up

The aim of this section is to present students' perception of the effects of three active learning strategies (small-group activities, scaffolding, individual write-up) that were incorporated in Active Learning Modules I & II.

Perceived effects of the small-group problem-solving activities on student learning

On the survey question, open-ended question 6 asked about how the small-group problem-solving activities helped students apply scientific concepts to real situations.

From the students' responses, three major factors were identified as being supported by small-group activities (See also Table 4-16.):

- (i) affective factors
- (ii) cognitive factors: enhancing students' understanding and sense-making process (e.g., enhanced understanding, clarified what's confusing, enhanced perspectives, offered new perspectives, putting disasters into perspective), and,
- (iii) metacognitive (procedural) factors

Some of the students' examples that reflected the affective category are the following: 'enabled me to get excited,' 'enhanced interest and awareness.' The cognitive category includes students' responses such as 'enhanced understanding and perspectives,' 'clarified what's confusing,' 'offered new perspective,' and 'put disasters into perspective.' The procedural category included responses such as 'engaging in step-by-step process,' 'staying on the problem,' 'performing tasks as scientists (doing the work of scientists),' and 'facilitated ability to apply the concepts to real-life problem.'

The results are summarized in Table 4-16 and they indicate that the small-group activities that were employed as an active learning strategy were perceived as supportive by the students because they provided opportunities for them to apply what they know (scientific concepts and ideas) to real-life problems as well as by providing them with different supporting mechanisms (i.e., affective, cognitive, and procedural supports). Some examples of students' written responses with regards these three themes are presented in Table 4-17.

In addition, some interview excerpts presented below supported this notion of

group-activity benefits for the learning process. For example, from the ‘learning quality’ perspective, one interviewee identified small-group activities as important for enhancing her learning while she was engaging in the process of both listening to others’ view points and giving feedback. In addition, from the engagement perspective, small-group activities provided an active learning environment where everyone could contribute something to the group decision-making process. The following examples illustrate these points:

Angel: “...I think in group activities, it can be little bit more beneficial, because you're getting more different viewpoints, so when you're actually talking about something other people are giving their own feedback, so you are learning couple of times more..

(A2) (while recalling one of the most recent activity she experienced) ‘...I liked it because a lot of people, I mean, I think every member of my group, we gave feedback, like we talked about it exactly, we planned out scene-by-scene what is going to happen on in our documentary. And, it was just interesting because you know everyone DID have something to say.

Perceived effects of collaborative learning activities on critical thinking.

Students’ responses to 18 items on a five-point Likert scale were used to measure the perceived effects of collaborative learning activities employed as one of the active learning strategies for student critical thinking. Each statement is followed by the sentence starter “*The collaborative learning activities used in this course helped me develop my ability to:*,” All items of the questionnaire pertained to the importance assigned to various attributes of critical thinking (e.g, Identify what information is needed to solve a problem, Set goals, Apply scientific concepts/ ideas to real-world problems, etc.). The respondents were asked to rate 18 statements according to their perceptions of the effects of collaborative learning activities on their learning and critical thinking. Response categories for each item were scaled from (1) strongly disagree to (5) strongly agree.

Table 4-17.

Students' Written Response Examples: Perceived Effects of the Small-Group Problem Solving Activities

<p>Open-ended Question 6: How did the small-group problem-solving activities help you apply scientific concepts / ideas to real problems / situations?</p>
<p>Examples of Student Written Responses:</p>
<p>(a) Affective factors: (e.g., to get excited; enhanced interesting and awareness, etc.):</p> <ul style="list-style-type: none"> - <i>“understanding nature from a fun but educational parts”</i> - <i>“It helped me when watching the news about natural disasters. I was a lot more interested</i>
<p>(b) Cognitive factors: (e.g., enhanced understanding; clarified what's confusing; enhanced perspectives & impacts; offered new perspectives):</p> <ul style="list-style-type: none"> - <i>“Questions often made me put disasters into perspective”</i> - <i>helped me look at things from a different perspective”</i> - <i>“It made it more clear in case there was any confusion”</i> - <i>“They put me in realistic situations & offered new perspectives.”</i> - <i>“everyone got to add their perspectives on situation”</i> - <i>“We kind of bounced ideas of each others. Helped develop real science”</i> - <i>“It made me think logically about it.”</i>
<p>(c) Procedural & metacognitive factors: (e.g., engaging in step-by-step process; staying on the problem; performing tasks as scientists; facilitated ability to apply the concepts to real-life problem:</p> <ul style="list-style-type: none"> - <i>“They set up very real scenarios in which a problem was given and step by step instructions and tools were provided in the same manner that a professional would use.”</i> - <i>“Made me concentrate on real problems.”</i> - <i>“Structured format to show how something complicated works.”</i> - <i>“I learned more about applying to real problems & less about scientific concepts”</i> - <i>“They were directly related to what concepts we learned in class, so was able to apply them.”</i> - <i>“made me concentrate on ideas and help people do it”</i> - <i>I liked the systematic approach we used.</i>

A profile of responses to the statements is presented in Table 4-18. The percentages for each statement for each point on the Likert scale are noted as well as the mean.

In general, as seen in the Table 4-18, the results indicate that most students perceived that the collaborative learning activities used in the course were effective for them to develop critical thinking and problem-solving skills.

In particular, participants considered the collaborative learning activities used in this course to be helpful in developing their ability to “understand the impact of real-life natural disaster problems,” “understand global perspectives on natural disaster problems,” “approach the problem from various perspectives (economic, social, and

cultural, etc.),” and “apply scientific concepts/ ideas to real-world problems” as the four most effective areas that supported their critical thinking. The three least helpful areas of the effects of collaborative learning activities for developing their ability were “recognize flaws in my own thinking,” “set goals,” and “plan my work.”

Table 4-18. Perceived Effects of Collaborative Learning Activities on Critical Thinking

On Critical Thinking and Problem-solving skills								
<i>The collaborative learning activities used in this course helped me develop my ability to:</i>								
Item No.	Statement	Strongly Disagree—Strongly Agree					M	SD
		1	2	3	4	5		
1.	Identify what information is needed to solve a problem.	3.1%	9.3%	31.8%	44.2%	11.6%	3.52	.93
2.	Plan my work.	4.7	15.5	35.7	31.8	12.4	3.32	1.03
3.	Set goals.	4.7	16.3	34.9	32.6	11.6	3.30	1.03
4.	Stay on task while working on a problem.	2.3	12.4	34.9	36.4	14.0	3.47	.96
5.	Organize information.	3.1	9.3	34.1	35.7	17.8	3.56	.99
6.	Apply scientific concepts/ ideas to real-world problems. (1.6)	4.7	6.2	26.4	38.8	22.5	3.64	1.13
7.	Divide complex problems into manageable components.(.8)	3.9	7.0	41.1	31.0	16.3	3.47	1.02
8.	Apply a systematic approach.(.8)	3.9	9.3	33.3	40.3	12.4	3.46	1.01
9.	Consider other people’s perspectives while making decisions.	3.9	9.3	27.9	40.3	18.6	3.60	1.02
10	Approach the problem from various perspectives (economic, social, and cultural, etc.) (.8)	.8	5.4	21.7	49.6	17.8	3.68	1.03
11	Recognize contradictions/inconsistencies in ideas, data, etc.	3.1	10.1	28.7	43.4	14.7	3.57	.97
12	Use established criteria to evaluate solutions.	3.9	7.8	33.3	37.2	17.8	3.57	.99
13	Recognize flaws in my own thinking.(.8)	.8	.8	35.7	24.8	15.5	3.27	1.09
14	Understand the impact of real-life natural disaster problems.	2.3	3.1	24.8	41.1	28.7	3.91	.93
15	Understand global perspectives on natural disaster problems. (1.6)	.8	1.6	24.8	38.8	29.5	3.87	1.02
16	Express my thinking clearly in writing and speaking (.8)	7.0	9.3	31.8	34.1	17.1	3.43	1.14
17	Evaluate arguments and evidence so that strengths and weaknesses of competing alternatives can be judged.	3.9	7.8	37.2	37.2	14.0	3.50	.96
18	Use discussion strategies to analyze and solve a problem.(2.3)	3.1	9.3	32.6	38.8	14.0	3.44	1.09

Note. Numbers in parenthesis represent the missing data percentages for each statement.

Perceived effects of group discussion on student critical thinking. On the survey, open-ended question 5 asked about the supportive features of group discussion

for student decision-making as follows: As you engaged with the learning activities, how did *the group discussion* help you make decisions?

From the students' responses, two major themes were identified, which are associated with facilitating either individual thinking process or group discussion process (See also Table 4-16).

- (i) Facilitated individuals engaging in CT process and support sense-making (n=56)
- (ii) Facilitated group decision-making process: collaborative & constructive (n=34).

Examples from the data that reflect category (i) include 'enable me to hear/consider multiple perspectives,' 'sustenance of engaging in thinking,' 'enable to perform beyond my capability,' 'express my ideas,' 'evaluating levels of understanding process,' 'figuring out what to do and make decisions for my own work,' and 'altering my own thinking & clarification process.'

Category (ii) included students' responses that were associated with the group discussion process such as, 'forced me to contribute and be engaged/ be collaborative 'and 'interdisciplinary input informed decision and optimal outcome.'

The results are summarized in Table 4-16, and these results suggest that group discussion was perceived as useful by students to facilitate group decision making by providing opportunities for sharing ideas..

Interview data supported this result, with one participant describing the process in more detail:

K1: I do think that discussing it with other people did, I mean, we could make better decisions about how storyboard and about what it might be like for the purpose for that decision. Other people would bring things up, and I know one guy who I don't know who is just in our group brought up how having such a high unemployment rate --...because I think we were talking about 40 percentage of unemployment rate there specially after disaster. How --if you lost your job because the job was gone, after disaster-- how difficult it would be, if you had to find a new job, when there were so many people fighting for employment. and that was an aspect of that wouldn't have occurred to me--in that class, that time, for whatever reason--it wouldn't have occurred to me to think about the competition that you face, so I think that was definitely a real-life aspect that somebody brought up and that I wouldn't have realized, and that's really that type of thing that makes group work good as that somebody else can put in their opinions, something that you wouldn't have necessarily thought of the new perspective, so I think that was helpful situation.

K2: ... I DO believe that having the group discussion and being able to compare your responses and even get a new perspective from somebody in the class is very helpful.

These excerpts indicate that the small-group discussion could bring some benefits to both group and individuals, which were reflected in two beneficial notions such as ‘Two are better than one’ and ‘It help[ed] me think beyond my thought.’

On the survey, although the majority of the students reported benefits of group discussion on their thinking and learning, seven students reported they found it wasn’t that helpful and they preferred either individual learning or class discussion.

Perceived effects of Scaffolding provided in Active Learning Modules I & II. To investigate how students perceived the value of scaffolding (procedural and conceptual) provided in Active Learning Modules I & II, perception survey data and interview data were analyzed. Although this result is based on an interview that included only two student participants, these data provided the researcher with a more detailed description about how students perceived the supportive mechanisms employed in Active Learning Modules I and II.

As discussed in the previous chapter, cognitive scaffolding is provided to help learners reason through complex problems and it guides learners regarding what to consider (Hannafin, Land, & Oliver, 1999). In this study, students were encouraged to use the prompting questions for critical thinking while engaging both the group discussion and individual activity. For procedural scaffolding, students were provided with a support that made explicit the sequence of activities for a complex task. This scaffolding was provided to help students to approach the problem in a manageable and ordered way.

This section will try to explore the students’ perceived values of scaffolding embedded in the activities in terms of how it facilitated their learning and critical thinking, which is based on the perception survey results (Open-ended Question 6, Refer to Table 4-16) and interview data.

Two notions were identified as follows:

- a. Procedural scaffolding provided through the instructional material and

activity structure helped students get prepared and to approach the task in a manageable way.

b. Prompting questions provided in the worksheet helped students engage in critical thinking.

As discussed earlier, open-ended question 6 on the student survey corroborates these findings. To illustrate, in response to the question “How did the small-group problem-solving activities help you apply scientific concepts / ideas to real problems / situations?” a majority of responses (n= 67) addressed either ‘procedural & metacognitive factors (n = 41)’ or ‘cognitive factors (n = 25) (refer to Table 4-16). This indicates that the small-group activities that employed both of these scaffolding as a design principle provided students with opportunities to facilitate learning process and enhance their learning. For example, for procedural & metacognitive support, students addressed ‘engaging in step-by-step process; staying on the problem; facilitated ability to apply the concepts to real-life problem’. For the cognitive supportive factor, students’ response displayed the effects such as ‘enhancing understanding; clarifying what’s confusing; enhancing perspectives and impacts’

In addition, students’ interview excerpts are presented in Table 4-19, which implies that providing scaffolding embedded in the activities may have worked for facilitating student learning process.

The participant, Angel, addressed the benefit of the individual worksheet provided as a prerequisite activity of the group activity, which was supportive in ‘everyone’s being prepared’ to be fully engaged in group activities. Kay praised the unit structure of having the individual work first, and then group work then more individual work, which is indicated in Table 4-19.

With regards to cognitive scaffolding, Kay referred to the prompting questions that were provided in the activities more specifically. In association with critical thinking, she mentioned, “.... *When you have to assess 'why something is important' or, which is most important', that is going to improve your critical thinking...I DO believe that having the group discussion and being able to compare your responses and even get a new perspective from somebody in the class is very helpful.*” This implies that providing the prompting questions in the activities is important for facilitating students to engage in their learning and critical thinking.

Table 4-19.

Interview Excerpts Regarding the Effects of Scaffolding

Example of interview excerpts regarding the effects of scaffolding in support of learning
<p>a. Procedural scaffolding</p> <p><i>Angel: ...I think the whole worksheet was really beneficial because it lays perspectives of communities... Yeah.. I think definitely it was [helpful for me to be prepared for the activity and for thinking about the situation]!! Because, everyone was PREPARED, like we ALL did the worksheets. So, all we had to make contribute. So, definitely! I'm sure that if none of did worksheet it would have been a lot more difficult.</i></p> <p><i>Kay: "...To have all the materials ready to go beforehand was extremely helpful because you can't really answer the questions if you don't have any of the materials with you....</i> <i>"...I liked the structure of having the individual work first, and then group work then more individual work is very good, because you DO get the time to discuss things with a group of people. but in the same time, in a large lecture class, I feel like group work shouldn't have been heavily relied on. Just because with group projects you end up being with a group of people you don't know, you don't necessarily work well together... I thought that particular assignment [AL II: Bangladesh Global Warming activity] structure was very effective.</i></p>
<p>b. Prompting questions</p> <p><i>K: I think that is very helpful in order to lay things out, really rate what you think would be just an impact, (you know) in the part of the world, something important to incorporate into activities. That helps.</i></p> <p><i>K: (um..) When you have to assess 'why something is important' or, which is most important', that is going to improve your critical thinking...I DO believe that having the group discussion and being able to compare your responses and even get a new perspective from somebody in the class is very helpful.</i></p>

Perceived Effects of Individual Writing Opportunities. The aim of this section is to respond to the question of how students perceived the value of engaging in individual writing opportunities provided through the course with regards to their learning.

In the open-ended section of the survey, a few students mentioned specifically the individual writing opportunities as a supportive mechanism for their learning and thinking. However, the majority students (n = 63) identified large numbers of write-up opportunities for both in-class and assignments as facilitative factors that supported their learning and thinking, which included a series of video-clip analysis activities, individual reports, and final research projects. (Refer to Table 4-16).

In addition, with regards to both the individual reports and final projects, one interviewee reported that they were very effective for her learning, which supports the notion of effects of individual writing opportunities in detail. For example, Kay said that

the individual writing opportunities forced her to go out and do her own research, which she thought enabled her to learn the most while engaging in doing project by herself.

Kay: "...I think out-of-class papers were definitely helpful, including the final project. it's just because it forces you to go out and do your own research. So, you're probably going to learn a lot from that... I think from almost every paper, it's just been entirely my own research, some of that has been provided in the class website, but most of it, it IS ME researching the topic, it's not necessarily completely related to class, but I DO I feel like I probably learned the most, from the projects outside of the class..." "... Other than that[video-clip analysis], the only place probably I learn the most is right now doing the final project, I'm doing on Tornados, and I feel like I'm really learning a lot, because I DO have to do the research by myself."

Kay: I think those assignments really DID help with both scientific and aspects of real-life. I think they did an excellent job with the outside of class assignment with applying both ideas. And I think it would have definitely further my thinking about natural disasters..."

To summarize, the student survey result and interview results indicated that the individual writing opportunities provided through the course might help students be more actively engaged in their learning by providing opportunities for them to do their own research while writing the individual reports. In addition to Individual reports opportunities as a part of Active Learning Modules, the results emerged from the data indicated that students were engaged in critical and analytical thinking while writing responses to the questions in the video-clip analysis worksheet.

Summary

In this section data analyses were presented to answer the research question posed in terms of the factors that contributed to active learning enhancing students' learning and critical thinking in a large class, based on students' perception survey, interview, and observation data. The major factors identified from the data were: 1) students' learning experience involving active engagement in their learning through the course; 2) identifying the major factors perceived as being supportive for student learning and critical thinking; and 3) addressing general perceived effectiveness of active learning strategies that included receiving external support and input from group discussion and

scaffolding, applying knowledge to real-life problems, individual writing opportunities.

Research Question 4: Relationships between Student Learning, Critical Thinking, and Other Demographic Data

The fourth research question posed was: What are the relationships between student learning, critical thinking, and other demographic data?

In this analysis, several different data including students' mean scores from posttest, mean scores from their individual reports, and other demographic data were included. Also, other data such as students' GPA and the number of science courses taken in high school were correlated with student learning.

With regards to student learning, some major descriptive statistics on the pretest and post tests were summarized in Table 4-2. Also, a description of students' demographic information were presented in Table 4-1.

As seen in Table 4-2, there was literally no change from pretest to posttest scores among the students who participated in both tests, which included only 11 individuals who indicated a difference in their total scores. Thus, in this analysis, for the 'student learning' variable, the score students achieved on the posttest was used as the score representing 'student learning'. For 'critical thinking' score, the percentage mean score from two individual reports was used to correlate with student learning. Also, some demographic data (e.g., gender, academic year, etc.) and other data such as the number of science courses taken in high school were correlated with student learning outcomes on the geoscience assessment. As described earlier, the learning outcomes included the post score comprising of geoscience concept and reasoning. 'Critical thinking' is represented by the scores from individual reports students submitted during the two Active Learning Modules sessions. As described in chapter 3, the pretest was administered in the 2nd week of the course and posttest was administered in the last week of session. Two Active Learning Modules were employed in week 6 and in week 14.

Correlations between Student Learning and Critical Thinking

In order to identify possible relationships between students' learning and critical thinking, Pearson's r was calculated between the two factors. For the critical thinking variable, student scores from the two individual reports activity were used. Based on rubrics, students' individual reports were scored, and the percentage mean scores of these two individual reports were represented as students' critical thinking'.

In this analysis, the score students gained from the posttest represented 'student learning', and the percentage mean score students gained from two individual reports (Hurricane Smith and Global Warming) were included. In order to identify if there is any positive relationship between student learning and their critical thinking, Pearson's r was calculated between the two variables. As shown in Table 4-21, there was no statistically significant correlation ($r = .15$, $p = .15$, $N = 90$). This result indicates that there was no significant correlation between students' performance on the geoscience assessment and students' achievements in writing individual reports that required them engaged in some critical thinking aspects such as identification, analysis, integration, justification, and evaluation.

Relationships between Student Learning and GPA

In order to identify possible relationships between student learning and GPA, Pearson's r was calculated between the two factors. The students' learning was based on scores achieved in the posttest. For GPA, students' self-reported GPA collected from their demographic information on the pretest were correlated with the learning outcomes. Even though students' self-reported GPA were used for this correlation analysis, the students' actual GPA was accessible for comparing the distribution with the students' self-reported GPA, which includes the mean and standard deviation. This method allowed us to get a general sense of the distribution between the two groups. The result from this comparison is presented in the Table 4-20., which indicates that there is a similar distribution including similar mean and SD between students' actual GPA and the self-reported GPA.

Table 4-20.

Comparison of the distribution between self-reported GPA and actual GPA

	N	Mean	SD	Range	
				Minimum	Maximum
Self-reported GPA	108	3.36	.42	2.00	4.20
Actual GPA	106	3.34	.43	2.00	4.00

Note. Normality for both self-reported and actual GPA was examined and both were found to be normal distributions.

The results of the correlations between student learning and their self-reported GPA are presented in Table 4-21. There was a statistically significant positive correlation ($r = .30$, $p < .01$, 2-tailed, $N = 108$), between student learning and GPA. This result indicates that students who performed better on the geoscience assessment tend to be higher achievers in other courses in general.

Relationships between Student Learning and Previous Science Courses Taken in High School

In order to identify possible relationships between students' learning and the number of previous science courses taken in high school, Pearson's r was calculated between the two factors. For the number of science courses students took in high school, students' self-reported data collected from their demographic information page of the pretest were used. In the demographic information sheet, students checked which science courses they had taken (e.g., physics, chemistry, biology, and earth science) as well as the year in which they took them (e.g., 8th ~ 12th grade). For this correlation analysis, the total number was calculated and used for this variable. The results of the correlations between student learning and number of science courses previously taken are presented in Table 4-21. There was a significant positive correlation between student learning and the number of science courses taken by students in high school ($r = .27$, $N = 107$, $p < .01$, 2-tailed), suggesting a positive fair degree of relationship between these two factors. This result indicates that students who performed better on geoscience assessment tended to have taken more science courses in high school.

To identify if there was any relationship between student learning and the number of earth science courses taken in high school, another correlation analysis was conducted between these two factors. The results of the correlations are presented in Table 4-21. As shown in Table 4-21, there was no significant correlation ($r = .71$, $p = .38$, $N = 104$, 2-tailed) between the number of earth science courses students took in high school and achievement on geoscience assessment.

Table 4-21

Correlations (Pearson's r) Among Student Learning, Critical Thinking, Number of Science courses taken in High School, Academic Year and GPA

Variables	M	SD	1	2	3	4	5	6	7
1.Student Learning	10.20	3.88	1.00						
2.Critical Thinking	64.85	25.39	.15	1.00					
3.Academic Year			.07	.13	1.00				
4.EARTH science course				.05		1.00			
5.Total Number of science course			.27*	.20			1.00		
6.GPA			.30*	.35*				1.00	
7.Gender			.25* (112)					.35* (76)	1.00

Notes. Concept scores could range from 0-9.

Quantitative Reasoning scores could range from 0-14.

Posttest total could range from 0-25.

Critical thinking could range from 0-100.

* Correlation is significant at the 0.01 level (2-tailed).

**Correlation is significant at the 0.05 level (2-tailed).

In addition, as seen in Table 4- 21, there was a positive fair degree of relationship between GPA and student learning (0.30 , $p < .05$, $N = 108$) as well as between GPA and critical thinking (0.35 , $p < .01$, $N = 76$). Also, there was a positive fair degree of relationship between student learning and the number of science courses taken in high school ($r = 0.27$, $p < .01$, $N = 107$).

Aside from the correlations addressed above, no other significant correlations among student learning, academic year, and critical thinking were found. Also, there was little positive relationship between student learning and critical thinking ($r = 0.15$), which was not significant (0.15 , $p = .15$, $N = 90$).

Interaction between Students' Initial Knowledge and Improvement

In order to assess if there is any interaction between students' initial knowledge and improvements in student learning from pretest to posttest, a follow-up analysis was conducted, which attempted to answer the question 'did those with lower initial knowledge improve considerably more than did students with higher initial knowledge?' To illustrate, to identify the initial knowledge groups that students belonged to, median of pretest was identified (Mdn=10.5) and used as a standard to split students' initial knowledge into two groups. In SPSS, using median split, the result showed 75 (58.1%) students belonged to the 'lower' group and 54 students (48.9%) belonged to the 'higher' group for their initial knowledge level. For assessing the students' improvements, difference in total score from pretest to posttest was used. Out of 129, the majority of students (n=117, 90.7%) performed the same on the posttest. Only 11 students' (8.5%) scores changed from pretest to posttest, which includes 8 (6.2%) students who improved scores on the posttest. This indicates that there was no interaction between prior knowledge and improvements

Since we have only 11 students who made a difference in pre-and post test, assessing interaction between students' initial knowledge and improvements was not meaningful. Instead, Table 4-22 presents the case summaries of the 11 students who changed from pretest and posttest. Descriptive statistics for the 8 students who improved in posttest are 6 female 2 male, including 2 sophomore, 2 junior, and 4 senior students.

As a follow-up analysis, in an attempt to assess if there is any interaction between gender and this improvement, the value from the Chi-Square Fisher's exact test was used. The test is appropriate when there is a 2*2 Chi-square table and one of the cells has an expected frequency of less than 5. In assessing the significance of the interaction between gender and improvement, this result showed there is no significant interaction between gender and improvement ($p = .463$, $p > .05$).

Interaction between Gender and Academic Standing

As a follow-up analysis, in order to assess if there is any interaction between gender and academic year, a two-way ANOVA in SPSS was used for this analysis. From this analysis, we can report three effects as follows:

Table 4-22.

Case summaries of the students who changed in pretest and posttest Case Summaries

Case	Pretest	Posttest	Gender	Academic Year	Difference
1	7.50	6.50	.	.	-1.00
2	9.50	10.50	female	Senior	1.00
3	13.00	14.00	female	Sophomore	1.00
4	14.50	15.00	male	Senior	.50
5	16.00	16.50	female	Sophomore	.50
6	5.00	5.50	.	.	.50
7	10.50	13.00	female	Senior	2.50
8	7.50	8.50	female	Junior	1.00
9	14.00	14.50	.	.	.50
10	8.00	7.00	female	Senior	-1.00
11	8.00	7.00	male	Junior	-1.00

- There was a significant main effect of gender on the mean difference of the posttest, $F(1,91)= 6.79, p=.011$. On the posttest, female students ($M = 10.97, SD =3.52$) performed significantly better than male students ($M = 8.02, SD =4.10$).

- There was a significant main effect of the students' academic year on the mean difference of posttest, $F(3, 91) = 5.10, p= .003$

- There was no significant interaction effect between the gender and the academic year of the students on the posttest, $F(3, 91) = 4.06, p=.18, r= .05$. This indicates that male and female genders did not perform differently by academic year. Specifically, the mean scores of senior students was similar in males ($M= 11.33, SD= 2.97$) and females ($M= 11.37, SD = 3.23$), with female students performing better than male students in the posttest; For the first year and sophomore, female students also performed better than male students; However, for the junior year group, male students ($M=9.06, SD= 4.29$) performed better than female students ($M=7.64, SD= 3.11$)

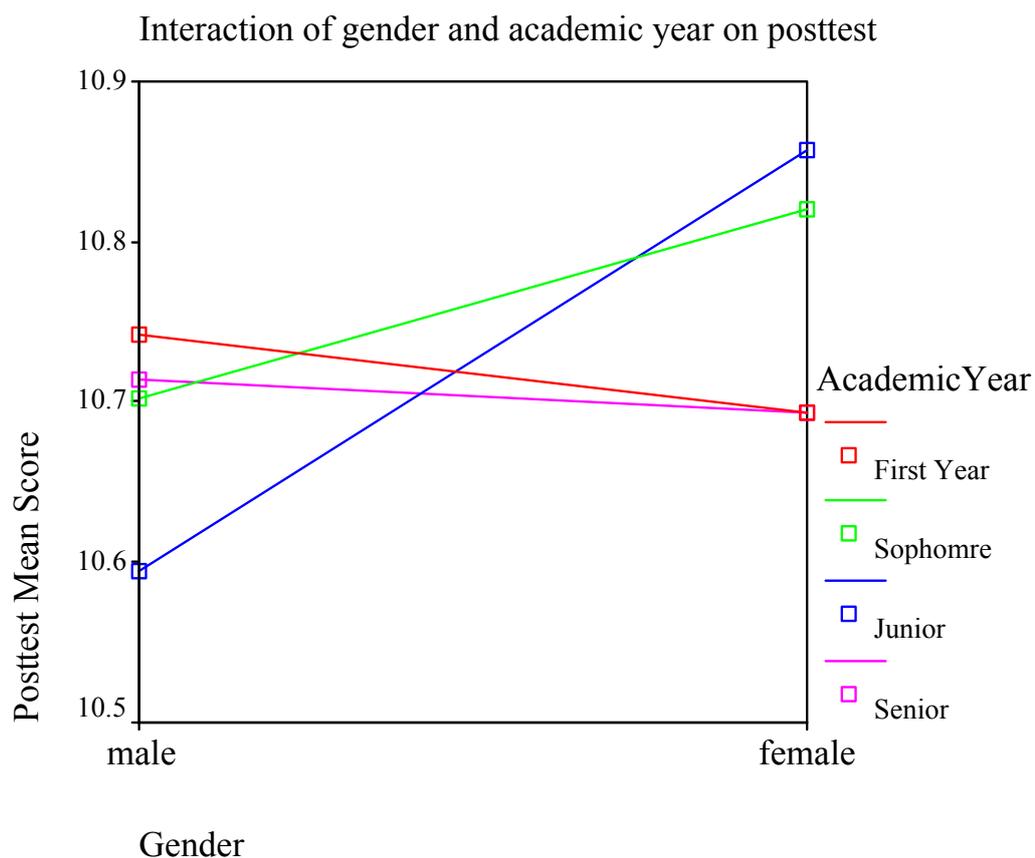
In order to assess more accurately the effect of gender and academic year on the posttest, a follow-up analysis using ANCOVA in SPSS was conducted, which showed what effect students' performance had on the posttest after controlling for the effect of the covariate, students' performance on the pretest. That is, we controlled for the effect of the students' scores on the pretest in this analysis. From this analysis, we can report the effects of gender and academic year as follows:

- The covariate, students' performance on the pretest, was significantly related to

students' posttest score, $F(1, 90) = 18531.96$, $p < .05$, $r = .99$. However, when we adjusted for the covariate pretest scores, there was no significant effect of gender ($F(1, 90) = .89$, $p = .35$, $r = .00$) and academic year ($F(1, 90) = .35$, $p = .79$, $r = .01$) on the posttest. Also, there was no significant interaction between gender and academic year ($F(3, 90) = 1.65$, $p = .18$, $r = .05$). The graph that presents the interaction of gender and academic year when the pretest was covariate is represented in Figure 4-3. This graph represents a slight disordinal interaction trend approaching significance between gender and academic year: Male sophomore and junior students tended to perform better than female students, while first year and senior female students performed slightly better than male students who belong to same academic year.

Figure 4-3.

Graph of the Interaction of Gender and Academic Year on Posttest



Summary

In this section, the data analysis results for the fourth research question were presented, which was based on correlation analysis to identify the relationships among the variables that contributed to students' demographic data, student learning, and critical thinking.

The major relationships identified from the data were: 1) there was a positive fair degree of relationship between GPA and student learning ($0.30, p < .05, N = 108$) as well as between GPA and critical thinking ($0.35, p < .01, N = 76$); 2) there was a positive fair degree of relationship between student learning and the number of science courses taken in high school ($r = 0.27, p < .01, N = 107$); 3) there was little positive relationship between student learning and critical thinking ($r = 0.15$), which was not significant ($0.15, p = .15, N = 90$); 4). Aside from the correlations addressed above, no other significant correlations among student learning, academic year, and critical thinking were found. In addition, additional findings from a follow-up analysis indicated that there was no significant interaction between gender and academic year ($F(3, 90) = 1.65, p = .18, r = .05$).

Next chapter 5 will discuss the conclusions and implications that can be drawn from the data findings presented in Chapter 4.

Chapter 5

DISCUSSION

This study addressed design challenges that are common in the implementation of strategies to enhance student learning and critical thinking in undergraduate large classes. Some of the commonly faced pedagogical challenges included:

- helping students engage in an active learning process
- helping students enhance their learning and critical thinking

In addition, several practical challenges were raised, which included:

- physical learning environment of undergraduate general education courses, which have practical limitations to support students' engaging in an active learning process
- faculty with limited resources and time to support the implementation of active learning to enhance student learning and critical thinking

To respond to these challenges, in this study, three active learning strategies were proposed as supportive mechanisms to enhance student learning and critical thinking in an undergraduate general science course: small-group learning with authentic tasks, scaffolding, and individual writing. This study focused on the effects of these active learning strategies on student learning and critical thinking through the course.

Specifically, the active learning strategies were incorporated into the design of two Active Learning Modules on the topics of hurricane evacuation and global warming. To illustrate, students were required to engage in group work with authentic tasks. To support student critical thinking and learning, scaffolding was incorporated into the instructional materials and the activity structures (e.g., individual worksheet, the structure of the task, etc.), including cognitive scaffolding, procedural scaffolding, and metacognitive scaffolding. In particular, these two Active Learning modules provided students with opportunities to engage in identifying the problem, evaluating decisions, proposing solutions, presenting supportive data, and integrating perspectives, which are important for students to engage in a critical thinking process.

A brief summary of the results will be described in this chapter. Then the findings will be discussed with regard to the three active learning strategies. Also, limitations of the study, implications for instructional design, implications for future research, and conclusion will be presented.

A Brief Summary of the Results

The first research question posed was: What was the effect of active learning strategies on student learning?

The use of active learning strategies for enhancing student learning in a large class had a positive effect on student learning. Overall, the result of the paired t-test was a slight gain in mean scores from pretest to posttest. Specifically, for the geoscience concept learning section, the active learning strategies employed had a positive effect on undergraduate students' learning of geoscience concepts. For the quantitative reasoning section, there was an actual decrease in means, but findings from further investigation on the difficulty difference between pre-and post-test as well as students' lower motivation on the posttest might explain this result.

The second research question posed was: What level of critical thinking did students display in individual reports? And was there a change over time?

In both Individual report I and Individual report II, students' average critical thinking levels fell in the category of "developing" for all subcategories (e.g., identifying problems while considering social context, developing a perspective, justifying decisions, presenting evidence/data, and integrating issues, etc.). In terms of the change over time, there was a gain in students' percentage mean scores from Individual report I (M= 68.34) to Individual report II (M= 75.66), which was significant with a p-value of .001. Thus, the use of the active learning strategies was associated with a statistically significant gain in student scores on Individual reports, although there was no significant change between the two critical thinking levels over time.

The third question posed was: How do undergraduate students describe their learning environment that employed active learning strategies to support their learning and critical thinking?

With regards to this question, the results were drawn from the data collected

primarily from the student perception survey questionnaire (Appendix G), and the results were supported with data from the interviews (Appendix F) and observations.

The use of active learning strategies reportedly had a positive effect on students' engagement in the learning experience. The three active learning strategies employed in the course were perceived as being supportive for student learning and critical thinking. Overall, students perceived positive impacts or values of the active learning strategies on the following: 1) their active engagement in their learning, 2) receiving external support and input from group discussion and scaffolding as well as for applying knowledge to real-life problems, and 3) individual writing opportunities.

Students' Overall Learning Experience in the Course: The results were primarily drawn from the students' responses to 12 statements on a five-point Likert scale, which were associated with students' overall learning experience in the course (e.g., 'I am satisfied with overall structure of the course,' 'I enjoyed working with others in the classroom (solving problems & working on the activities together,' etc.). Responses categories for each item ranged from (1) strongly disagree to (5) strongly agree. The results were supported with data from the interviews and observations.

The majority of students were reportedly satisfied with their learning experience, including the course topics, overall course structure, and collaborative class activities. In addition, students perceived in-class group activities and the learning materials used in the course as supportive in their learning. In particular, students perceived that they were actively engaged in their learning and group activities.

Students' 'Active' Engagement in their Learning: The majority of students (92%) in the class were reportedly actively engaged in their learning in the course. With regards to primary factors that facilitated the students' active engagement in their learning, the focus of the designed active learning strategies (e.g., useful and applicable activities that were pertinent to real-life and group-work) were perceived as important in facilitating their engagement.

Perceived effects of the small-group problem-solving activities on student learning: Students perceived that small-group activities supported them in applying scientific concepts to real situations. Three major factors were identified as being supportive: affective factors, cognitive factors, and metacognitive factors.

Perceived Effects of Collaborative Learning Activities on Critical Thinking: Students

considered the collaborative learning activities used in this course to be helpful in facilitating their critical thinking. In particular, the four most effective areas that supported students' critical thinking were identified as: i) understanding the impact of real-life natural disaster problems, ii) understanding global perspectives on natural disaster problems, iii) approaching the problem from various perspectives (economic, social, and cultural, etc.), and iv) applying scientific concepts/ ideas to real-world problems.

Perceived effects of group discussion on student critical thinking: Students perceived group discussion as being helpful in making decisions by facilitating either the individual critical thinking process or group decision-making process.

Perceived effects of Scaffolding provided in Active Learning Modules I & II: Students believed that procedural scaffolding provided through the instructional material and activity structure helped them to prepare for and approach the task in a manageable way. Also, students viewed the prompting questions provided in the worksheet as helpful for engaging in critical thinking.

Perceived Effects of Individual Writing Opportunities: The majority of students identified large numbers of writing opportunities for both in-class and out-of class assignments as facilitative factors that supported their learning and thinking. Students perceived that the individual writing opportunities helped them to be more actively engaged in their learning by providing opportunities to do their own research while writing the individual reports.

The fourth research question posed was: What are the relationships between student learning, critical thinking, and other demographic data?

The major relationships identified were as following: i) there was fair degree of positive relationship between GPA and student learning as well as between GPA and critical thinking. ii) there was also a positive relationship between student learning and the number of science courses taken in high school, and iii) there was a slight positive relationship between student learning and critical thinking.

The next section will present a discussion of implications as well as limitations, which center around the importance of the active learning strategies in enabling students to engage in active learning as well as critical thinking in a large class.

Effects of Active Learning Strategies on Student Learning and Critical Thinking

Although this study focused on student learning as represented by students' performance on an assessment of their geoscience scientific reasoning skills (SRS), scientific thinking skills, and geoscience concepts of the problem under study, this study suggests that the use of active learning strategies in a large class were useful to enhance student learning. In addition, the results of this study indicated that the majority of students were reportedly satisfied with their learning experience, and students perceived in-class group activities and the learning materials used in the course as supportive in their learning. In terms of engagement in their learning, a majority of students reported that they were actively engaged in their learning and group activities.

These findings are consistent with prior studies that employed similar active learning approaches in different subjects (e.g., biology, chemistry, etc), which have demonstrated the positive impacts of employing active learning strategies on enhancing student learning as well as on influencing the learning experience of students in undergraduate large classes (Yuretich, et. al., 2001; Oliver-Hoyo, 2004).

With regards to the effects of active learning strategies on critical thinking in higher education, a previous study by Burbach, et. al. (2004), confirmed that active learning techniques (e.g., journal writing, small-group learning, etc) integrated into an introductory leadership course improved students' critical thinking skills. In their study, students' critical thinking was measured by the Watson-Glaser Critical Thinking Appraisal (WGCTA), an assessment designed to measure an individual's critical thinking skills, and their study result showed that two subset scores (Deduction and Interpretation) and Total Critical Thinking test score were significantly higher at the end of the course.

The finding of this study, to some extent, extended existing research about the usefulness of active learning strategies in enhancing students critical thinking as well as in support of students' engaging in the critical thinking process: (i) The results from students' scores on Individual reports revealed a statistically significant increase, and (ii) the results from students' perception survey and interview identified specific areas of critical thinking process students perceived as being supportive (e.g., approaching the problem from various perspectives, applying scientific concepts/ ideas to real-world problems, and so on.).

In the current study, the active learning environment employed small-group learning with authentic tasks. These strategies may have helped students to be cognitively engaged, resulting in enhanced student learning and critical thinking. In support of this notion, Blumenfeld, Kempler, and Krajcik (2006) pointed out the influence of specific features of learning environments on students' cognitive engagement. They noted that when learning environments employ specific learning sciences principles such as authenticity and collaboration, they help students be more cognitively engaged. The concept of *cognitive engagement* includes "students' willingness to invest and exert effort in learning, while employing the necessary cognitive, metacognitive, and volitional strategies that promote understanding" (p.475). While cognitively engaged, students think deeply about the content and construct an understanding that entails integration and application of the key ideas of the discipline. An "authenticity" feature of learning environments achieved by drawing connections to the real world and to practice can enhance student interest and engagement in their learning. In addition, promoting collaboration in learning environments may encourage students' motivation and cognitive engagement (Blumenfeld, et. al., 2006). When students are productively engaged in explaining, clarifying, debating, and critiquing their ideas, collaboration can lead to cognitive engagement. Thus, employing small-group learning with authentic tasks as a part of the active learning strategies in this study may have supported students' cognitive engagement, resulting in enhanced student learning and critical thinking.

In terms of factors fostering critical thinking development, some previous studies (Lizzio, Wilson, & Simons, 2002; Tapper, 2004; Tsui, 1999, 2002; Yazici, 2004) have focused on students' perception of learning environments in support of their learning and critical thinking in higher education. However, very few studies on critical thinking among college students examine the impact of instructional factors (Tsui, 2002): Tsui's study (1999) revealed that self-assessed growth in critical thinking is positively related to such instructional factors as conducting independent research, working on a group project, giving a class presentation, and taking essay exams (Tsui, 2002). Based on the evidence derived from the case studies, the findings of her study suggested that the development of critical thinking is likely to be linked to an emphasis on writing and rewriting as well as class discussion (Tsui, 2002).

Investigating the effects of specific instructional strategies using direct indicators is needed, and studies addressing classroom experiences with active learning tend to rely on self-reported data rather than observational data (Tsui, 2002). Although studies focusing on students' perceptions may have some limitations, it nonetheless offers some value, as students are able to obtain reasonably accurate perceptions of the effectiveness of their learning environments (Aueyung, 2004; Fraser, 1998).

Regarding the specific areas of critical thinking processes students perceived as being supportive (e.g., approaching the problem from various perspectives, applying scientific concepts/ ideas to real-world problems, and so on.), the results of this study are consistent with previous studies that investigated students' perceptions of their learning environments (Yazici, 2004; Tsui, 1999, 2002). In terms of collaboration, students perceived that collaborative learning enhanced their critical thinking skills. The study done by Yazici (2004) has also shown that collaborative learning improved undergraduate business students' understanding of quantitative operations management (OM) methods and enhanced their confidence in their critical-thinking. A wide range of collaborative activities (e.g., exams, projects, presentations, etc.) were incorporated in the course, and a questionnaire was used to measure students' perceptions of their understanding of OM, critical thinking skills, communication and team-building skills, and independent learning skills. In terms of students' perceptions of enhanced critical thinking skills, specific areas such as recognition, analysis, and ability to apply knowledge to the problem under study were included, and the study revealed that students felt that their ability to analyze, formulate, and solve problems were enhanced.

Implications

Implications for Instructional Design

As proposed earlier in this study, higher education has increasingly emphasized the need to engage students actively in their own learning and to develop students' critical thinking. However, the implementation of active learning strategies that would enhance student learning and critical thinking in undergraduate large classes has proved to be challenging. The results of this study can inform educational practice about employing active learning strategies to enhance student learning and critical thinking in

an undergraduate large class environment.

This study focused on three active learning strategies: small-group learning with authentic tasks, scaffolding, and individual writing. It is acknowledged that the scope of this study was not intended to determine which of the three active learning strategies had a differential effect on student learning and critical thinking. Rather, these three active learning strategies were suggested as supportive mechanisms to be incorporated into the undergraduate course. Based on the results from this study, this section presents implications for Instructional Design with regards to these three strategies.

Small-group learning with authentic tasks. This strategy addressed the need to provide learners with opportunities to work in small groups with authentic tasks. Prior research as well as educational standards documents (e.g., National Science Education Standards) advocate engaging in authentic practices as part of the learning experience (Edelson & Reiser, 2006). In learning environments where students engage in authentic tasks that are similar to the activities that professionals engage, deeper learning occurs as a result of students engaging in learning by doing and applying ideas (Krajcik, Phyllis, & Blumenfeld, 2006).

The results of this study showed that students perceived that small-group activities with authentic tasks supported them in applying scientific concepts to real situations. In terms of critical thinking, this study identified the four most effective areas that students perceived as being supportive for them to engage in critical thinking: i) understanding the impact of real-life natural disaster problems, ii) understanding global perspectives on natural disaster problems, iii) approaching the problem from various perspectives (economic, social, and cultural, etc.), and iv) applying scientific concepts/ideas to real-world problems.

With regards to the findings above, this study did not investigate the direct effects of small-group learning with authentic tasks on student learning and critical thinking. However, the results from the students' perception of the effectiveness of collaborative learning activities on their critical thinking may be linked with the nature of students' activities specifically designed to enhance critical thinking. Existing theories (e.g., situated cognition) and research suggest that when learning is anchored in meaningful contexts for learners, they are more likely to understand how concepts are applied and why they are useful (Bransford, et al., 1990; Edelson, 2001). While pointing out the

need for accessibility and applicability in learning, Edelson (2001) noted that “integrating content and process together in the design of learning activities offers the opportunity to increase students’ experience with authentic activities while also achieving deeper learning content understanding” (p. 355). He also contended that “Useful knowledge must also have connections to other knowledge structures that describe situations in which that knowledge applies” (p.359). For this principle to be realized in designing learning activities, he suggested activities should enable learners to apply their knowledge in meaningful ways so that it is useful. In the current study, collaborative learning activities may have supported student learning and thinking by providing them with this knowledge construction opportunity in their learning context.

In addition, the opportunities to work in small-groups provide learners with a social structure where students distribute cognition among group members (Edelson & Reiser, 2008). With regards to the effects of small-group composition on student learning, Springer, Stanne, and Donovan (1999) described three theoretical perspectives: motivational perspective, affective perspective, and cognitive perspective. From a motivational perspective, small-group learning provides a rationale for collaborative learning environments where learners share group goals, encourage and help one another, while emphasizing the importance of individual accountability. From an affective perspective, small-group learning provides a nonthreatening environment where learning occurs more naturally and where students learn by participating in more collaborative learning processes. From a cognitive perspective, based on Piaget or Vygotsky’s theories, they stated small-group learning provides the opportunity for students ‘to discuss, debate, and present their own and hear one another’s perspective’ (p. 25), which will enable students to learn from one another. From the results of a meta-analysis, they noted “various forms of small-group learning are effective in promoting greater academic achievement, more favorable attitudes toward learning, and increased persistence through undergraduate science, mathematics, engineering, and technology (SMET) courses and programs” (p.21). Thus, collaborative interaction can contribute to individual learning (Andriessen, 2006, in referring to Greeno, 2006; Sawyer, 2006; Kuhn & Udell, 2003). Likewise, the findings from this study suggest that it can be beneficial to provide learners with small-group learning opportunities. In particular, students reported group discussion as being helpful in making decisions by

facilitating either the individual critical-thinking process or group decision-making process. This points to the importance of the small-group discussion in contributing to processes conducive to critical thinking (e.g., Andriessen, 2006).

As an effort to facilitate critical thinking, Brookfield (1987) emphasized providing group work opportunities and stated the following:

“When we develop critical thinkers, helping them form resource networks with others who are involved in this activity may make a crucial difference. Because identifying and challenging assumptions, and exploring alternatives, involve elements of threat and risk taking, the peer support provided by a group of others also trying to do this is a powerful psychological ballast to critical thinking efforts. Where such a network does not already exist, one of the most important tasks of those trying to facilitate critical thinking is to encourage its development (p. 79)”.

As such, instructional designers can create learning environments that provide authentic tasks requiring learners to engage actively in both knowledge-building and knowledge-in-use processes (Edelson, 2001). Designers can implement this strategy by creating small-group learning activities, which provide students opportunities to speak their own opinions, listen to others' ideas, reason with decisions, and agree/disagree while reaching consensus or going through their own-sense-making process.

Scaffolding. This strategy was used to respond to the challenges that learners might encounter when engaging in authentic tasks that are complex in nature. Prior research has suggested that structuring a complex task can make it more accessible for learners who are new to the domain (Reiser, 2002, 2004; Quintana et al, 2004). One method of structuring a task is to “decompose” it into manageable components (Quintana et al. (2004), a strategy that was also used in this study.

This study also relied on the use of question prompts as a strategy to scaffold or simplify the complex task. To enhance student learning and their critical thinking, King (1995) suggested the use of critical thinking questions, and stated that thought-provoking questions (e.g., why is... important?) activate critical thinking and induce high-level cognitive process (e.g., analysis of ideas, evaluation, etc.). The results from a series of King's studies have shown that the questioning strategy is an effective strategy for students to exchange more explanations and to achieve higher scores on comprehension tests (1994b). In addition, other empirical studies (e.g. King, 1990; Ge &

Land, 2003) showed positive impacts of question prompting on student learning including memory of the facts, comprehension, and problem-solving.

Findings from this study revealed that students perceived that the scaffolding positively affected their learning and critical thinking in the following ways: i) procedural scaffolding provided through the instructional material and activity structure helped them to prepare for and approach the task in a manageable way, and ii) cognitive scaffolding through prompting questions provided in the worksheet helped them to engage in critical thinking.

As such, scaffolding can be implemented by designing visible strategies for student thinking in the materials and learning activities (e.g., thought-provoking questions for cognitive scaffolding, embedded learning activity for reflection, etc.). Also, by creating a structured sequence of activities with discrete elements or by simplifying it into several small tasks, designers can create learning environments that provide metacognitive scaffolds. This strategy can enhance students' active engagements in their learning and critical thinking while engaging in multiple, simpler tasks that eventually lead to completing a complex task.

Individual Writing. Prior research addressed the active learning process associated with individual writing (Kalman, 2007), a strategy that was used in support of student learning and critical thinking in this study. While engaging in the writing process, students go through a process of identifying the issues presented, analyzing and synthesizing discussions with other students, and evaluating decisions made during group activities.

With regards to the benefits of individual writing opportunities that require students to reflect on their learning process (e.g., reflective journal writing), a multitude of research has indicated journal writing can increase student learning (Connor-Greene, 2000; Mayo, 2003a, 2003b) and enhance critical thinking (Maslow, 1979; Hettick, 1990; Hodeges, 1996). This suggests that an emphasis on writing can facilitate student learning and critical thinking by encouraging students to reflect on and articulate their thinking (Dunlap, 2007; Moon, 2008). In particular, given that reflection is part of learning and given that critical thinking is very close to reflection (Moon, 2007), it seems important for students to engage in writing opportunities that encourage them to generate more reflection and to engage in critical thinking processes.

A study done by Burbach et al. (2004) is similar to the current study in that it utilized individual writing opportunities to support active learning in an undergraduate class. Specifically, Burbach et al. (2004) investigated the effects of active learning strategies (e.g., small-groups, case study, and questioning strategies) on students' critical thinking in an introductory leadership course, which resulted in a significant increase in the total critical thinking at the end of the course. Although the focus of the study was not on investigating direct effects of individual writing on students' critical thinking, the findings indicated that utilizing journal writing as a part of active learning in the course appeared to increase critical thinking measured by an assessment (WGCTA) designed to measure an individual's critical thinking skills (e.g., deduction, interpretation, etc.).

In this current study, individual writing opportunities were provided as a part of class activities as well as assignments. Also, Individual Reports I & II were incorporated into Active Learning Modules to activate critical thinking: students wrote individual reports that included identifying the issues presented, analyzing and synthesizing what they discussed with other students, and evaluating the decisions made during group activities.

The results of the study provided some evidence in support of the positive effects of individual writing, which were identified from students' perception surveys and interview results: students reported that the individual writing opportunities helped them to be more actively engaged in their learning by providing opportunities to do their own research while writing the individual reports. In particular, the majority of students identified the large number of provided writing opportunities for both in-class and out-of-class assignments as being facilitative factors that supported their learning and thinking. In particular, this study confirmed that the individual reports employed in the Active Learning Modules functioned as a tool to reflect on the process of learning as well as the decisions made from the previous group activities.

Small-group discussion may have provided students with opportunities to engage in a collaborative reasoning process, which may have aided their writing activities (Andriessen, 2006). Reznitskaya et al.'s study (2001) showed that fifth-grade students who had opportunities to engage in small group discussions wrote essays that contained a significantly greater number of arguments, counterarguments, rebuttals, and references to text information than the essays of students who did not experience collaborative

reasoning. Students in the experimental group participated in small-group discussions where they were asked to take positions on an issue, provide supporting reasons and evidence for their opinions, challenged each other's viewpoint while asking for clarification.

The findings of the current study suggest that to enhance students' critical thinking, designers can create a learning environment where students engage in individual writing. By requiring students to engage in a reflection process to monitor and evaluate their progress, individual writing functions as a tool to develop students' critical thinking. Also, it is suggested that students' having opportunities to engage in small-group discussion before writing individual reports can be beneficial for students' critical thinking.

Implication for Curriculum Development

The results of this study indicate that active learning strategies integrated in a large undergraduate course had positive effects on student learning. Although it was promising to observe improvements in student learning and critical thinking in this study, a one-semester implementation of active learning strategies in a course may not have been sufficient to foster students' critical thinking development long term. While teaching critical thinking is a goal in higher education (Burbach, Matkin, & Fritz, 2004), a teacher's effort to increase students' critical thinking in a single course may not be sufficient; instead, curriculum-wide efforts may be needed. This study demonstrated that active learning strategies can be incorporated into an undergraduate general science education course to help development of critical thinking skills. However, further development would require systemic supports that draw on departmental/ college-level efforts that would attend to the challenges in practice, and that would include introducing and supporting integration of active learning strategies into curricula more broadly in higher education.

Limitations and Implications for Further Research

It is acknowledged that this study has a limitation regarding the ability to control external variables. That is, this study has no comparison group, which has limitations

for validating the effectiveness of the proposed approaches. Course conditions (a large class with an enrollment of 170 students) for the current study did not allow for an experimental group, reflecting the logistics the study encountered in practice. In addition, students' lower scores on the quantitative reasoning skills section in the posttest was puzzling, which might have been associated with either test difficulty or students' lower motivation to take the assessment seriously at the last session of the course. Given the ecological validity issue, however, this study adds value, in that this study was conducted in an actual undergraduate class and not in a research laboratory.

Another limitation of the current study is related to the research scope. This study focused on improving student learning and enhancing critical thinking through employing active learning strategies in a large class setting. The data available for addressing the research questions were limited to the effects of active learning strategies on student learning outcomes, rather than learning processes engaged within the same learning context. To illustrate, students reported being actively engaged in the learning process throughout the course and believed they had developed an increased awareness of the topics taught in class in a way that connected to their daily life and major of study. More qualitative approaches to the research questions that examined the learning quality as well as learning process students engaged in would provide insights into how students engaged the activities and whether other effects were apparent as a result of using the strategies.

This study focused on exploring one aspect of the effects of active learning strategies on undergraduate student learning and critical thinking; further investigation is recommended for future research. In terms of the effects of scaffolds employed in the Active Learning Modules, more research is needed on how the scaffolds were used in practice to support students reaching their goal as well as how they increased students' engagement in the knowledge construction processes (Krajcik, Phyllis, & Blumenfeld, 2006). Although, the scaffolds were employed to enhance student learning and critical thinking, the learning *process in which students* engaged was not investigated in this study. Based on existing research (Hannafin, Land, and Oliver, 1999; King, 1995; Lin, 1999), it was hypothesized that the scaffolds employed would have enhanced students' reasoning skills, resulting in improved student learning related to natural disasters.

The findings from the student perception survey and class observations in this

study were consistent with the notion that students were actively engaged in the learning activities as well as learning materials provided through the Active Learning Modules (e.g., in-class small-group activities, individual worksheets, Individual reports). A further investigation of students' reasoning in response to the prompting questions provided would provide more evidence with regards to this perspective. Thus, studies focusing on scaffolds employed in the learning context could provide more detailed information with regards to the function and utility of specific scaffolding strategies for enhancing students' critical thinking. For instance, Oliver and Hannafin (2000) investigated a question dealing with students' use of embedded scaffolds, and they noted that only a few students used the scaffolds provided. From this perspective, further research that investigates students' use of the embedded scaffold to identify correspondence to the researchers' intentions in using the scaffold would be meaningful.

To summarize, investigating the specific effects of the scaffolds (e.g., cognitive, procedural, metacognitive scaffolding) on student learning would enable us to determine whether the purpose of different scaffolding types were congruent for enhancing student's critical thinking process.

To illustrate, in this study we used question prompts to enhance student critical thinking, and, the results showed that students perceived that the prompting questions provided in the worksheet helped them engage in critical thinking processes. Although this finding supports other existing literature regarding the benefits of question prompts on student learning and critical thinking (e.g. King, 1991, 1994), further research is recommended on how these specific scaffolds were effective in the context. For instance, it would be meaningful to investigate if specific scaffold types worked for enhancing any specific attribute of critical thinking (e.g, the effects of question prompts on the particular reasoning process). In a previous study by Ge and Land (2003), it was reported that question prompts such as "what are the parts of the problem" and "what are the technical components?" (p. 37) were identified as supportive for students' problem representation in the context of undergraduate information technology course. In addition, Belland (2007) addressed a knowledge-building component in which students organized their answers based on problem representation question prompts and the claim to which they lend support. From these perspectives, it would be meaningful to investigate whether the scaffolds employed worked for amplifying students'

knowledge construction process, which knowledge components were facilitated, and how they worked. A further study investigating whether the question prompts embedded in the learning modules worked for students to articulate their reasoning process would enable the researcher to find more detailed information regarding the effects of scaffolds on student learning and critical thinking.

With regards to critical thinking, while addressing the need for identification of classroom strategies that engender critical thinking, Halpern (1993) noted:

“A quality assessment would allow us to determine if gains are attributable to written assignments, active participation in problem solving, the development of a close relationship with a caring instructor, a combination of these variables, or some other yet undetermined variable. An assessment that attempts to identify the specific educational experiences and that results in improved critical thinking would require a more fine-grained analysis of the nature of the instruction. Further research dealing with this perspective is recommended, which will provide this sort of information” (p.276).

Also, further research investigating individual students’ understanding development displayed through several artifacts (e.g., individual reports) throughout and across various projects would be a worthy project, as it might reveal different aspects of student learning on an individual level, which might have not been obvious through the assessments used in the current study.

Implications for Educators

In this study, the introductory geoscience course provided a learning environment where active learning strategies were incorporated into an undergraduate general education course for enhancing student learning and critical thinking. While students engaged in small-group learning with authentic tasks, scaffolding was provided to enhance their reasoning and critical thinking, and they wrote individual reports aimed at encouraging reflection and engagement in the critical thinking process.

Based on the findings from this study, the following recommendations are offered to educators involved in teaching undergraduate general education courses and who seek to enhance undergraduate students’ learning and critical thinking, particularly in large classes. First, educators need to align the learning activities with assessments and learning goals. Once learning goals and objectives for the course are set in place,

educators need to ensure the alignment of their instruction with goals and assessments. For example, in the class studied, while collaborating with the professor who was teaching the course, specific learning goals and objectives were identified before designing all the learning activities and instructional materials. To increase the alignment of instruction with goals, the same specific targeted skills/abilities were reflected in an assessment development to evaluate students' concepts and reasoning skills. As a practical strategy, educators may need to create a table listing each of the subcategories of learning objectives that students should accomplish through the course related to the specific learning activities and assessments. In particular, the course goal is to develop students' thinking and reasoning, so assessment around basic knowledge and facts would not be appropriate.

Second, educators need to make efforts to design their classrooms as supportive learning environments where students actively engage in their learning process as well as in knowledge construction. The results of this study provide some support for the use of current events, situations, and authentic problems as contexts for students to apply their knowledge to real-life complex problems. Thus, educators who are focusing on students' critical thinking and knowledge-in-use are suggested to consider integrating authentic learning activities into their instruction. It should be noted, however, that providing students with complex problems is demanding and time consuming for both students and teachers.

In the course studied, the use of active learning strategies reportedly had a positive effect on students' engagement in active knowledge construction while engaging in small-group work with authentic tasks. Also, the students' critical thinking score increased, which was assessed through writing in individual reports. Furthermore, the collaborative learning activities employed in the course were perceived by students as being supportive for facilitating their critical thinking. Four areas that were reported as most effective for supporting student's critical thinking included the following: (a) understanding the impact of real-life natural disaster problems; (b) understanding global perspectives on natural disaster problems; (c) approaching the problem from various perspectives; and (d) applying scientific concepts/ ideas to real-world problems.

A common theme emerging from the qualitative data showed that engaging students in a collaborative reasoning on an authentic task with a group prior to engaging

in individual reflection on their reports helped them to approach the problem from various perspectives. Another theme emerging from the qualitative data revealed that it is important for students to be engaged in authentic tasks, which facilitated their knowledge transfer: Students expressed that their collaborative learning activities helped them to apply scientific concept/ ideas to real-world problems. This finding advocates the importance of providing students with instruction anchored in real world situations, which can help with transferring knowledge to new situations (Bransford, 2000). This approach to problematizing student work also is accounted for as a scaffolding mechanism in complex learning tasks (Reiser, 2004), as students were able to go beyond their individual abilities with the support of their group members. As such, this finding suggests that it is important for educators to provide a learning environment that employs some effective instructional strategies such as authentic tasks, collaborative learning, and scaffolding as well. This finding also indicates that our initial goal of the Geoscience project (NSF funded research project) that aimed to develop students' thinking skills in transferring science knowledge and observation to decision making in the real world seemed achieved by providing students with active learning environments in a large class.

In terms of providing scaffolding, several practical strategies are suggested. First, provide a structure to help students to prepare individually before engaging in the group activities. In this study, before working in their groups, individual students had time to work on individual worksheets that were designed to help them to be ready individually to discuss the issues in a group. This prior preparation was identified as being supportive for students to engage in a productive collaborative discussion. Also, it was reported that this pre-group work helped them to deal with a complex task by performing a manageable task beforehand. Providing this type of structure in complex learning tasks is also suggested as a strategy for providing scaffolding (Reiser, 2004). Thus, it is important to provide students with opportunities to get prepared for the group activities, which will lead to a more productive discussion.

Second, faculty should provide students with thought-provoking questions for cognitive scaffolding in the student's learning materials. The use of question prompts activates students' critical thinking (King, 1994). The prompts should emphasize students' reasoning process and help to make thinking explicit. In this study, some

specific areas of critical thinking subcategories were identified that need more adaptive support as well (e.g., justifying own decisions with providing data/evidence), to help students in the weaker areas of the critical thinking/ reasoning process.

The use of the individual writing embedded in the collaborative learning activities seems promising, which presumably helps students to be engaged in a reflective and critical thinking process. In this regard, it is suggested that the nature of writing task should be considered in terms of “what should students write about?” (See Chapter 2). In this study, students were required to write Individual Reports, which included subcategories such as identifying key issues, evaluating others’ decisions, justifying own decisions while supporting them with evidence, and integrating other perspectives. In this way, the nature of the writing tasks aimed to provide opportunities for students to engage in a critical thinking process. In employing this approach, educators may also consider the question of “when will be the best time for the writing activities?” In this study individual writing opportunities were provided as a final stage of individual decision-making/ reasoning after completing group activities. In addition, across many sessions, students had opportunities to write their responses to questions while working on the individual worksheets provided (e.g., while watching movie clips, students wrote their responses to the questions that were aimed to have them think about the questions from scientific perspectives). It will be important for educators to determine which type of writing task should be provided and how often and when the individual writing can be incorporated in the course.

Although the suggestions above were generally made based on some positive effects found in the study and the common themes that emerged from qualitative data, there are some additional lessons learned from what did not work as anticipated in this study. The majority of the students in the course studied were actively engaged in their learning in general. However, in contrast to class observations showing students’ active engagement, students’ artifacts collected from their group work did not show as much evidence of their active engagement. This could be due to the difficulty of students working in groups to write down all that they discussed while engaging in their group work in a lecture hall setting. However, interestingly, compared to the group worksheets collected from the course, individual worksheets (pre-group activity) and Individual reports (follow-up group activity) showed a great deal of student engagement in their

learning. Another possible explanation for this contradiction may be associated with students' greater interest in attaining good grades in their individual work, as group work participation was less accounted for their grading. This suggests that educators should consider balancing individual grading assessments with group work grades.

Another suggestion is to take into consideration providing students with enough time to engage in each activity. From this study, one theme that emerged from the qualitative data revealed that the students were rushed to finish the group activities, and they felt that insufficient class time was provided for some activities. This suggests that it is important for educators to give students enough time to fully engage in their learning activities while encouraging them to make use of the group activity for helping them complete pre/follow-up individual learning. Also, educators need to emphasize quality of the group work, rather than just completion. To address this challenge, as an alternative, educators may consider some group work to be assigned outside class meetings. Also, use of technologies for collaborative learning can be considered. For instance, using emerging technologies (e.g., group wiki) can extend their classroom activities while working as a group on the same issue together outside of the classroom, and this would help students to access their group work anytime at their convenience without rushing to finish the group work within the allotted class time. Also, the use of technology would eventually benefit student learning, since students can keep records on what they think and what they want to share with others in a group.

In line with this suggestion, technology integration is another area that should be considered for the design of learning modules to enhance critical thinking in a large class. Taking possible benefits of technology support into consideration, it seems promising to support various facets of student learning and thinking process (e.g., collaborative learning activity, individual knowledge-building, etc.) in a way to provide more adaptive scaffolding (e.g., visualization, communication scaffolding, etc.). In addition, this technology-integrated learning environment would help students work in a data-rich environment, a required skill for scientific literacy. However, this consideration should be based on understanding how, when, and what technology can appropriately support in a given context.

Another lesson learned from this study is related to enhancing the working relationship within a group. For the group activities in the Active Learning Modules,

each member was assigned a specific role for each task. Also, all questions and individual worksheets were written to help each individual student achieve the responsibilities of his/her assigned roles as well as to facilitate engaging in the critical thinking process. Then, this individual expertise was incorporated into collaborative group work and discussions. It seemed this strategy worked for helping students to be well-prepared for the group activities. However, some other recommendations from literature regarding forming a group, such as forming a group based on students' mixed abilities and their gender, and group accountability were not incorporated in this study. Utilizing similar strategies may be useful for faculty to maximize the benefits that small-group work may bring to student learning.

As for efforts that can be made from a larger scale (e.g., university-wide efforts), it is recommended to integrate critical thinking skills into several undergraduate courses and to assess students' critical thinking development in diverse disciplines. For instance, Washington State University (www.cltl.wsu.edu, 2006) developed a critical thinking scoring rubric designed to rate the level and quality of the students' critical thinking and encouraged the faculty participants to adapt its use for their courses which included History, Physics, World Civilization, and Crops and Soils. Regarding faculty adaptation of the rubric, some used only two or three dimensions of the rubric while others integrated it entirely (<http://wsuctproject.wsu.edu/fa.htm>) for their instruction and evaluation. The rubric was geared toward general critical thinking skills, rather than toward a specific discipline, and aimed to integrate assessment with instruction in order to enhance higher-order thinking in the university. Based on collected students' papers from both classes that integrated the rubric and the courses that did not use the rubric, they compared students' critical thinking scores. Five faculty members originally participated in the study, which reported that papers from the classes that used the rubric rated consistently higher in critical thinking than those that did not use the rubric. Also, they identified, compared to lower level courses (e.g., Physics 102), upper level courses (e.g., Soils 415) showed higher scores in students' critical thinking.

This suggests that developing assessments that can be incorporated into diverse disciplines and providing faculty with adaptable means for evaluating students' learning outcomes would be promising to address the general needs for students' critical thinking development in higher education.

Also, it is suggested to facilitate the dissemination of rubrics and learning activities that are well- designed and developed for enhancing students' critical thinking. As an example of this dissemination effort, the Cutting Edge project funded by the National Science Foundation opened a portal website (<http://serc.carleton.edu/index.html>), which collected resources for Geoscience faculty. The goals of the project were to determine the current state of geoscience instruction and how to design and deliver professional development experiences to enhance geoscience instruction (<http://serc.carleton.edu/NAGTWorkshops/programdescription.html>). This digital library initiative effort should help many educators teaching undergraduate science courses by helping them to access diverse resources (e.g., classroom and lab activities, assessment, etc.).

This current study was conducted to enhance student learning and critical thinking in a large introductory geoscience course, which also made an effort to verify the effects on student learning and critical thinking through educational research while implementing a set of assessments that was developed to measure students' reasoning skills and critical thinking. This entire approach is a resource to educators who are teaching a large introductory general education courses in a lecture-hall setting and willing to enhance students' active engagements in their learning and critical thinking. By anchoring active learning strategies with appropriate scaffolding affordances and employing appropriate assessments, the study offers an approach to providing a learning environment where students are actively engaged in their learning in a large class, which expects to enable educators to adapt and apply to their teaching context.

Conclusions

As an effort to attend to the challenges facing current teaching practices of undergraduate general education courses, three active learning strategies -- small-group learning with authentic tasks, scaffolding, and individual writing – incorporated in an undergraduate large-enrollment course. The three active learning strategies employed in this study showed promise as supportive mechanisms for students to actively engage in their learning process as well as to enhance their learning. The active learning strategies may have served a role in enhancing student learning quality as well (e.g., students'

active engagements in the constructive learning process).

With regards to students' critical thinking, the active learning strategies also served a role in facilitating student engagement in various facets of critical thinking. The students in this study were reportedly engaged in applying, analyzing, evaluating, and synthesizing what they learned to deal with real-life problems, while they were supported through the scaffolding incorporated in the learning modules that were carefully designed in order to promote students' critical thinking.

It is crucial for undergraduate students to learn to think critically and to analyze and synthesize information to solve diverse problems (e.g., social, economic, scientific problems, etc.) (Dunlap, & Grabinger, 1996). Krischner (2001) noted that "there is a call for higher education to enable students to acquire 'competencies' rather than just specific, knowledge-based learning outcomes...Competencies are a combination of complex cognitive and higher-order skills, highly integrated knowledge structure, interpersonal and social skills, and attitudes and values" (p2).

In this study, while engaging in a critical thinking and constructive knowledge-building process, students were supported in processes necessary to acquire relevant knowledge, make decisions, engage in scientific reasoning, and develop interpersonal skills, leading to the ability to transfer (Dunlap, & Grabinger, 1996). That is, active learning strategies enabled students to be exposed to both an application and synthesis of knowledge, although the findings from the study were not able to detect direct associations.

This study discussed several design components to promote critical thinking within large classes in higher education. These included the following: (a) present tasks and problems that require students to engage in higher level thinking; (b) employ group learning activities that provide students opportunities to discuss the problem and work through it together; and (c) use instructional facilitating strategies such as questioning and discussion. In addition, the researcher introduced an instructional framework for restructuring an environment into an active learning environment. Thus, this study focused on providing a learning environment including the *activities*, the *tools* and the *assessment*, which were designed to enhance student learning and critical thinking.

In sum, this study represents a collaborative effort between Instructional Design and Geoscience fields. The collaboration was designed to address the challenges of

implementing students' active learning in undergraduate large classes, and to provide students with a theoretically-grounded active learning environment that incorporated activities, tools, and assessments to support deeper learning. In particular, the focus on providing appropriate scaffolding through the learning activities may have helped students to engage in specific critical thinking process and to actively engage in their learning. From this perspective, this study extended previous work in that it focused on providing a learning environment where students actively engaged in both small-group activities with authentic tasks and individual learning activities, while providing additional support through scaffolding in the Active Learning Modules. Given the practical challenges to design, implement, and assess students' critical thinking, it is suggested for researchers, instructional designers, and educators who are teaching undergraduate courses to work collaboratively to provide optimal learning environments where students can learn most actively and can be fully engaged in their learning process.

Ritchhart and Perkins (2005) stated: "We already know enough about the teaching of thinking to have a substantial impact, and yet the reality of collective practice falls short" (p.796). They emphasized the importance of fostering a culture of thinking in all areas where thinking might thrive (e.g., individual, classroom, schools, communities, and societies). The current study could play a role in attending to the needs addressed above as well as the challenges of undergraduate general education courses.

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Appendix A. Class Observation Protocol & Observation Record Template

Appendix B. Active Learning Module I: Instructional Materials (Sample)

Appendix C. Active Learning Module II: Instructional Materials (Sample)

Appendix D. Sample Scoring Rubric for Critical Thinking (Sample)

Appendix E. Pre & Post-test on Students Learning

Appendix F. Structured Interview Questions

Appendix G. Student Perception Questionnaire (Sample)

Appendix A.

Class Observation Protocol & Observation Record Template

Class Observation Protocol

Date:	
Class number:	
Main topic for discussion	
Led by:	
Class activities	What is going in the class sequentially and maybe also talk about how long each activity lasts?
Student participation/questions	How many students ask questions or make comments independent of Kevin's directed questions? Also if you notice specific students participating repeatedly, maybe that can be noted?
Group activities	What is the focus of group activities and what is the output? How long do they take to complete? How is the group activity concluded or debriefed?
Kevin's/TA's activities	Are they presenting or lecturing or facilitating a group activity? Also if they ask questions, how many questions are they asking and are they directed all over the room or in a specific location?

Appendix B.**Active Learning Module I: Instructional Materials (Sample)**

Community Name: _____

Group Designation: __ Media __

Media group discussion chart

List full names of all group members here:

Before you begin, list below the specific function and priorities of your group.

Function:

Priorities:

-----Second time release statement-----

1. List below the dangers and impacts associated with Hurricane Smith in its new location.

2. What do you think are the three most important dangers/impacts to address from the list above? Why are they important?

3. What is your decision?

Decision Point 2

Do not evacuate	Keep an eye on data	Tell citizens to prepare for evacuation	Evacuate	Reverse prior evacuation decision (Please be sure to identify your new decision as well)
------------------------	----------------------------	--	-----------------	--

Why did you make that decision? List your reasons and the data that you used as evidence.

Reasons	Data and source (list page number or name)

Community discussion chart

Before you begin, as a community, what are the most important things (geographical, social, cultural) that you will need to keep in mind as you make decisions?

List important information:

- 1.
- 2.
- 3.
- 4.
- 5.

-----First time release statement-----

3. List below the dangers and impacts associated with Hurricane Smith in its current location.

4. What is the most important issue identified by the groups in your community?

Mayor/City Council _____

School System _____

Emergency services _____

Infrastructure services _____

Chamber of Commerce _____

Disability Advocates _____

Media _____

5. Which groups are the most important to consider? Why?

6. What is your decision?

Community Decision Point 1

Do not evacuate	Keep an eye on data	Tell citizens to prepare for evacuation	Evacuate
------------------------	----------------------------	--	-----------------

Why did you make that decision? List your reasons and the data that you used as evidence.

Reasons	Data and source (list page number or name)

-----Second time release statement-----

1. List below the dangers and impacts associated with Hurricane Smith in its current location.

2. What is the most important issue identified by the groups in your community?

Mayor/City Council _____

School System _____

Emergency services _____

Infrastructure services _____

Chamber of Commerce _____

Disability Advocates _____

Media _____

3. Which groups are the most important to consider? List them.

4. Are the same groups listed as last time? Why or why not?

5. What is your decision?

Community Decision Point 2

Do not evacuate	Keep an eye on data	Tell citizens to prepare for evacuation	Evacuate	Reverse prior evacuation decision (Please be sure to identify your new decision as well)
----------------------------	--------------------------------	--	-----------------	--

Why did you make that decision? List your reasons and the data that you used as evidence.

Reasons	Data and source (list page number or name)

-----Third time release statement-----

1. List below the dangers and impacts associated with Hurricane Smith in its current location.

2. What is the most important issue identified by the groups in your community?

Mayor/City Council _____

School System _____

Emergency services _____

Infrastructure services _____

Chamber of Commerce _____

Disability Advocates _____

Media _____

3. Which groups are the most important to consider? List them.

4. Are the same groups listed as last time? Why or why not?

5. What is your final decision?

Community Decision Point 3

Do not evacuate	Keep an eye on data	Tell citizens to prepare for evacuation	Evacuate	Reverse prior evacuation decision (Please be sure to identify your new decision as well)
----------------------------	--------------------------------	--	-----------------	--

Why did you make that decision? List your reasons and the data that you used as evidence.

Reasons	Data and source (list page number or name)

6. Did you identify different threats after each time release? Why?

7. What do you think are some of the consequences of your final decision on the community?
What might happen in the next few days?

-----Third time release statement-----

1. List below the dangers and impacts associated with Hurricane Smith in its new location.

Individual Report

You have been appointed as Special Aide for Disaster Management to the office of the Mayor of your specific community. The Mayor is asking for your recommendation on how to best address the Hurricane Smith situation. You must prepare a final report describing your expert decision regarding Hurricane Smith, which the Mayor will use to inform the Hurricane Evacuation Plan for the community.

In your report (3 pages, double spaced, 12 point font), you must provide an analysis of the hurricane situation and your suggestions about the evacuation decision. You should also support your suggestions with data and reasons wherever appropriate. That is, you must provide YOUR proposed decision to address the situation and the reasoning behind the decision. Make sure to base your report on the findings and decisions of your group & community members, as well as your own understanding of the situation. In your report, the Mayor would like you to address the following details:

1. **Identity:** identify the group and the community of which you were a part.
2. **Group decision:** What was the final decision of your group? Did you agree with that decision? If you yes or no, explain why, based on the discussions, the data, and your understanding of the situation.
3. **Community decision:** What was the final decision of your community? Did you agree with that decision? If yes or no, explain why, based on the discussions, the data, and your understanding of the situation.
4. **Your final decision:** What is your final decision as to the Hurricane Smith evacuation plan?
 - (a) Explain why your decision is the best and include any evidence you can cite, including scientific theory and concepts for the causes of hurricanes. You should make a persuasive argument for why this is the best decision, so make sure to provide clear, substantiated arguments and data.
 - (b) Include graphs, diagrams, maps or any data that support your reasoning.
 - (c) Describe examples from the real world and any other explanations that you think support your decision, if appropriate.

Save your report as a Word document with your name as the title of the document. In the document, make sure to specify your name and email address. Submit the word document in the assignment drop box set up on the ANGEL course website.

Appendix C.
Active Learning Module II: Instructional Materials (Sample)

Name: _____

Guidelines for this Individual Activity

This individual worksheet is designed to help you understand and prepare for the group activity and final paper on the impact of Global warming in Bangladesh. The worksheet will help you think about the socio-cultural context of Bangladesh and the impact of global warming on Bangladesh.

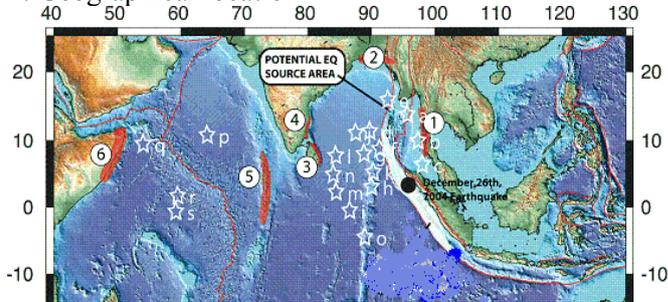
To complete the individual worksheet, you should:

- Read the set of information provided on ANGEL carefully.
- Write down answers to each question, based on your understanding of the material.

Remember to bring this worksheet with you to class on Tuesday, Dec. 4!

I. Understanding Bangladesh

1. Geographical location



a. Which number (1-6) represents Bangladesh?

b. How does the location of Bangladesh influence its weather?

2. Based on information on the socio-cultural context of Bangladesh (e.g., habitat, food, occupation, communication systems, infrastructure, etc.), imagine you are living in Bangladesh and describe what your daily life might be like.

II. Flooding in Bangladesh

Flooding is a nation-wide problem in Bangladesh. Based on your understanding of Bangladesh, try to **connect the specific context of Bangladesh with problems arising from flooding**.

- Below, write down the major facts about flooding in Bangladesh. For example, when does flooding occur, how often, and what types of flooding occur?

Seasonal influences	
Frequency of flood	
Various floods types	

- What kinds of damage result from flooding in Bangladesh? And how severe are these damages? (Think especially about influence on the daily lives of the people of Bangladesh.)

- NOW** think about *how it would be different to deal with flooding in Bangladesh and flooding in the U.S.A.* (For e.g., what difference does *population density* make in dealing with flooding in both countries?) In each column, write down specific things you must consider in dealing with flooding in each country.

	Bangladesh	US
Population density		
Literacy level		
Transportation		
Communication systems		

(other factors you consider important)		

- Write down what you think is especially important to consider when dealing with flooding in Bangladesh and provide your reasoning about why you think it important.

III. Global Warming & Bangladesh Flooding

Now focus your attention on the relationship between global warming and flooding in Bangladesh.

- What impacts can global warming have on Bangladesh? (Think about agriculture, daily life, society, etc.,)
- Which impacts of global warming have the most serious implications for Bangladesh? Why do you think so?
- Some claim that *surrounding/rich nations should share the blame for Bangladesh's flooding problems*. Do you agree with this statement? Why or why not?

- b. Based on the list of all impacts you generated, which do you think are the most important aspects of flooding on Bangladesh that you want to present? Also, think about why these are the most important aspects to present.
4. a. What impacts does global warming have on Bangladesh? Think of all the material you have read and discussed and identify all possible impacts. Remember impacts may be negative or positive.
- b. Based on the list of all impacts you generated, which do you think are the most important aspects of global warming on Bangladesh that you want to present? Also, think about why these are the most important aspects to present.
5. a. What will Bangladesh be like in 30 years if global warming continues?
- b. What responsibilities (if any) should other countries share for the Bangladesh flooding problem?

III. Instruction for Storyboarding

There are 12 storyboards and a script rectangle on next page. The script is at the bottom of the next page.

1. Storyboard

Each storyboard includes three things:

- 1) Title of the scene
- 2) content of the scene
- 3) presentation style for the scene

Following is an example of a storyboard on the topic of smoking:

Title: Intro to Risks of Smoking in Children
<p>Put content in the box</p> <p>Content: facts and list of potential risks of smoking in children</p> <p>Images: collage of smoking men, teens, mother and child, older lady</p>

*****It is not necessary to follow the format of the example. You can be as creative as you want.
Creativity is one of the keys to a successful documentary!*****

2. Script

Write down scripts for voice over the entire documentary in the big rectangle at the bottom.

*****Write on the back of the storyboard sheet if you need more storyboards*****

Appendix D.
Sample Scoring Rubric for Critical Thinking

Rubric for Group in Geo Class

1. Presents and prioritizes the danger and the impact of Hurricane Smith based on the group role.					
Emerging		Developing		Mastering	
1	2	3	4	5	6
<ul style="list-style-type: none"> Neither presents the danger situation nor the impacts from Hurricane Smith. Does not prioritize the impacts/dangers; provides only one correct priority danger/impact Provides no or very little justification for prioritization 		<ul style="list-style-type: none"> Partially recognizes and summarizes the danger and the impact of Hurricane Smith Neglects some important dangers/impacts of Hurricane Smith. Presents at least two correct priority dangers/impacts; Priority sequence may be appropriate Justification is provided for both listed priorities; however it may not be completely accurate and the reasoning provided is insufficient 		<ul style="list-style-type: none"> Clearly recognizes and summarizes the obvious and implicit danger and impact of Hurricane Smith. No important dangers/impacts are ignored. Presents three correct priorities in accurate sequence with explanations for prioritization Clear and compelling reasoning is provided for accurate prioritization for all three issues 	

2. Identifies and considers the influence of community context on prioritization and decision-making					
Emerging		Developing		Mastering	
1	2	3	4	5	6
<ul style="list-style-type: none"> Neither considers their community, nor integrates the influence of context in group perspective. Analysis does not use any information from the packet or other sources. 		<ul style="list-style-type: none"> Provides some recognition of context and consideration regarding their role and future decision making, although in a limited way. For example, some aspects of the community are addressed but not all important aspects may be evident Analysis includes partial information from the packet or other sources, but primarily relies on their existing knowledge or experience about Hurricane. 		<ul style="list-style-type: none"> Analyzes the issue with a clear sense of scope and context related to the community and their role. Most important community issues affecting their group are clearly recognized and described. Analysis considers whole influence of context by using data from the packet or other sources. 	

3. Presents and analyzes appropriate data and evidence for decision-making.					
Emerging		Developing		Mastering	
1	2	3	4	5	6

<ul style="list-style-type: none"> Resources selected are irrelevant to the problem Resources are not identified at all Data /evidence selected are inappropriate or unrelated to discussion on Hurricane Smith evacuation 	<ul style="list-style-type: none"> Identification of appropriate but insufficient data Only 60-80% of pertinent data are identified Interpretation of data in supporting group position may not be completely appropriate 	<ul style="list-style-type: none"> Salient/pertinent resources within the packet are clearly identified and listed in the group chart Pertinent data are presented in sequence Interpretation of data is accurate and support group decision on Hurricane Smith evacuation
---	--	---

4. Identifies and assesses conclusions, implications, and consequences					
Emerging		Developing		Mastering	
1	2	3	4	5	6
<ul style="list-style-type: none"> Fails to provide a conclusive summary or fails to provide any data/context within the summary Fails to provide any consequences or does not support with data or reasoning 		<ul style="list-style-type: none"> Provides an appropriate conclusion but does not provide sufficient data/context/ evidence to support conclusion May not adequately integrate the prior decisions in the summary Provides at least one appropriate consequence but may not provide data support or reasoning 		<ul style="list-style-type: none"> Presents an appropriate conclusion Considers context, data, and evidence in discussion of conclusion Adequately integrates discussion of both decisions in summary Provides one or more appropriate consequences with appropriate data support and/or reasoning 	

Scoring Rubric for Individual Essay

1. Identifies decisions appropriately from group and community discussions

Emerging		Developing		Mastering	
1	2	3	4	5	6
<ul style="list-style-type: none"> • Fails to provide any introduction to important issues raised in either discussion or only presents one of the issues. 		<ul style="list-style-type: none"> • Clearly identifies issues raised in group and community discussions. • May summarize the most important questions raised in both groups and provide own perspective. 		<ul style="list-style-type: none"> • Clearly recognizes and summarizes the embedded and implicit danger and impact of Hurricane Smith. • Identifies integral relationships essential to analyzing this issue. 	

2. Identifies and presents evaluation of group and community decisions.

Emerging		Developing		Mastering	
1	2	3	4	5	6
<ul style="list-style-type: none"> • Offers own evaluation without any reference to group or community discussions • Does not provide reasoning or evidence to support evaluation 		<ul style="list-style-type: none"> • Provides own evaluation based on group and community discussions • Acknowledges differences/similarities with group and community perspectives 		<ul style="list-style-type: none"> • Clearly states evaluation of group and community discussions • Acknowledges differences/similarities with group and community perspectives • Provides reasoning/evidence for own evaluation 	

3. Provides a clear and appropriate solution.

Emerging		Developing		Mastering	
1	2	3	4	5	6
<ul style="list-style-type: none"> • Offers an unclear or simplistic solution or position. 		<ul style="list-style-type: none"> • Offers a generally clear solution/position although gaps may exist. 		<ul style="list-style-type: none"> • Offers a solution/position that demonstrates sophisticated, integrative thought and is developed clearly. 	
<ul style="list-style-type: none"> • Presents position based on group/community discussions without any indication of own consideration 		<ul style="list-style-type: none"> • Presents own position such that it includes some original thinking that acknowledges, refutes, synthesizes or extends assertions from group/community, although some 		<ul style="list-style-type: none"> • Presents position in such a way that it demonstrates ownership for constructing knowledge or framing original questions, while integrating and 	

	aspects may have been adopted.	acknowledging other influences.
--	--------------------------------	---------------------------------

3b. Presents appropriate evidence and argument to justify own solution

Emerging		Developing		Mastering	
1	2	3	4	5	6
<ul style="list-style-type: none"> • Fails to present justification own solution. 		<ul style="list-style-type: none"> • Presents and justifies own solution without addressing other views, or does so superficially. 		<ul style="list-style-type: none"> • Clearly presents and justifies own solution while qualifying or integrating contrary views or interpretations. 	
<ul style="list-style-type: none"> • No argument is constructed for why this is the best solution 		<ul style="list-style-type: none"> • Argument is stated, but it is vague or general and does not address pertinent issues. 		<ul style="list-style-type: none"> • Argument is well constructed, and supported with persuasive reasoning. 	
<ul style="list-style-type: none"> • No evidence is provided or evidence to support the argument is weak or irrelevant. • Fails to provide any data/context within the solution. 		<ul style="list-style-type: none"> • Evidence to support the argument is relevant but not always important. • Provides an appropriate solution but does not provide sufficient data/context/ evidence to support it. 		<ul style="list-style-type: none"> • Evidence to support the argument is strong and relevant. • Considers context, data, and evidence in discussion of own solution 	

3c. Integrates perspectives from group and community into proposed solution

Emerging		Developing		Mastering	
1	2	3	4	5	6
<ul style="list-style-type: none"> • Deals with a single perspective and fails to discuss group/community perspectives. • Treats other positions superficially or misrepresents them. • Little integration of perspectives and little or no evidence of attending to others' views. No evidence of reflection or self-assessment 		<ul style="list-style-type: none"> • Begins to relate alternative views to qualify analysis. • Analysis of other positions is thoughtful and mostly accurate. • Acknowledges and integrates different ways of knowing. Some evidence of reflection and/ or self-assessment. 		<ul style="list-style-type: none"> • Addresses others' perspectives and additional diverse perspectives drawn from information to qualify analysis. • Analysis of other positions is accurate and respectful. • Integrates different perspectives and connects to one's own positions. Evidence of reflection and self-assessment (uses constructions like: I thought this but now it is... because, 	

		my original position was this, but now it is ...because etc.)
--	--	---

4. Communicates effectively

Emerging		Developing		Mastering	
1	2	3	4	5	6
<ul style="list-style-type: none"> • Work is unfocused and poorly organized and lacks logical connection of ideas. • Format is absent, inconsistent or distracting. • Few or no sources cited. 		<ul style="list-style-type: none"> • Basic organization is apparent; transitions connect ideas, although they may be mechanical. • Sufficient sources cited although not always appropriately to support position. 		<ul style="list-style-type: none"> • Language clearly and effectively communicates ideas • Organization is clear, with clear transition between ideas is well done. • Sufficient, relevant, and accurate sources cited appropriately to support position. 	

Appendix E.
Pre & Post-test on Students Learning

Demographic Information

Instruction: Please complete the following questions.

1. Last Five Digits of Penn State ID Number

Date of Birth (MM/ DD / YYYY) (/
/)

2. Gender

Male Female

3. Racial Background:

White Hispanic Asian African-American
 Pacific Islander American Indian Other _____

4. (Anticipated) Major

5. GPA (if 1st year, high school GPA)

6. SAT score (Combined Math & Verbal)
(approximate O.K)

7. Class Standing

First Year Sophomore Junior Senior Graduate Student

8. In which high school grade did you take:

Physics	8	9	10	11	12	Never
Chemistry	8	9	10	11	12	Never
Biology	8	9	10	11	12	Never
Earth Science	8	9	10	11	12	Never

GEOSCIENCE SRS TEST QUESTIONS:

Please answer the following questions to the best of your ability.

Category I. Quantitative Reasoning Skills

I-1.: Hurricane Preparedness

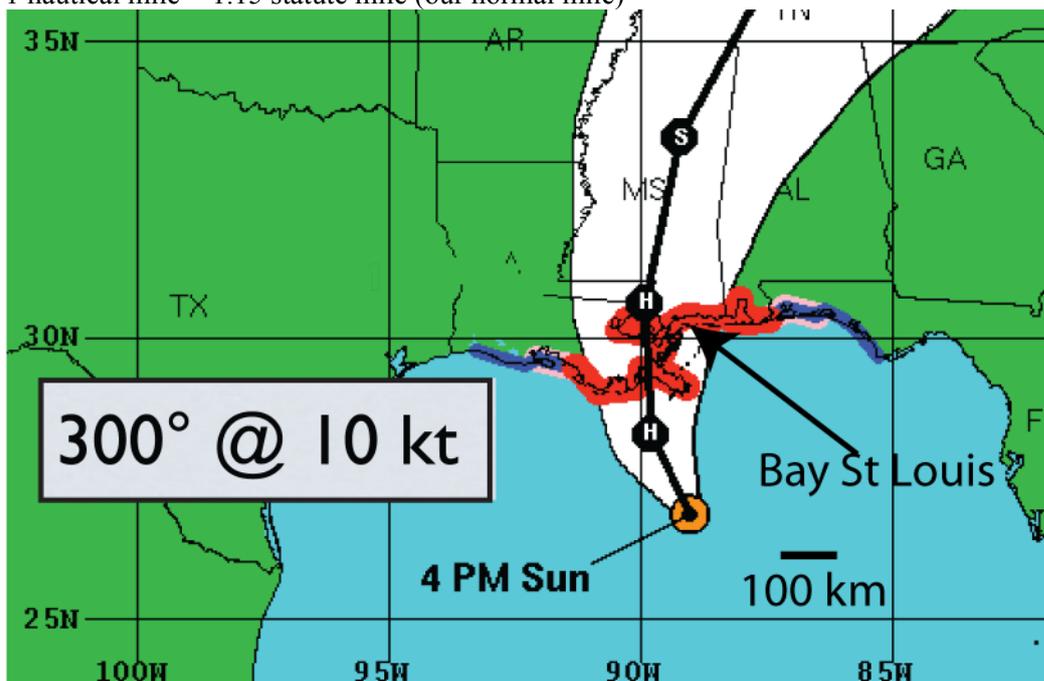
Traditionally the U.S. Weather Service presents hurricane information using a variety of different units: some using the metric system, some using the ‘English’ (standard U.S. system), and sometimes using nautical measurements. We need to be able to move among these measurement systems to make decisions regarding hurricane hazards.

On August 28, 2005, at 4 p.m. (Central Daylight Time) Hurricane Katrina was located as shown on the map below. It was moving approximately north-northwest but was expected to turn more to the north. It is moving at approximately 10 knots (kt).

1 kt = 1 knot = 1 nautical mile per hour

1 nautical mile = 1.853 km

1 nautical mile = 1.15 statute mile (our normal mile)



[Q1-4]The bar on the figure shows 100 km distance, please determine the following:

1. How far will the hurricane travel to reach Bay St Louis (a town located right on the coast and very much at risk from the hurricane)

- (a) 100 km
- (b) 220 km
- (c) 350 km
- (d) 500 km

2. If the hurricane is traveling at 10 kt, how fast is it traveling in km/hr?

- (a) 18.5 km/hr
- (b) 5.4 km/hr
- (c) 10 km/hr
- (d) 25 km/hr

3. When will Hurricane Katrina reach Bay St Louis?

- (a) 3:30 p.m. on Wednesday
- (b) 11 a.m on Monday
- (c) 11 p.m. on Sunday
- (d) 6 a.m. on Monday

4. More than 300,000 people will need to be evacuated from the Bay St. Louis region. When is the latest that the evacuation can start and still allow most people to escape the hurricane? [It takes 2-3 hours to 'evacuate' the 100,000 fans at a typical Penn State football game in Beaver Stadium]. (Explain your thinking for determining this answer)

I -2. Earthquake prediction

Some sections of faults appear to have earthquakes on a relatively regular time schedule. That is, the same size earthquake occurs at approximately regular time intervals along the fault. Such earthquakes are termed 'characteristic earthquakes'. Along the San Andreas Fault in California there is a region near the town of Parkfield that has such characteristic earthquakes. Here we want to explore whether we can predict earthquakes in such a region.

The table below lists a series of earthquakes that have occurred near Parkfield since 1850

Earthquake #	Date	Magnitude
1	1857	6
2	1864	2
3	1879	5
4	1881	6
5	1885	3
6	1900	2
7	1901	6
8	1922	6
9	1926	4
10	1932	5
11	1934	6
12	1936	3
13	1966	6
14	1970	4

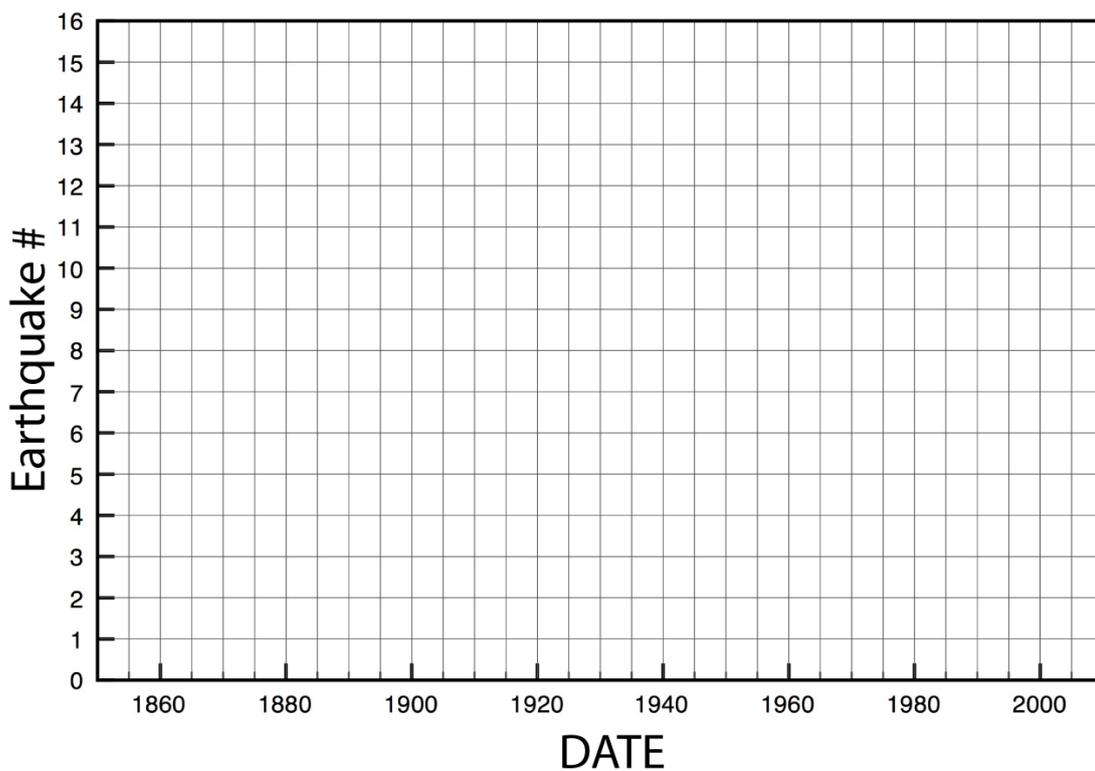


To explore whether we can predict earthquakes, we need to determine the characteristic behavior of earthquakes at this site.

5. What is the approximate average time between earthquakes?

- (a) 4.5 years
- (b) 9 years
- (c) 20 years
- (d) 40 years

6. Plot the data on the graph paper below. The x-axis should be the date of the earthquake, and the y-axis should be the earthquake number in the series.



7. Is there a simple trend to the data as plotted?

- (a) Yes, it can be easily fit by a single straight line
- (b) Yes, it is best fit by a function which has a stair-step shape to it
- (c) Yes, there are periods with several earthquakes followed by periods of no earthquakes
- (d) No, there is no pattern (the data are very scattered)

8. If you answered (a), (b), or (c) above, when do you predict earthquake number 15 to occur? How did you get that answer? Provide your calculations and reasoning for this prediction.

The concept of a *characteristic earthquake* assumes that the earthquakes are of similar size – usually the largest size is the characteristic size. In the table above, the earthquakes range in size from Magnitude 2 to Magnitude 6. If we limit our analysis to only the largest earthquakes (i.e. Magnitude = 6), will our answers change? The questions below should be answered on the assumption that we are talking of only characteristic earthquakes.

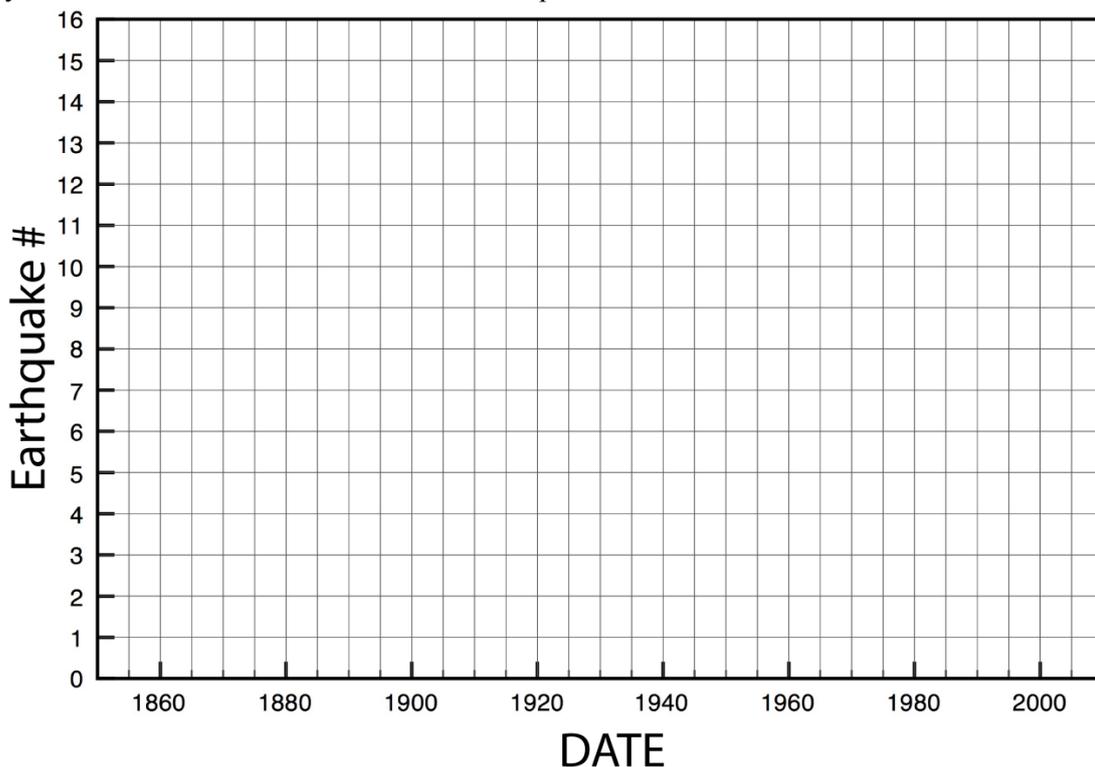
9. How many earthquakes in our data table can be considered characteristic earthquakes?

- (a) 14
- (b) 10
- (c) 8
- (d) 6

10. What is the approximate average time between characteristic earthquakes?

- (a) 4.5 years
- (b) 9 years
- (c) 20 years
- (d) 40 years

11. Plot the data on the graph paper below. The x-axis should be the date of the earthquake, and the y-axis now should be the characteristic earthquake number in the series.



12. Is there a simple trend to the data as plotted?

- (a) Yes, it can be easily fit by a single straight line
- (b) Yes, it is best fit by a function which has a stair-step shape to it
- (c) Yes, there are periods with several earthquakes followed by periods of no earthquakes
- (d) No, there is no pattern (the data are very scattered)

13. If you answered (a), (b), or (c), when do you predict the next characteristic earthquake to occur? How did you get that answer?

14. If you made an earthquake prediction in either part of this exercise, can you place an estimate on how precise that prediction is? What is your reasoning for this estimate?

Category II. Scientific Thinking Skills

15-16). Please read the description below and answer the following questions:

As early as the 11th century, Chinese doctors were manipulating the immune system. By blowing pulverized scabs from a smallpox victim into their patients' nostrils, they could often induce a mild case of the disease that prevented a more severe onslaught. In the 1700's, people rubbed their skins with dried scabs to protect themselves from the disease. These primitive practices were introduced into England and the American colonies. In 1771 and 1772, during a small pox epidemic, a Boston doctor named Zabdiel Boylston scratched the skin on his six-year-old son and 285 other people and rubbed pus from small pox scabs into the wounds. All but six of his patients survived.

15. What idea might Zabdiel Boylston have been testing?

16. Can you place this idea into a specific well-formulated hypothesis that could be analyzed using scientific observations?

Category III. Geoscience Concepts

17. What is the basis for the "scientific method?"
- Scientists come up with a theory and then seek out data to prove that it is correct.
 - Scientists experiment with data to observe the data that they like best.
 - Scientists try to discredit ideas proposed by others.
 - Scientists prove their hypotheses with data that demonstrates their correctness.
 - Scientists test their hypotheses with new observations and experiments.
18. Earth's lithospheric plates move at speeds of:
- a few millimeters per year
 - a few centimeters per year
 - a few meters per day
 - a few centimeters per day
 - a few millimeters per century
19. Which of the following would be the safest place to be in an earthquake?
- In bed
 - In a brick building
 - In a building with concrete walls
 - In a frame (wood) house
 - In a building with stone walls well cemented together
20. Which type of earthquake waves do the most damage?
- compressional waves
 - shear waves
 - body waves
 - P-waves
 - Surface waves
21. The double-deck freeway at the east edge of San Francisco Bay collapsed in the 1989 Loma Prieta earthquake because:
- it was too tall for its height.
 - it lacked steel reinforcing bars.
 - strong shaking lasted for more than the 30 minutes it was designed for.
 - it was built across soft muds.
 - water from San Francisco Bay rotted the foundation material, weakening it.
22. What was the first of two catastrophic events in Sumatra in December 2004 that killed tens of thousands of people. That first event was:
- a giant volcanic eruption
 - a giant tidal surge accompanying a late-season typhoon
 - the largest landslide in historic time
 - a continent-continent collision earthquake
 - a subduction zone earthquake
23. If an ash flow approaches you from across a kilometer-wide lake, are you likely to be safe or not? Explain why.
- Safe; hot ash flows would chill and stop as soon as they hit cold water.
 - Safe; ash flows move along the ground; they would continue harmlessly underwater.
 - Safe; hot ash flows would boil the water and that would stop them.
 - Not safe because a fast-moving ash flow would cause a deadly tsunami wave.

e. Not safe. Ash flows can cross much wider bodies of water.

24. Which of the hazards of volcanoes kill more people than anything else?

- a. lava flows
- b. ash flows
- c. ash falls
- d. landslides
- e. mudflows

25. Where in a hurricane are the winds strongest?

- a. in the eye
- b. just outside the eye (in the "eyewall")
- c. half way out to the outer fringe of the hurricane
- d. at the outer fringe

Appendix F.
Structured Interview Questions

Interview Protocol

1. Through the ANGEL course website, the Investigator (KyoungNa Kim) will make an announcement that 10-15 students are needed to participate in a follow-up interview at the end of the course. Most of the students of the course Earth101 already have been participating in the research by giving their consent at the beginning of the course. We will explain that this interview process will give us additional data to clarify the effects of the active learning processes on their learning. The questions are about what components of active learning they think supported their learning and reasoning skills developments through the course. If anyone volunteers to participate in the interview, they will be asked to send an email to kuk113@psu.edu (KyoungNa Kim).

If insufficient number of students (10-15) contact the researcher, the Investigator (KyoungNa Kim) will make an announcement in the class time that is allowed from the instructor. We will make sure the instructor leaves the classroom so that he will not know who volunteered to participate in the follow-up interview. We will ask students who are interested in participating to sign up in the class session and then contact them later.

2. All students who indicated interest in participating in the interview (either by email or during the class session) will be contacted by email to schedule interviews at their convenience. At the commencement of each interview, students will be informed of the general procedures of the interview through the consent form. We will ask them to sign the informed consent form and keep a copy for their records.

For the interview process, the procedure that will be taken is as follows:

[Introduction] At the beginning of the semester, we introduced this study. Many of you've consented and have participated in the research project as the part of the course requirements. Now you have completed the activities and produced various reports such as group charts, community charts, and individual reports. Please describe your impressions of how you engaged with the [name of active learning module: e.g., Hurricane Smith Activity].

In particular, I'm interested in the ways that your engagement with the learning activities supported your thinking through the course. The next few questions address this issue.

[Interview Questions]

I. Background Information Questions:

- What is your major?
- Are you first-year, sophomore, junior or senior?
- Have you ever taken any general education course that took place in a large hall with about 150 students before?

II. On the general characteristics of active learning employed in Earth 101 course:

< Overall >

1. Would you describe how you experienced the Earth 101 course in detail?
 - Have you had any *new and very helpful* experiences that made you more active in your learning with this course?
 - What were the characteristics of the course that helped you be more active and engaged in your learning? (e.g.,: small-group activity, problem-solving exercises, discussion,

etc.)

- In regards with supporting your thinking and learning, what are the advantages of this course format over the other format- such as lecture-based-learning, if it's any?
- What is the most helpful feature that supported your learning of natural disaster?

< In-class Activities >

2. Can you describe your in-class activities you experienced in Earth 101 such as watching the movie clips, small group problem-solving, and class discussion?
 - In which type, were you most active?
 - What would be the distinguishable characteristics compared to other general education course?
3. While you've been watching some of the video clips –either Hollywood movie or documentary movies, etc-. in class, you were also required to jot down your responses & thoughts to what you're seeing. Did you find them helpful? In what way?

(For instance, you wrote down your responses to the questions: (Interviewer can bring up some examples while presenting the activity sheet used in class; i.e., <In the Path of Killer Volcano>;“How did the scientists monitor the volcano? What were 2 signs that it would erupt in the very near future?,” and (b) <Fatal Flood>; “What were the fundamental changes to society after the 1927 floods? Do you expect similar fundamental changes as the region recovers from Katrina?”)
4. You've been working on the activities in class related to real problems in our society. How did this help your learning of natural disaster?

<Alternative format of assessment>

5. In terms of the assessment of the course, you didn't take any exams testing your knowledge or concept of natural disaster. Instead, you worked on the several assignments that you find interesting. Did you like or dislike it? How did this help you learn natural disaster?

< Assignments >

6. a) What did you have to do for your assignments?
- b) Many of your assignments were asking you to write about your understanding of a topic. Did these individual write-up assignments help you reflect on what you learned about natural disaster and what you discuss with other students in-class?

II. On the small-group work:

1. What kind of experience have you had in terms of small-group exercises that took place in the Earth 101course?
 - Could you describe any small-group activity you enjoyed?
2. In what ways did the small-group activities help you to make decisions?
3. How did the group discussions help you consider different aspects while you worked with other students?
4. As you engage with the small-group problem-solving activities (e.g., volcano stopping lava, Tsunami Warning Exercise, etc.), how did the small-group activities help you connect your knowledge of the natural disaster with real-life problems?

III. On the Active Learning Modules (Hurricane Smith or Bangladesh Flood Activity):

1. As you engaged with the activity [name of the activity, e.g., Hurricane Smith Activity, Bangladesh flooding), how did *the group discussion* help you make decision?
2. As you engaged with the activity, how did *the instructional materials you used* (e.g.; group chart, community chart) help you make decisions? For example, you were requested to list some aspects that should be considered first and provide your own reasoning for the each decision you made (i.e., Hurricane Smith activity). In what way, did this process help

you make decisions?

3. As you engaged with the activity [name of the activity, e.g., Hurricane Smith Activity], you worked in group first, then you were required to work on the individual report that asked you to discuss your own decisions and your reflections based on the group activity. How did this help you to consider different perspectives? How did *this process* help you deal with the complexity of natural disaster problems?
4. Hurricane Smith activity assigned you to a certain role such as emergency service, school system, media, etc. How did your role impact the way you discuss the problem? In what way did this sort of role-taking facilitate you being more active in the group discussion? (e.g., need to address the specific design features of Hurricane Smith Activity/ Bangladesh Flooding)

Appendix G.
Student Perception Questionnaire (Sample)

EARTH 101 Questionnaire

I. Learning Experience in the Course

This section of the questionnaire asks you to respond by describing your learning experiences as a student in the course Earth 101. Respond to each statement by checking one of the boxes from (1) strongly disagree to (5) strongly agree.

Strongly Disagree-----Strongly Agree

	Statements	1	2	3	4	5
On General course instruction						
1.	I enjoyed learning about the topic of this class.					
2.	The learning materials used in this class were helpful for learning.					
3.	I am satisfied with overall structure of the course.					
4.	I enjoyed the class activities.					
5.	I found the class activities useful to my understanding of natural disasters.					
6.	I found that the emphasis on the group activities and participation encouraged me to be active in learning.					
On Small-group work						
7.	I enjoyed working with others in the classroom (solving problems & working on the activities together).					
8.	I actively engaged with in-class exercises.					
9.	I found working with others to be less stressful than doing similar tasks alone.					
10.	I feel that my teammates collaborated in solving the in-class exercises.					
11.	I found that working with others improved my understanding of the course material.					
12.	I was able to help my teammates learn the course content.					

II. Effect of collaborative learning activities

This section asks you to respond by describing how group and collaborative learning activities might have helped you or developed your ability to do something. Respond to each statement by checking one of the boxes from (1) strongly disagree to (5) strongly agree.

Strongly Disagree-----Strongly Agree

	Statements	1	2	3	4	5
On Interpersonal/team Skills						
<i>The collaborative learning activities used in this course helped me develop my ability to:</i>						
13.	Orally present and support personal views.					
14.	Handle conflicts, negotiate agreements, and accept compromises.					
15.	Engage in discussion with an open mind.					
16.	Feel comfortable asking questions to clarify facts, concepts, and relationships.					
On Critical Thinking and Problem-solving skills						
<i>The collaborative learning activities used in this course helped me develop my ability to:</i>						
19.	Identify what information is needed to solve a problem.					
20.	Plan my work.					
21.	Set goals.					
22.	Stay on task while working on a problem.					
23.	Organize information.					
24.	Apply scientific concepts/ ideas to real-world problems.					
25.	Divide complex problems into manageable components.					
26.	Apply a systematic approach.					
27.	Consider other people's perspectives while making decisions.					
28.	Approach the problem from various perspectives (economic, social, and cultural, etc.)					
29.	Recognize contradictions/inconsistencies in ideas, data, etc.					
30.	Use established criteria to evaluate solutions.					
31.	Recognize flaws in my own thinking.					
32.	Understand the impact of real-life natural disaster problems.					
33.	Understand global perspectives on natural disaster problems.					
34.	Express my thinking clearly in writing and speaking					
35.	Evaluate arguments and evidence so that strengths and weaknesses of competing alternatives can be judged.					
36.	Use discussion strategies to analyze and solve a problem.					
Strongly Disagree-----Strongly Agree						

III. Open-ended Questions

1. *How actively* were you engaged in learning of natural disaster in this course?
 ___ A lot ___ Somewhat ___ Not at all

2. Why do you think you were engaged or not engaged in the activities?

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