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ENHANCING STUDENTS' CRITICAL THINKING IN SCIENCE: A TWO-YEAR DESIGN BASED EXPLORATION IN A LARGE UNDERGRADUATE SCIENCE COURSE

A Dissertation in

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ABSTRACT

The purpose of this study was to explore how to enhance students' critical thinking in an introductory undergraduate science course. As a design experiment, this study aimed to design, develop, implement, and refine learning activities, and investigate how the learning activities worked in fostering students' critical thinking in a large size classroom context.

In this study, critical thinking in science was framed with six categories, 1) identifying decisions, 2) evaluating decisions, 3) providing own decision, 4) argument and justification for own decision, 5) presenting supporting data/evidence, and 6) integrating other perspectives, as the result of literature review. To enhance critical thinking, three design principles, 1) authentic task, 2) question prompts, and 3) peer interaction, were associated with the learning activities for two consecutive years.

The research context was within a large general science course and the learning activities for a module were designed, implemented and refined for two years. Specially, changes in design strategies were made in the two design principles, question prompts and peer interaction, after the 1st implementation. With regard to the use of question prompts, the students of the 2nd year were provided with procedural and elaborative question prompts, while those of the 1st year only received procedural question prompts embedded in the Group and Community Discussion Charts. Second, instead of being engaged six times in two types of discussions, group and community discussions, the students of the 2nd year were required to take part in

a community discussion twice and to prepare for the discussion by learning about and understanding important aspects of dealing with the hurricane situation. For individual preparation, elaborative question prompts were embedded in the Individual Worksheet.

Quantitative and qualitative research methods were taken to investigate how the two different designs of the 1st and 2nd years worked for enhancing critical thinking in a large-size classroom. Data came from the students' written documents during and after the learning activities.

The result from the descriptive and comparative analysis on the written documents for two years indicated that there were changes in patterns of reasoning between the two years. It was evident that the groups engaged in decision-making for communities of the 2nd year showed more concrete and shaped reasoning than those of the 1st year.

The result of the t-test indicated that there was a significant difference in critical thinking demonstrated in individual reports between the students of the 1st and the 2nd years. The students of the 2nd year demonstrated better levels of critical thinking than those of the 1st year. Specially, among the six categories of critical thinking, the students of the 2nd year demonstrated better levels in three categories, 1) providing one's own decision, 2) argumentation and justification for one's own decision, and 3) integrating other perspectives, than those of the 1st year.

By the multiple-case study method, four themes were found to explain what made students demonstrated higher levels of critical thinking: 1) understanding of one's assigned role, 2) linking roles to make decisions, 3) answers to the question

prompts, and 4) use of data and source, were raised in explaining the different pattern between the students with higher and lower levels of critical thinking. Also, a trend was visible across artifacts for higher performing students in both years.

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CHAPTER 1

INTRODUCTION

Problem Statement

The purpose of this study was to explore how to enhance students' critical thinking in an introductory undergraduate geoscience course, by employing design based research methodology. As a design-based research study, this study includes the design of learning activities that encourages undergraduate students to develop critical thinking in a large science classroom context, and an investigation of the impacts on the students' learning when the learning activities were implemented.

An important goal of science education was to help students to use scientific concepts and understanding and apply scientific thinking in their everyday life. At the undergraduate level, general science education aims to develop lifelong learning of science in such a way that students can use data, scientific reasoning and evidence to deal with every day challenges in life or society and to deal with future challenges (Furlong & Sharma, 2005). Therefore, a significant question, in teaching introductory science courses at the college level, is how to develop students' critical thinking in science, avoiding direct instruction of only scientific concepts and knowledge with traditional lecture method.

Although there is a consensus on the need to develop critical thinking, the dissension occurs when attempting to define what it is. Most researchers agree that critical thinking is a higher order skill, which needs reasoning and judgment based on data and evidence (Yuretich, 2004). Ennis (1993) compares critical thinking to the

upper three levels of Bloom's taxonomy of educational objectives (analysis, synthesis, and evaluation), and refers to it as an ability to identify conclusions and reasons, to make a judgment, and to develop a position on an issue, defining it as reasonable reflective thinking focused on deciding what to believe or do. In science education in both K-12 and higher education settings, critical thinking has been an important dimension since it emphasizes analyzing events and phenomena using a scientific reasoning process to make conclusions (Bailin, 2002).

Recently a number of studies on science education at the college level have been interested in designing appropriate learning environments in which students can experience the critical thinking process through general science courses (Bissel & Lemons 2006; Gupta, 2005, Kalman 2002; Kronberg & Griffin, 2000; Tyser & Cerbin 1991; Wesp & Montgomery, 1998; Yuretich, 2004).

Furthermore, with the shift from teacher centered to learning centered approach on learning and teaching, various instructional interventions such as problem based learning, cooperative learning, active learning, inquiry based learning, etc., have been emphasized to support teaching and learning in science courses at college level (Smith, et al., 2009).

With the assumption that critical thinking can be taught and learned and students can become better thinkers through such instruction, the focus of recent studies on learning and teaching in the field of science education is to design and develop new instructional interventions allowing students to think critically while taking part in learning process. Progressive question strategies about real-life environmental problems (Gupta, 2005), analyzing biological problems with peers

(Kronberg & Griffin 2000), cooperative learning approaches (Wesp & Montgomery, 1998), in-class investigations and online interactive quizzes (Yuretich, 2004), and evaluating information in popular media science articles (Tyser & Cerbin, 1991) are some examples of employing new instructional interventions to promote students' scientific critical thinking in introductory science courses at college level.

Although there have been many efforts to make effective learning environments that support students' critical thinking, several limitations and problems restrict the potential impact of innovative ideas and instructional methods on general science education. First of all, large class sizes of general science courses with more than 100 students enrolled make it difficult for both instructors and students to engage in meaningful learning process. For instructors, it is difficult to keep in touch the different perspectives and needs students bring to the class and to manage their classes (Carbone, 1999; MacGregor, 2000). Although there have been efforts to overcome the constraints of large size classes with small group learning activities, active learning, and community building (MacGregeor, 2000), there is little attention in the design of a learning environment that increase critical thinking in science in large size class.

On the other hand, some limitations are found in the existing studies on developing learning environments that promote students' critical thinking in science courses at college level, although these studies introduce and implement new ideas that students can experience critical thinking in class. First, some studies (Dewey & Meyer, 2000; Kronberg & Griffin, 2000) do not show empirical data and evidence regarding the impacts and effects of the new intervention. Second, they do not

account for how much students' critical thinking is developed through the course, but test students' grades, attitudes, and satisfaction, after the course. Further, research does not account for learning processes while they are involved in critical thinking in science class. Third, most studies are conducted over a short-term period and focus on only on one implementation, setting limitations on fully articulating their instructional interventions.

Meanwhile, some studies on science education in K-12 settings focus on how students are engaged in meaningful learning activities when instructional interventions are evaluated by employing design experiment methodology (Brown, 1992). For instance, Kafai and Ching (2001) conducted design experiments multiple times to examine how a given project design task like creating multimedia software for science instruction affords opportunities for students to engage in science inquiry. The main focus of Kafai and Ching's study was to examine whether an instructional intervention, designed to promote students' scientific inquiry, would work in an elementary science class. Therefore, Kafai and Ching's study used design based research methodology to investigate the impacts of the intervention instead of testing or comparing pre and post learning outcome. Through the study, Kafai and Ching can understand what happened in class where Kafai and Ching designed and implemented project-based design activities.

Bell and Linn (2000) also conducted design experiments to test and elaborate on their design framework to promote students' scientific argument by examining how students use evidence, determine when they add further ideas and claims, and measure progress in understanding light propagation. Through qualitative analysis of

students' learning process, they confirm the benefit of their design principles for supporting knowledge integration.

These two studies on science education are characterized as kinds of design based research, which regards instructional interventions as strategies for developing and refining educational theories in a certain context (Edelson, 2002). Compared with traditional educational studies, which argue that instructional intervention serves as a way to implement theories for testing, design based research is more interested in designing, developing, and implementing instructional interventions, and investigating how they work in a certain context. After Brown (1992) and Collins (1992) suggested "design experiments" as a new methodology, design based research has been increasingly employed to refine and improve learning environments instead of strict laboratory setting to generalize research finding to another settings.

Another characteristic of design based research is that it is long-term research. It aims to situate instructional interventions to a certain learning context by improving and refining them with empirical data and evidence over an extended period of time. For instance, Zhang et al. (2009) conducted design based research in supporting 4th grade students to use collective cognitive responsibility in knowledge-building communities for over the span of three years. In their three-year study, they continuously refined their instructional intervention, gave the students various collective responsibilities, and provide more effective learning environments. In their 1st year, they focused on implementing fixed small groups; in their 2nd year, they implemented interacting small group with substantial cross-group knowledge sharing; and in the third year, they focused on opportunistic collaboration, with small

teams forming and disbanding under the volition of community members, based on emergent goals. From qualitative data and social network analysis, they suggest that a flexible, opportunistic-collaboration framework can give rise to high-level collective responsibility and dynamic knowledge advancement.

With some limitations and problems stemming from the characteristics of general science education and gaps in existing studies on enhancing critical thinking at college level, the main goal of this study was to understand how to support students critical thinking in science by developing and refining instructional interventions in a large geoscience course, in which more than 100 students were enrolled over the span of two years. Therefore, one of the purpose of this study was to design and develop a meaningful learning environment in which students could take part in scientific critical thinking process, and the other was to refine the learning environments, by finding out how the learning environment worked in the real class context. Specifically, in order to find evidence of whether students' critical thinking in science was supported by the designed learning environments, this study collected and analyzed the students' learning process and outcomes throughout the two-year implementation.

This type of design based research provides understanding about an introductory science learning context offered as a large size class at the undergraduate level. Further, the study presents an appropriate approach on learning and teaching to enhance students' higher order thinking, and suggests a means of overcoming the barriers to expand the new instructional ideas and interventions for college science courses.

Research Questions

1. What changes are visible in group decision making and reasoning as represented in the group worksheets between the1st and 2nd years?

2. What differences in levels of critical thinking are evident in the group reports and individual reports between the1st and 2nd years?

3. What differences are evident in the individual and group worksheets and individual reports between the students with higher and lower levels of critical thinking in the 1st and 2nd years?

Significance of This Study

This study has two aims: one is to design and develop meaningful learning activities through which students can take part in critical thinking processes in a large science classroom setting, and the other is to examine if students' critical thinking is increased through the learning activities in the science course. Therefore, this study has significant implications for both design and learning aspects of educational research.

With regards to design aspect, this study brings ideas and perspectives on how to design a large enrollment class to enhance students' critical thinking in science. In particular, this study suggests design principles, rationales, and ideas of how to implement, and how to evaluate students' meaningful learning in a large undergraduate general science course.

Second, the examination of students' learning outcome suggests how the learning activities, employing authentic problem, scaffolding strategies, and collaborative learning, influenced students' learning process and outcome. Since this study focuses on enhancing students' critical thinking in science, the examination will reveal the design principles roles in fostering students' critical thinking in science.

As a study on enhancing critical thinking, this study is interested in critical thinking in a science course context, not general critical thinking. This study will bring ideas of how to design and assess the critical thinking situated in a certain context.

Lastly, this study is significant in that it was long term, conducted over two successive years in an undergraduate course. Therefore, this study will be able to compare the results between two years and then suggests implications of design and learning in a large enrollment course.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews literature related to critical thinking in learning and teaching, and design principles and rationales to enhance critical thinking in science. The first section reviews the existing concepts and definitions of critical thinking. The second section reviews design principles and rationales for designing and developing learning activities, which enhance critical thinking in science. By reviewing theoretical and empirical studies on fostering thinking skills, especially in science learning, three design principles – authentic task, question prompts, and peer interaction – were identified.

Critical Thinking in Learning and Teaching

Concepts and Definitions of Critical Thinking

In the past few decades, critical thinking has been regarded as an educational ideal and a desirable human trait. There have been many efforts to conceptualize and define critical thinking within the context of learning and teaching and within the fields of philosophy and psychology, and their approaches on viewing critical thinking differ vastly. For example, philosophers focus on exact definitions and criteria of critical thinking, whereas psychologists emphasize methods and underlying cognitive operations involved in critical thinking (Quellmalz, 1987).

Philosophical Approaches on Defining Critical Thinking

Numerous scholars have contributed to identifying and clarifying the concepts of critical thinking. Building off of Johnson (1992)'s summarization of the five distinctive and representative concepts of critical thinking, Ennis (1962, 1985, 1987, 1989), McPeck (1981), Siegel (1989), Lipman (2003), and Paul (1989) argue that each of these concepts offers a unique concept and framework in understanding critical thinking.

Ennis' (1962) definition and concept of critical thinking have been used widely to explicate what critical thinking is. His initial simple explanation about critical thinking as the *correct assessment of statements* incurred much criticism. For example, Lipman (2003) points out that the "correct" assessing of statements does not guarantee that thinking will be of high quality because the term "correct" implies passivity and compliance with social norms, and individuals tend to do what society believes is right. In addition Lipman (1988), Siegel (1988) and McPeck (1981) also criticized Ennis' definition as being too simplistic.

Thereafter, Ennis elaborated his own definition and theory of critical thinking (see Ennis, 1985, 1987, 1989), providing a more complex and detailed explanation about critical thinking. He defines critical thinking as *reasonable reflective thinking that is focused on deciding what to believe or do*. In order to elaborate and support his definition, he proposes that there are five key components of critical thinking: practicality, reflectiveness, reasonability, beliefs, and action. He regards critical thinking as a practical activity, which includes most of the higher order thinking skills. Further, critical thinking requires certain types of abilities such as clarity of

thinking, ability to make appropriate inferences, engagement in advanced clarification, decision-making and taking action, and engagement in appropriate interaction. In contrast to his initial definition, his revised definition uses the terms "reflective" and "reasonable" to describe critical thinking. He urges that the quality of being "reasonable" makes critical thinking "quality" thinking, and the quality of being "reflective" means that critical thinkers should reflect on their thinking in order to be aware of strengths and weaknesses in their thought process.

Although Ennis approaches critical thinking through a productivity and process-oriented lens, McPeck incorporated the concept of "propensity" into his definition and conceptualization of critical thinking (1981). McPeck defines critical thinking as *the skills and propensity to engage in an activity with reflective skepticism* (p. 9). The term "propensity" can be interpreted as an affective characteristic possessed by a critical thinker. The term "skepticism" refers to the judicious use of skepticism in which truth is not taken for granted unless there are sufficient reasons to believe something is true, instead of questioning the truth of everything. Therefore, for McPeck, critical thinking is both a skill as well as a tendency.

While McPeck adds on to Ennis' definition, Lipman (1988) provides his own concept and definition of critical thinking. He views critical thinking as *skillful, responsible thinking that facilitates good judgment because it: 1) relies on criteria, 2) is self-correcting, and c) is sensitive to context* (p. 3). One important concept in his definition is the necessity for "criteria" when understanding critical thinking. He

suggests that "making judgments is a skill, critical thinking is skillful thinking, and skills cannot be defined without criteria to judge skillful performances" (p. 30).

Unlike his predecessors, Paul (1989) does not define critical thinking as a single definition. Tracing critical thinking back to the ancient Socrates' method, he contends that there are different types of critical thinking: weak, strong, or fair-minded. He provides several ranges of definitions of critical thinking. Among these, the most well-known definition is the following:

> Critical thinking is that mode of thinking-about any subject, content, or problem in which the thinker improves the quality of his or her thinking by skillfully analyzing, assessing, and reconstructing it. Critical thinking is self-directed, self-disciplined, self-monitored, and self-corrective thinking. It presupposes assent to rigorous standards of excellence and mindful command of their use. It entails effective communication and problem solving abilities, as well as commitment to overcome our native egocentrism and sociocentrism (Paul, 2004, p. 2).

To sum up, philosophers have established critical thinking as an educational ideal and measured it synonymously with good thinking. In short, they view critical thinking as an essential component of a well-educated person.

Psychological Approaches on Defining Critical Thinking

In the field of psychology, critical thinking is identified as a process related to skill, knowledge, and attitude (Halpern, 2002). The interest of psychologists in critical thinking is about how people should think critically and what kinds of mechanisms exist, instead of defining and clarifying critical thinking itself.

Halpern (2002) defines critical thinking from a psychological viewpoint as: "*the use of cognitive skills or strategies that increase the probability of a desired outcome; therefore, critical thinking is a kind of thinking that is purposeful, reasoned, and goal directed in solving problems, formulating inferences, calculating likelihoods and making decisions, when the thinker is using skills that are thoughtful and effective for the particular context and type of thinking task" (p. 5)*. Halpern's definition is skill and process-oriented and emphasizes purpose and goal, which should be achieved through certain thinking procedures.

However, while Halpern emphasizes cognitive skills and strategies, Kuhn (1999) views critical thinking as metacognition. Kuhn's main contention is that critical thinking is a second-order meta-knowing skill that entails knowing about one's own (and others') knowing, distinguished from first-order cognitive skills that enable one to know about the world. Kuhn regards critical thinking in the same manner as Paul's (1990) conceptualization in that it is "the art of thinking about your thinking" (p. 32). According to Kuhn, metacognition consists of three important skills: metacognitive, metastrategic, and epistemological. The development of metacognitive understanding is essential to critical thinking because critical thinking involves reflecting on what is known and how that knowledge is justified. Second, metastrategic skills are essential to critical thinking because those who have developed metastrategic skills apply consistent standards of evaluation across time and situations. Third, the development of epistemological understanding is fundamental in critical thinking because people must see the value in this kind of thinking if they are to engage in it.

While Halpern and Kuhn have different points of view on defining and identifying critical thinking, they clarify that critical thinking is a complex thinking skill with several components. In addition, these psychological perspectives help to assess critical thinking in learning, by identifying the kinds of cognitive and metacognitive skills that are involved in critical thinking. Therefore, this study adopts these psychological perspectives in order to identify and assess the components of students' critical thinking in science.

Problems of Defining and Conceptualizing Critical Thinking

Although philosophers and psychologists have provided numerous definitions, there is little agreement on what critical thinking is in the area of learning and teaching. In fact, the definitions and concepts of critical thinking have been developed through several debates among scholars who have provided their own definitions. For example, McPeck (1981), Siegel (1988), and Lipman (1981) studied and identified flaws in Ennis' early definition of critical thinking in order to develop their own definitions. Later, Ennis (1989) also identified some faults in other scholars' definitions and views on critical thinking. McPeck (1981, p. 2) speculates that the existence of varied concepts of critical thinking stems from approaching the concept as though it were a self-evident slogan whose precise ingredients were considered to be clear and self-justifying by those who favor its promulgation. He stresses that the phrase "critical thinking" is both over-worked and under-analyzed. Furthermore, in order to teach critical thinking, he insists that clarifying what it is

should be the first step before answering questions related to critical thinking. This clarification will make the learning objectives and methods clearer.

Johnson (1992) summarizes the problem of forming precise definitions in the critical thinking movement. He reviews the five representative definitions in the community – those of Ennis (1987), McPeck (1981), Siegel (1988), Lipman (1981), and Paul (1989)--and identifies problems with the scope and connections of their definitions. For example, Ennis's definition equates critical thinking with rational thinking and suggests there is a very close connection between critical thinking, creative thinking, and problem solving, but it does not provide any clear relationship with other types of thinking. In addition, Ennis's definition makes the scope of critical thinking unclear because it extends to too many actions and beliefs.

In response to the dilemma of defining critical thinking, Johnson suggests that a possible solution is to go back to consider the term "critical" and think about what a good critic is. He explains that "critical" means to estimate the value of something and those who make good critics have certain skills, an appropriate background, and traits like fair-mindedness, honesty, and so on. The focus of Johnson is to clarify the term "critical thinking" conceptually by summarizing and comparing the existing definitions to avoid any confusion with other thinking skills.

However, Kuhn (1999) criticizes the existing definitions proposed by educational philosophers as not being based on empirical studies, but purely conceptualizations. In addition, Kuhn points out that they do not account for directions and processes of development of critical thinking. Instead of defining what critical thinking is, she argues that identification of how critical thinking develops

and what kind of competencies and skills are involved are more significant issues in the practice of learning and teaching. Furthermore, empirical evidence from studies on the developmental process of critical thinking will help in clarifying what critical thinking is.

General Critical Thinking vs. Specific Subject Critical Thinking

One of the most significant questions in the critical thinking movement in learning and teaching is whether critical thinking should be taught separately or if it should be immersed within a specific domain (Abrami, et. al, 2008; Ennis, 1989; Kuhn, 1999; McPeck, 1981; Perkins & Salomon, 1993).

The debate on whether general critical thinking or domain specific critical thinking should be taught started with McPeck (1981). While developing the concept and definition of "critical," he raises an issue concerning the scope of critical thinking:

> Thinking is always thinking about something – for example, some problem, activity or subject area. And only things such as problems, activities or subjects can be thought about critically. Critical thinking always manifests itself in connection with some identifiable activity or subject area and never in isolation. Consequently, just as there are innumerable activities and types of activities that can be thought about critically, so there are innumerable ways in which critical thinking can be manifested. Just as certain activities can be done well or poorly, so certain activities can be done critically or uncritically. There are many distinct types of behavior that could count as 'critical thinking behavior.' (p. 5)

For McPeck, teaching critical thinking should not be isolated from specific fields or problem areas; rather, knowledge and skill are needed in order to constitute

critical thinking. However, if one is a critical thinker in a certain area called X, he or she might not be a critical thinker in area Y.

After McPeck's argument, Ennis (1989) elaborates on this issue and, after reviewing other scholars' works, he sees it as a matter of general critical thinking versus domain specific critical thinking. With regards to the question as to whether critical thinking should be embedded in a specific domain, he summarizes three principles:

1. *Background Knowledge*. Background knowledge is essential for thinking in a given domain.
2. *Transfer.* (a) Simple transfer of critical thinking dispositions and abilities from one domain to another domain is unlikely; however, (b) transfer becomes likely if, but only if, (1) there is sufficient practice in a variety of domains, and (2) there is instruction that focuses on transfer.
3. *General Instruction*. It is unlikely that any general critical thinking instruction will be effective.

Essentially, Ennis takes a mixed approach, which professes that there is a separate general principle of critical thinking but students are also involved in subject-specific critical thinking instruction. Therefore, his point of view on this issue lies in the middle between general critical thinking and subject or domain specific critical thinking. Ennis also concludes that the two principles, background knowledge and transfer, have been widely accepted, but the third principle is still controversial. In order to resolve this issue, he instructs that more empirical research

on which is more effective is needed and the term of "subject" or "domain" needs to be clarified. With regard to this issue, some scholars use the term "context" instead of "subject" or "domain" (Bilin, 2002; Halpern, 1992; Kuhn, 1999; Norris, 1985; Perkins & Salmon, 1993).

Ennis (1989) presents four types of instructional approaches on teaching critical thinking as follows:

- General approach: Teaching critical thinking abilities and dispositions separately from the presentation of the content of the existing subject-matter offerings.
- Infusion approach: Students are encouraged to think critically about the subject, and general principles of critical thinking dispositions and abilities are made explicit.
- Immersion approach: Students are deeply immersed in the subject, but general critical thinking principles are not made explicit.
- Mixed approach: A combination of the general approach with either the infusion or immersion approaches. There is a separate course aimed at teaching general principles of critical thinking, but students are also involved in subject-specific critical thinking instruction.

Using these four types of approaches on teaching critical thinking as a basis, Abrami and his colleagues (2008) meta-analyzed the effectiveness of these approaches on enhancing critical thinking skills and dispositions. They report that all instructional approaches were significantly effective for teaching critical thinking.

Among them, the mixed approach, where critical thinking is taught as an independent track within a specific content course, had the largest effect, whereas the immersion approach, in which general critical thinking principles are not made explicit, had the smallest effect. They also report that both instructional approaches, the general and the infusion approaches, had modest effects. Based on this result, they suggest that it is important to make critical thinking skills clear; it is especially important to do this when designing courses to enhance critical thinking.

Developmental Models of Critical Thinking

Psychologists in the area of critical thinking pay particular attention to how critical thinking is developed and how it is measured. These psychologists' views are helpful in identifying the components and dimensions needed to develop critical thinking.

Several studies (Bullen, 1998; Faccione, 1990; Garrison, Anderson, & Archer, 2001; Henri, 1992; Kuhn, 1991; Newman, Webb & Cochrane, 1995; Norris & Ennis, 1989; Perkins & Murphy, 2006; Quellmarlz, 1987) provide developmental models of critical thinking and provide what kind of dimensions should be dealt with in order to teach critical thinking in practice (see Table 2. 1).

Table 2. 1.

Summary of Critical Thinking Models

Study	Dimensions for/of Critical Thinking
Faccione (1990)	Interpretation Analysis

	Evaluation
	Inference
	Explanation
	Self-regulation
Kuhn (1991)	Differentiation of opinions from evidence
	Support of opinions with non-spurious evidence
	Proposal of opinions alternative to one's own and to know what
Norris & Ennis (1989)	Elementary Clarification
	Basic Support
	Inference
	Advanced Clarification
	Strategies and Tactics
Garrison, Anderson & Archer (2001)	Triggering Events
	Exploration
	Provision
	Resolution
Newman, Webb & Cochrane (1995)	Clarification
	In-depth Clarification
	Inference
	Judgment
	Strategy & Formation
Bullen (1998)	Clarification
	Assessment of Evidence
	Making and Judging Inferences
	Using Appropriate Strategies and Tactics
Perkins & Murphy (2006)	Clarification
	Assessment
	Inference
	Strategies
Quellmalz (1987)	Analysis
	Comparison
	Inference
	Evaluation

Most developmental models of critical thinking include "analysis," "inference," "evaluation," and "clarification." In particular, the models of Newman and his colleagues (1995), Bullen (1998), Henri and his colleagues (1992), and Garrison and his colleagues (2001) were developed to investigate how online discussions promote critical thinking skills in an online learning environment. For example, Perkins and Murphy (2006) created their developmental model to identify

and measure individual engagement in critical thinking in online discussions. In this study, their developmental model helped to show how students were engaged in specific critical thinking processes.

On the other hand, Quellmalz's model (1987) was proposed to generalize and specialize in reasoning skills in the areas of science, social science, and literature. Quellmalz argues that there are four general reasoning skills - "analysis," "comparison," "inference," and "evaluation" in the three subject domains, but each skill has a different definition in each domain. For example, in science, "analysis" means to "identify the components of a process or the features of animate and inanimate object," whereas in social science, "analysis" refers to "identify[ing] the components of an argument or the elements of an event." (p. 91)

Although these studies have provided different dimensions of critical thinking, they suggest a need for identifying essential dimensions of critical thinking in order to teach critical thinking. In addition, the dimensions for critical thinking help to assess students' critical thinking. Therefore, this study also adopts the need for identifying and exploring the various dimensions of critical thinking in order to truly develop critical thinking. By reviewing the existing models and reflecting on the task of the Hurricane Smith Module, the dimensions for critical thinking are "identification," "evaluation," "providing one's own decision," "justification," "providing supporting data," and "integration."

Existing Studies on Enhancing Critical Thinking at the College Level

The existing studies on enhancing critical thinking in science at the college level show the focus on developing various learning activities to promote students' critical thinking. Therefore, the studies focus on the learning activities in which students are actively involved in the learning process, avoiding direct teaching of scientific concepts and knowledge through lectures.

Most of the researchers and instructors who are interested in teaching science at the college level agree that higher order thinking, specifically critical thinking, is an important learning goal, so appropriate instructional strategies rather than didactic instruction are needed for students in general science courses (Gupta, 2003; Kronberg & Griffin, 2000; Yurentich, 2003).

Based on their educational beliefs and philosophies, faculty members who teach general science courses have conducted studies on enhancing critical thinking. To develop students' critical thinking skills, Kronberg and Griffin (2000) employed analysis problems in an introductory biology course at the college level. The analysis problem method for developing critical thinking skills was originally introduced by Allen and Moll (1986) in order for students to analyze and synthesize biological concepts. Although the analysis problem is in a multiple-choice format, it requires that students apply their knowledge and understanding of the situation to solve the problem successfully. Since the problem is based on a certain situation and the answers consist of the best answers and alternatives, students need to apply their knowledge and understanding to select the best answer carefully. For example, given the question, "A differential white blood cell count shows: neutrophils 61%,

eosinophils 2%, basophils ½%, lymphocytes 23%, monocytes 3 ½%. What is the likely diagnosis?" There are five choices students can choose: a) acute infection, b) chronic infection blood clots, c) allergy, or d) anemia. Even though the best answer to the question is "allergy," answer choice "c," (because in an allergic condition, the number of eosinophils should be elevated above three to five percent), students must also understand the other biological concepts and evaluate the given information. If students are not familiar with these concepts and do not have the necessary background knowledge, they will fail to select the best answer to this question. Kronberg and Griffin developed a set of analysis problems to teach their introductory biology course over a period of 10 years and reported that their method has helped students internalize the vast amounts of complex material that they need to be successful in the discipline. This study does not report any statistical or qualitative data in its findings. This is a limitation of previous studies.

Tyser & Cerbin (1991) used news exercises to develop critical thinking in their introductory biology courses. In their study, they used three steps to develop critical thinking in their course: 1) identifying evidence in the article, 2) evaluating the validity of the claim, and 3) writing a logically persuasive line of reasoning. Students were assigned six or seven news exercises at approximately biweekly intervals during the semester. For each exercise, students were asked to read a short science news article and contemplate a list of take-home questions that included one or two hypothetical claims posed by the instructor about the article. A week later, students took a short quiz made up of questions selected from the list. To evaluate the effectiveness of their method, using news exercises to develop critical thinking in an

introductory science course, Tyser and Cerbin compared two sections – an experimental section using news exercises and a control section not using news exercises. They found that the experimental group performed better on the objective questions ($t= 3.46$, $df=1$, $p < .01$) and on the reasoning section ($\chi 2 = 11.93$, $df = 1$, $p < .01$).

Yuretich (2003) applied various teaching methods, including in-class investigations, multiple choice exams, online quizzes or review and cooperative learning to encourage students' critical thinking in a general course at the collegiate level. For in-class investigations, he used a question format that requires students to synthesize and evaluate information they have gathered from the readings and lectures. He also used online interactive quizzes because students could get feedback from the online environment, and it challenges students to obtain the desired answer. In developing questions, he used higher levels of Bloom's cognitive taxonomy. Based on his findings after the successive implementation of these methods for approximately 10 years, Yuretich reported that exam performance had improved on students' numerical exam scores ($M = 77.14$ in 2001, 74.51 in 1998, 72.98 in 1996, 71.29 in 1993), and most students agreed that in-class activities increased.

Gupta (2003) used a progressive questioning method to improve students' critical thinking and problem solving skills in his senior-level science course. For his environmental science course, he addressed local community environmental problems and prepared progressive questions to solve the real life problems related to water pollution. Most of the progressive questions asked about the "causes," "results," and "natural phenomena" of water pollution. To help students prepare to

answer these questions, he had them examine audiovisual aids on wastewater and water treatment plants and read chapters about the Industrial Revolution and pollution. Also, he had classes discuss students' answers to the questions. Based on applying new approaches on his teaching, he reported that students' test scores and understanding about environmental problems improved and their class participation increased.

Although these studies are valuable in developing and implementing new instructional methods in large enrollment general science courses, some limitations exist. First, there is no clear definition of the critical thinking that instructors want to develop through their science courses (Gupta, 2005; Kronberg & Griffin, 2000; Tyesr & Cerbin, 1991; Yuretich, 2003). Second, some studies (Gupta, 2005; Kronberg & Griffin, 2000) just introduce new methods to develop critical thinking and do not show empirical evidence on how they affect the development of students' critical thinking. Furthermore, most of the studies (Gupta, 2003; Tyser & Cerbin, 1991) were conducted over a short-time period so there are limitations related to improving and refining the new methods.

Summary of Critical Thinking in Learning and Teaching

The literature related to critical thinking in learning and teaching reveals the need to define and conceptualize critical thinking situated in a specific context (Bailin, 2002; Kuhn, 1999; Perkins & Salomon, 1993) and to adopt developmental models to clarify what critical thinking is and how to teach it in a certain context (Kuhn, 1999; Norris & Ennis, 1989). This study approaches critical thinking in the

context of a geoscience course that aims to help undergraduate students understand scientific phenomena. Therefore, this study adopts the infusion approach that requires well-understood subject matter instruction in which students are encouraged to think critically about the subject. In addition, with the developmental approaches on critical thinking, this study defines critical thinking as "identifying decisions," "evaluating decisions," "providing one's own decision," "argumentation and justification," "presenting supporting data/evidence," and "integrating other perspectives."

Secondly, there have been few studies on enhancing critical thinking in the science course context at the college level, and the existing studies showed a lack of evidence in regards to what and how students improved their critical thinking through the treatments. In addition, previous studies did not show robust design rationales to create a new learning environment that aimed to increase students' critical thinking in science. This study will employ three robust design principles-- authentic task, scaffolding, and peer interaction--to develop students' critical thinking in science. The rationale for the employment of these principles is presented in the next section.

Design Principles and Rationales for Enhancing Critical Thinking

This section explores the design principles and rationales to design and develop the learning activities in which undergraduates can promote their critical thinking in science learning. By reviewing existing literature, three design principles

were identified to enhance thinking skills: authentic task, scaffolding, and peer interaction.

Authentic Task

Many researchers suggest that scientific thinking and higher order thinking are enhanced by the use of authentic task or problems (Berge, et al., 2004; Brown, et al., 1989; Collins, et al., 1989; Newman, 1991).

Jonassen (1999) suggests that "authentic" means that learners should engage in activities which present the same type of cognitive challenges as those in the real world, so that authentic tasks or problems should replicate the particular activity structures of the context.

Using authentic tasks in teaching and learning is based on the socio-cognitive approach of learning, which focuses on students' experience in their everyday life. Researchers with a socio-cognitive perspective on learning insist that traditional school settings have only taught *inert* knowledge decontextualized from the real world, which resulted in students having difficulties applying and transferring their knowledge in their everyday life (Brown, et al., 1989; Collins, et al., 1989; Newmann, 1991). Furthermore, they argue that knowledge is situated, being in part a product of the activity, context, and culture in which it is developed and used. Based on the epistemological view on knowledge, Brown and his colleagues (1989) propose cognitive apprenticeship, a method borrowed from craft apprenticeship, which argues that students can be engaged in authentic practice through activity and social interaction.

In the field of learning environment design, using authentic tasks has been regarded as one of the most important instructional strategies that provide students with activities that practitioners and experts engage with in real problem solving situations (Wilson, 1993).

There are several studies on the characteristics of authentic tasks and how to develop them in designing learning environments (Berge, et al., 2004; Choi & Hannafin, 1996; Herrington & Oliver, 2000; Jonassen, 1999). Berge and his colleagues (2004) provide two reasons why using authentic tasks is powerful in developing students' higher order thinking. One reason is that authentic tasks help students to be involved in professional activities that experts are actually doing in their field. Second, the characteristics of authentic tasks--ill-structured, meaningful, open-ended, and familiar--help students to engage in the construction of meaning and knowledge.

In designing learning environments for science education, authentic tasks have been used as a means of developing students' scientific thinking and reasoning. In particular, using authentic tasks in teaching science is supported by the needs and goals of science education. According to National Science Education Standards (CSMEE, 1996), everyone needs to use scientific information to make choices that arise every day and to be able to engage intelligently in public discourse and debate about important issues that involve science and technology. This notion implies that science is deeply situated in everyday life and encourages teaching science with authentic problems that students will encounter the real world.

Use of Authentic Task

There are several studies employing authentic problems within the design of learning environments focused on promoting students' thinking (Bell & Linn, 2000; CTGV, 1990; Kafai & Ching, 2001).

The Cognition and Technology Group and Vanderbilt (CTGV) (1990) designed and developed a learning environment that engaged students in mathematical reasoning. In this study, it was assumed that mathematical problems are ill-structured and complex; therefore, in order to engage students, activities relevant to the real world had to be implemented. CTGV developed video resources to provide mathematical problems reflecting the real world. After watching the video, students were required to define their tasks and sub-tasks to solve the complex problems. This study found that the authentic tasks situated in the real world were effective in improving students' problem solving and attitude toward mathematics.

In Bell and Linn's study (2000), a debate about "How far does light go?" was used to encourage students to link and connect their observations to theoretical perspectives and to use evidence from everyday experience to build a more cohesive and robust set of ideas. In this study, the researchers assumed that students would come to class with pre-existing personal experiences and ideas about the scientific phenomenon, so one of the important design principles is to help them integrate and apply their existing knowledge and experience to science theory. They found that students constructed arguments that typically include warrants for evidence and personally relevant conceptual ideas and communicated their understanding by adding new frames based on the evidence they investigated.

Kafai and Ching's study (2001) used a different type of authentic problem from the other studies. Instead of the emphasis on relevance with the real world, they designed a task in which students had ownership of the problem. In this study, students were required to design software in order to explain scientific contents through group activities, and they investigated whether there were scientific talks while students had created the software. This study reports that giving ownership to students through this software design positively impacted the quality of science integration.

Lastly, Gupta (2003) used local community environmental problems as authentic tasks in his environmental science course at the college level. The university he serves is well-known as a large poultry producer so he addresses this point to solve real life problems related to water pollution. He reports that addressing real problems in the classroom made students participate more actively in class discussions and devote more time to solving the problems.

The above studies indicate that to deal with a similar and complex problem that occur in their everyday life (CTGV, 1991) and to engage in active learning (Gupta, 2003), creating an authentic task is a useful strategy in order for students to make connections between new concepts and their personal understanding (Bell & Linn, 2000). Based on these advantages, this study adopts authentic tasks to provide more meaningful learning activities with student ownership in the designing of specific modules for the course, *Earth 101: Natural Disaster*, and the designs were aimed to develop students' critical thinking.

Scaffolding

Theoretical Framework of Scaffolding

Scaffolding is a broad concept that covers various instructional strategies on how to help students gain specific learning goals and engage in the learning process. The concept of scaffolding is traced back to Vygotsky's Zone of Proximal Development (ZDP), defined as the "*the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance and in collaboration with more capable peers*" (Vygotsky, 1978, p. 86).

In Vygotsky's notion of ZPD, there is a gap between potential and actual development; a child has the capacity to reach a higher level of development if he or she has the appropriate support and social interaction with adults or peers at a higher level of development.

Wood, Bruner, and Ross (1976) revitalized Vygotsky's view on ZPD by introducing and defining scaffolding as an "adult controlling those elements of the task that are essentially beyond the learner's capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence" (p. 90). Simply stated, scaffolding implies that students can attain a goal or engage in a practice otherwise out of reach, given appropriate assistance (Davis & Miyake, 2004).

Types of Scaffolding

Scaffolding has been identified as an important strategy in supporting learning in project-based and design experiments. There are several studies on classifying the kinds of scaffolding and their usages in designing learning environments (Bell & Linn, 2000; Hannafin, Land, & Oliver, Linn, 2000).

Hannafin and his colleagues (1999) present four types of scaffolding based on the mechanisms and functions of open learning environments (OLE): conceptual, metacognitive, procedural, and strategic scaffolding. Table 2. 2 shows their classifications of OLE scaffolding. According to Hannafin, et al.(1999), scaffolding can be differentiated by mechanisms and functions and varies according to the locus of problems posed in the enabling context.

Table 2.2.

OLE Scaffolding Classifications (Hannafin, et al., 1999)

Scaffold Types and Functions	**Related Methods & Mechanisms**
Conceptual Guides learner in what to consider; consider actionswhen problem task is defined	Recommending the use of certain tools at particular stages of problem solving Providing students with explicit hints and prompts as needed (Vygotskian scaffolding, intelligent tutoring) Providing structure maps and content trees
Metacognitive Guides how to think during learning: ways to think about a problem under study and/or possible strategies to	Suggesting students plan ahead, evaluate progress, and determine needs Modeling cognitive strategies and self-regulatory processes

consider; initial role in finding and framing problems, and ongoing role during resolution	Proposing self-regulating milestones and related monitoring
Procedural Guides how to utilize the available OLE features; ongoing "help" and advice on feature functions and uses	Tutoring on system functions and features Providing "balloon" or "pop-up" help to define and explain system properties
Strategic Guides in analyzing and approaching learning tasks or problem; provided initially as macro-strategy or ongoing as needs or requests arise	Enabling intelligent responses to system use, suggesting alternative methods or procedures Providing start-up questions to be considered Providing advice from experts

Linn's perspective on scaffolding (2000) is much broader than that of Hannafin and his colleagues (1999, p. 131-134). Based on longitudinal studies on designing learning environments for science education and synthesis of instructional frameworks, Linn presents the framework for scaffolded knowledge integration with four tenets and the associated design principles as follows:

- Making science accessible
    - Encourage students to build on their scientific ideas as they develop more and more powerful and useful, pragmatic scientific principles.
    - Encourage students to investigate personally-relevant problems and revisit their science ideas regularly.
    - Scaffold science activities so students participate in the inquiry process.
- Making thinking visible

  - Model the scientific process of considering alternative explanations and diagnosing mistakes.
  - Provide scaffolding for students so that they can explain their ideas sufficiently.
  - Provide multiple, visual representations from varied media.

- Helping students learn from each other
  - Encourage students to listen and learn from one another.
  - Design social activities to promote productive and respectful interactions.
  - Scaffold groups to design criteria and standards.
  - Employ multiple social activity structures.

The basic assumption for this scaffolded knowledge integration framework is that science education should help students connect ideas from science class to personally-relevant contexts in order for them to revisit these ideas outside of class. Making science accessible emphasizes building on what students know in order to enable students to connect new ideas, which means creating materials that invite students to develop a deeper, more well-linked and connected understanding of scientific phenomena. Secondly, making thinking visible involves modeling the process of knowledge integration by asking students to explain scientific evidence and by creating and providing multiple representations. Thirdly, helping students learn from one another is a way of encouraging students to take advantage of collaborative knowledge building. Lastly, promoting autonomy involves establishing a rich, comprehensive inquiry process that students can apply to varied problems both in science class and throughout their lives.

With several guidelines and frameworks of scaffolding, most design studies have focused on specific types of scaffolding under a specific context and have reported the impacts on students' learning.

Use of Scaffolding

There have been several studies on the use of scaffolding. Herrenkohl, Palinscar, DeWater, and Kawasaki (1999) studied the role and value of scaffolding in elementary science class. In this study, they designed a learning environment to foster a sophisticated epistemology of science by having students experience science as a process of revision. Students were required to work in small groups and to build and evaluate explanations. During their group work process and classes, they were provided with three procedural guidelines as scaffolding: 1) predicting and theorizing, 2) summarizing results, and 3) relating predictions and theories to results. The result of the pre- and post-tests of this study revealed positive changes in students' conceptual understanding as well as in their beliefs about the nature of scientific problem solving.

Saye & Brush (2002) used scaffolding to enhance critical reasoning about history and social issues in multimedia-supported learning environments. They conceptualized two types of scaffolds that assist students' learning: (a) hard scaffolds and (b) soft scaffolds. Hard scaffolds are static supports that can be anticipated and planned in advance based on typical student difficulties with a task. In contrast to hard scaffolds, soft scaffolds are dynamic and situational. Soft scaffolding requires

teachers to continuously diagnose the understandings of learners and provide timely support based on student responses. They suggest that expert guidance may be embedded into the learning environment to give students conceptual and strategic road maps that assist them in understanding the process of disciplined inquiry.

Use of Question Prompts

Question prompts have been adopted as a scaffolding strategy in several design studies. Question prompts have been found to be effective in helping students focus their attention and monitor their learning through elaboration on questions asked (Rosenshine, Meister, & Chapman, 1996).

Scardamalia, Bereiter, and Steinbah (1984) first used procedural prompts, such as "An example of this is…" and "Another reason that is important is….," to scaffold learners with specific procedures or suggestions to help them plan their writing. Later, King (1991, 1992, 1994) provided students with strategy-questioning prompt cards to teach them how to make inferences and generalizations and to ask for and provide task-appropriate elaboration. In one of her studies (1991), King emphasized the role of question prompts in scaffolding metacognition. She grouped questions into three metacognitive categories: planning, monitoring, and evaluation, which closely paralleled the general problem-solving mode. Questions such as "What is the problem?" and "What do we know about the problem so far?" were asked to help students with planning.

In Davis and Linn's study (2000), activity and self-monitoring prompts were used to scaffold students' knowledge integration. In this study, they found that activity prompts encouraged students to reflect on their progress in activities, while self-monitoring prompts encouraged students to reflect on their own learning by asking questions. These results show that both prompts worked well for students' science projects, but they had different functions in encouraging students' learning. Activity prompts helped students finish activities, but they did not necessarily help the students develop an integrated understanding. Otherwise, self-monitoring prompts provided scaffolding to help students think about their goals for and progress on a project.

After this study, Davis (2003) questioned whether students needed to be prompted to reflect or need guidance in reflecting productively in knowledge integration in middle school science. To investigate ways of prompting students for reflection, Davis designed and created two types of prompts: generic prompts, which represent a view that asks students to "stop and think," and directed prompts, which provide hints indicating potentially productive directions for a science topic. The result shows that students who received generic prompts developed a significantly more coherent understanding of science than the students who received direct prompts. Also, she found that students reflected unproductively more often in response to directed prompts as compared to the generic prompts.

Ge & Land (2003) also used question prompts in scaffolding undergraduate students' problem-solving process in an illstructured task in problem representation, developing solutions, making justifications, and monitoring and evaluating. In their

study, the question prompts referred to a set of questions that were domain specific and metacognitive, prompting students to attend to important aspects of a problem at different phases and assisting them to plan, monitor, and evaluate the solution process. The question prompts include a series of questions asking student to think about the following: “How do I define the problem?”, “What solutions do I need to generate?”, “What are my reasons, or what is my argument for my proposed solution?”, and “Am I on the right track?”. The results indicate that the question prompts had significantly positive effects on student problem-solving performance.

In Ge and her colleagues’ study (2005), question prompts were elaborated. This study used three types of question prompts-- Question-Elaboration (QE), Question-Guidance (QG), and Non-Question Prompts (NQ)-- with graduate students who took an instructional design course. In this study, QE referred to the condition in which students were required to respond to the question prompts, whereas QG was the condition in which the question prompts were presented as guidelines. The questions prompts were same for the students under both QE and QG, but the presentation of the question prompts was different. The participants in the NQ condition were asked to complete each of the two case studies by producing a final solution report without any question prompts, whereas the participants in the QE and QG conditions were provided with a list of question prompts after the presentation of the case study. The question prompts used in the QE and QG conditions asked the students to think about possible reasons and methods for the design project. For example, questions like “Is this design project in response to a problem or a need? Is there really a need for Web-based instruction? How do you know? How can you

determine this?" was to ask how to do design project. Overall, the both the QE and QG conditions were effective in guiding students' problem solving process, elaborating their thinking, and monitoring and evaluating the solution process. In addition, this study shows that different question prompts served different cognitive and metacognitive functions. For example, procedural guidance afforded by the question prompts helped the students to organize information for problem representation, whereas the elaboration feature of the question prompts facilitated the students in elaborating the initial state of the problem, identifying constraints, and considering different alternatives for representing problems. Also, this study suggests a need to design question prompts adaptively to meet the needs of individuals with different levels of prior knowledge, real-world experience, and problem-solving competence.

Although the above studies used question prompts that had already been designed and developed by researchers, Herrenkohl and Guerra's study (1998) had students develop questions by themselves in a science class. "What questions could we ask when it is our job to check predictions and theories?" was the researchers' main question when they asked students to create important questions. They found that the question chart created by the students was an effective and important scaffold for students taking on the role of audience members in promoting dialogic discourse and higher order intellectual reasoning. Herrenkohl and Guerra used the audience role procedures to engage students in: 1) asking for clarification to questions, 2) disputing or challenging others' perspectives and claims, and 3) coordinating bits of

knowledge. Their focus on listening skills and audience roles is held to be a critically important element of community discourse (Duschl & Osborn, 2002).

To sum up, question prompts as a scaffolding strategy are effective to develop students' thinking, by asking them to elaborate on their learning and to monitor and reflect where they are at in the learning process. Therefore, this study employs question prompts as a scaffolding strategy in order for students to develop several dimensions of critical thinking in a science course.

Peer Interaction

Theoretical Perspectives on Use of Peer Interaction

Social interaction with peers and adults has been regarded as a powerful strategy to make learning meaningful and productive. Epistemologically, emphasis on social interaction is based on the conceptions of socio-constructivists like Vygotsky and Dewey, who suggest that people learn best by a social knowledge-construction process (Bielaczyc & Collins, 1999).

Brown and his colleagues (1989) present benefits from collaborative group work for cognitive apprenticeship, which focuses on contextualized and meaningful learning. Firstly, through collaborative work within groups, students can get insights and solutions to solve problems that would not come about without this group interaction. Secondly, giving a role to each student in the group makes each group member understand a variety of roles and engenders reflective narratives and discussion about the appropriateness of each role. Thirdly, group work can be

efficient in drawing out, confronting, and discussing both misconceptions and ineffective strategies. Lastly, through the group work process, each student can develop skills needed for collaborative work.

Recently, numerous studies have been conducted to explain the benefits of providing group work opportunities in class. Webb (1989) points out that learning in small groups helps students develop reasoning and understanding because they have opportunities to explain their ideas to others.

Various strategies for group work have been employed in designing problems based on learning (Hmelo-Silver, 2000), goal based scenarios (Schank, 1994), and learning communities (Bielaczyc & Collins, 1999). Specifically, Schank's learning by doing approach (1999) suggests that role based group work provides students with ownership in regards to their specific role in a scenario. In the goal based scenario, there are several procedures and components in completing learning. First, students should identify their "mission" in the very beginning. Determining a mission allows them to understand what they should do and to identify how to do it. The mission is usually too complex to accomplish alone and requires students to perform collaborative work in order to solve the problem of the mission by focusing on understanding their own role. For example, if the mission is related to diplomatic problems, a group of students will have several roles, including President, Secretary of State, and U.S. ambassador. Each of the students focuses on performing his/her own role and collaborating with other group members in order to achieve the mission.

Use of Peer Interaction

Recently, Abrami and his colleagues (2008) found that collaboration among students while developing critical thinking skills appears to provide advantages. In their meta-analysis, they analyzed the effect of collaborative learning on teaching critical thinking by comparing the presence or absence of collaborative learning conditions. They found that collaborative learning conditions were more effective than conditions which did not provide collaboration in teaching critical thinking.

To enhance critical thinking skills, Anderson and his colleagues (2001) developed a teaching program in which students were engaged in critical thinking, and they investigated the effects of peer interaction within their group work project. In this study, students took part in peer-based exercises, in which they learned to critique imaginary examples of project outlines and plans, followed by similar peer-based critiquing of one another's proposed projects. To investigate the effects of peer interaction, the researchers analyzed students' dialogues with one another and conducted content analysis of their written work. The results indicate that students learned the importance of justifying arguments and engaged in justification of their arguments actively via peer interaction. This study shows that collaborative learning where students are required to engage in interaction with others can increase critical thinking skills.

However, Ge and Land (2003) report that peer interaction under ill-structured problem solving conditions did not show significant effects, although their qualitative findings indicated some positive effects of peer interaction in facilitating cognitive thinking and metacognitive skills.

With regard to collaborative learning, some research reports positive effects of small group and peer interaction on students' learning (King, 1989; Pea, 1993; Webb, 1989), but Abrami and his colleagues' meta-analysis on instructional interventions affecting critical thinking reports that the effects of collaborative learning is minor compared with other substantive instructional study features.

Cohen (1994) points out the importance of how to implement collaborative learning. She claims that groups need to be given group tasks that are fostered by procedural guidelines. For example, Herrenkohl and her colleagues (1999) studied the role and value of scaffolding in fourth grade science learning. In their study, students worked in small group and whole class contexts to build and evaluate explanations and were required to follow three strategic steps in science: 1) predicting and theorizing, 2) summarizing results, and 3) relating predictions and theories to results. Based on their previous studies, they did not expect the students to ask questions of one another spontaneously and did not think that providing materials and opportunities for physical manipulation would be sufficient enough to get students to develop a complex thinking practice. They gave explicit guidelines about what students should do in the project and in their role as audience members, instructing them how to question and comment on one another's work. The results of this study show that students' conceptual understanding increased, and their scientific reasoning was supported by their roles.

Summary of Design Principles and Rationales

Literature review reveals that the three design principles--authentic task, scaffolding, and peer interaction--are useful in fostering students' thinking skills and problem solving skills in science education.

In a science education setting, being confronted with authentic problems and tasks, instead of well-defined problems with a correct answer, helps students integrate scientific learning into their everyday life. In particular, integrating scientific phenomena that are familiar to students through everyday contexts helps engage students in the critical thinking process, which involves analysis, evaluation, and synthesis.

Among the scaffolding strategies, question prompts are beneficial in monitoring, evaluating, and elaborating students' learning process. In learning environments, to enhance scientific critical thinking, procedural and elaborative question prompts (Ge, et al., 2005) can help students to identify, evaluate, justify, and integrate their scientific learning.

Thirdly, peer interaction via a small group is essential for students to engage in and exchange their scientific knowledge and reasoning. Through collaborative learning and small group work process, students can have opportunities to identify and evaluate their own and others' opinions, justify their own arguments, and integrate others' perspectives. However, in order to support effective collaboration and interaction with others, careful design is needed.

CHAPTER 3

METHODOLOGY

Introduction and Research Questions

This study was a part of a two-year design experiment aimed to enhance undergraduate students' critical thinking in a large geoscience course, named *Earth 101 Natural Disasters*, *(Hollywood vs. Reality)*, by providing new learning activities. Specifically, the interests of this study were: 1) to design and implement learning activities by employing the three design principles, reviewed in Chapter 2, and 2) to investigate the impacts of the new learning activities on developing critical thinking within the larger classroom context. Two new learning modules were implemented over a two-year time frame. Each module had an instructional component as well as a practice/activity component, which included a variety of worksheets, to be completed in groups and individually. The focus of this study was on one of these modules, the Hurricane Smith Module, and the outcomes as represented in student artifacts of group work and individual work. These interests raised the following research questions within the Hurricane Smith Module:

1. What changes are visible in group decision making and reasoning as represented in the group worksheets between the 1st and 2nd years?

2. What differences in levels of critical thinking are evident in the group reports and individual reports between the1st and 2nd years?

3. What differences are evident in the individual and group worksheets and individual reports between the students with higher and lower levels of critical thinking in the 1st and 2nd years?

Methodological Approach

This study employed design experiment as the methodological approach because of the following reasons:

- The purpose of this study was to understand a certain learning context (Brown, 1992; Collins, 1992; Design Based Research Collectives, 2003; Hoadley, 2004), a large enrollment general science course with the purpose of prompting students' critical thinking in science.
- One of the goals of this study was to design, develop, implement, evaluate, and redesign the affordance of the learning activities (Collins, Joseph, & Bielaczyc, 2004; Design Based Research Collectives, 2003; Edelson, 2002; Wang & Hannafin, 2006) so that undergraduate students could actively engage in the scientific thinking process.
- This study had two aspects: design and learning aspects (Davis & Linn, 2000). In regards to the design aspect, this study aimed to design, develop, implement, evaluate, and redesign the affordance of the learning environment (Collins, et al., 2004; Design Based Research Collectives, 2003; Edelson, 2002; Wang & Hannafin, 2006) so that undergraduate students could actively engage in the scientific thinking process. Regarding the learning aspect, this

study investigated how the two designs work to support learning in real classrooms.

- Several experts, an instructor, an instructional designer, and the researcher worked together to design and implement the learning environment collectively (Design Based Research Collectives, 2003; Reigeluth & Frick, 1999).

Design experiment is a new research methodology for studying learning and teaching suggested by Brown (1992) and Collins (1992). Both researchers criticize the traditional educational methodology, especially the experimental design of the laboratory setting, because it does not reflect a real classroom context. Design experiment aims to understand "complex" and "messy" teaching and learning settings, not controlling for internal and external variables that might affect the outcomes (Brown, 1992; Collins, 1992), and focuses more on "design" as an important means in research (Edelson, 2002). Therefore, the main idea of design experiment is not to identify the effects of particular variables, but to improve a design by testing how it works with empirical evidence (Brown, 1992; Collins, et al., 2004; Edelson, 2002).

Traditional laboratory and design experiment differ in that design experiment focuses more on explaining a certain learning and teaching context, that target population, and collecting empirical data about how the design works in it. Thus, most design experiments adopt a narrative explanation about the research settings, and then either use quantitative, qualitative, or a mixed method to collect and analyze

the impacts of the designs. Collins and his colleagues (2004) state the goal and methods of design experiment clearly as stated below:

> Design experiments bring together two critical pieces in order to guide us to better educational refinement: a design focus and assessment of critical design elements. Ethnography provides qualitative methods for looking carefully at how a design plays out in practice, and how social and contextual variables interact with cognitive variables. Large-scale studies provide quantitative methods for evaluating the effects of independent variables on the dependent variables. Design experiments are contextualized in educational settings, but with a focus on generalizing from those settings to guide the design process. They fill a niche in the array of experimental methods that is needed to improve educational practices (p. 21).

As a design experiment, the foci of this study were on: 1) designing, developing, implementing, testing, and redesigning affordances of a learning environment, and 2) investigating how the design of the Hurricane Smith Module works for two years, Fall 2007 and Fall 2008. To better understand the learning and teaching context, the first part of the methodology section will give a detailed description of the two years' design efforts and the context where the design was employed in the Hurricane Smith Module. Then, the latter half of this section will describe the data collection process and the analysis technique used to find out through empirical evidence how the design worked.

Research Context

Introduction of the Class

The context of this study was within a geoscience course, *Earth 101- Natural Disasters (Hollywood vs. Reality)*. Offered as one of many general science courses, this three-credit course was made available to undergraduate students every fall semester at the Pennsylvania State University.

The goal of this course was to help students develop both an understanding of natural hazards and disasters, and enhance their understanding of scientific approaches to problem solving and the decision making process. During the course, approximately four or five topics were selected among various natural disasters: volcanoes, earthquakes, hurricanes, tornadoes, flooding, and tsunamis. This course aimed to provide opportunities for students to analyze the causes and consequences of natural disasters, and to evaluate popular media portrayal of disasters based on perspectives from scientific research.

Usually more than 150 students are enrolled in this course each semester, with most of them being non-science majors who want to take the course to fulfill part of their general education course requirements, specifically, their natural science requirement.

Rothman and Narum (1999) point out the problems that many large general science courses face as the following:

- The course was generally organized around lectures to passive students.

- Classroom practices generally did not reflect awareness of research on learning and were not geared to the variation in students' learning styles.
- The classroom had fixed furniture that was designed for a teacher-centered environment.
- The course was designed for students to work alone, not in a group.

The subject of this study, the geoscience course, had similar problems, including: 1) the fixed furniture in the classroom is not conducive to student-centered learning, 2) there are too many enrolled students with significant variations in their level of knowledge of science and learning styles, and 3) there are more than 150 students, which makes organizing group activities and interaction challenging.

To overcome these limitations, Active Learning in Large Enrollment Classes: Learning Modules that Work, a project funded by the National Science Foundation (NSF), was established. Using a large "lecture" based classroom setting, and with the collaboration of an instructor from the Department of Geosciences and six instructional designers from the Instructional Systems program at the Pennsylvania State University, the project focused on the development of active learning modules. These modules were based on natural hazard case studies that provide both content and context for understanding how science works in real-life settings (Furlong & Sharma, 2005). The instructor, who was from the Department of Geosciences, was chiefly involved in developing this module, and had taught the course every fall semester with two teaching assistants.

Hurricane Smith Module

Taken from the larger Active Learning project, this study focused on the Hurricane Smith Module, which was designed, developed, and implemented in Fall 2007 and Fall 2008. The goal of the Hurricane Smith Module was to enhance students' critical thinking levels in science, by combining an understanding of hurricanes as a natural disaster with an understanding of the context of how hurricanes work in the real world.

Given some limitations of the large classroom setting as mentioned previously, the instructor and six instructional designers from the Instructional Systems program designed the Hurricane Smith Module in which the undergraduate students develop their critical thinking in science. The three design principles reviewed in Chapter 2 were employed.

Authentic Task

First of all, the scenario of Hurricane Smith was developed, based on a real hurricane case, Hurricane Floyd, which struck the Southeastern U. S., based on the design principle of using authentic tasks. Since the students were familiar with natural disaster in their everyday life, the design team assumed that the real case would help students engage in activities that present to them a cognitive challenge (Jonassen, 1999), as well as involve them in professional practice (Berge, et al., 2004).

During the module, students were presented with a scenario wherein they were provided with updated information about the hurricane, its path, and its strength by the National Weather Service. The students were asked to consider the impacts of the Hurricane on a certain community and to make a decision about whether or not the population of the community should be evacuated. In order to have ownership in this issue, one of three communities, Morehead City of North Carolina, Hilton Head of South Carolina, or Deerfield Beach of Florida, as seen in Figure 3.1, was assigned to each student. Furthermore, each of them played a key role related to disaster management in a community. Resources for each community were uploaded in ANGEL, the course management system at the Pennsylvania State University.

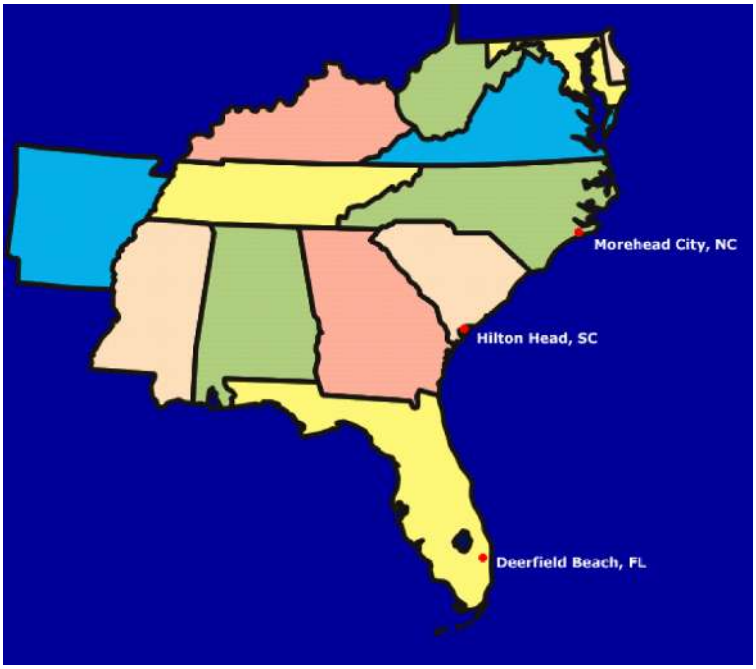

Figure 3.1. Locations of Three Communities in the Hurricane Smith Module

Peer Interaction

For the in-class activities pertaining to the Hurricane Smith Module, two design principles were used to foster students' decision making based on an authentic task. The design team assumed that peer interaction, whereby the students work collaboratively to solve the same task, would help them to develop reasoning and understanding (Webb, 1989), as well as restructure the large classroom setting (MacGregor, 2000). In particular, in order for students to have meaningful peer interaction, the design team adopted role based group work in which each student had a specific role related to disaster management within one of three communities that Hurricane Smith would impact. The main reason why role-based group work was used as a peer interaction strategy was to provide opportunities in which the students with specific roles in a community learning context consider what they should do in an emergency situation, and identify and evaluate others' ideas and opinions.

Question Prompts

To facilitate peer interaction, question prompts (Davis, 2003; Ge, 2005; Ge & Land, 2003; Linn & Davis, 2000) were used to scaffold students' reasoning process. The students received print materials with several question prompts so that they could focus their attention on the impacts of the hurricane on their community and made decisions about whether their community should evacuate or not and explained their rationale.

Participants

The participants of this study were undergraduate students who enrolled in Earth 101, an introductory geoscience course, which was offered in the Fall 2007 and Fall 2008 semesters at the Pennsylvania State University. In the 1st year, Fall 2007, 176 students were enrolled and in the 2nd year, Fall 2008, 178 students were enrolled. Among these students, 156 and 155 students agreed to take part in this study in the 1st and 2nd years, respectively. A majority of enrolled students in both the 1st and 2nd years were seniors, and most students had majors unrelated to science, such as Accounting, Journalism, Communication, etc. Differences in gender and year/level in college were minimal.

Table 3.1.

Participants of the 1st and 2nd years

College Year	2007		2008	
	Male	Female	Male	Female
First Year	1	3	8	1
Sophomore	27	23	16	16
Junior	12	8	9	13
Senior	42	38	52	40
N/A	1	1	0	0
Subtotal	83	73	85	70
Total	**156**		**155**	

Designs and Implementations

Since one of the important goals of a design experiment is to improve and refine the design strategies employed in a certain context (Design Based Collective 2003; Zhang et al., 2009), the design experiment is usually conducted at least twice. This study implemented the instructional module over two years in an undergraduate general science course in Fall 2007 and Fall 2008.

During the two semesters, the Hurricane Smith Module was created based on the three design principles and was refined to offer a learning environment conducive to fostering students' scientific critical thinking.

1st Year

In the 1st year, the Hurricane Smith Module was implemented with the original design, which the instructor and the six instructional designers had developed. As the Hurricane Smith Module got started, the instructor gave a presentation about what a hurricane is. Then, the students had access to an information packet about the hurricane as well as the community via ANGEL, a learning management system used at the Pennsylvania State University. With the information packet, students were assigned to groups with five to six students according to their roles and were then assigned to one of three communities.

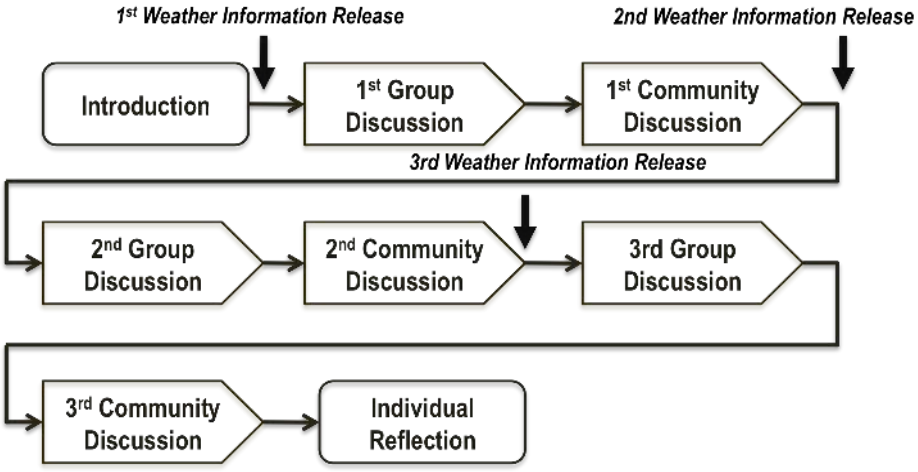

Figure 3.2. Learning Flow of the Hurricane Smith Module in the 1st Year

Group and Community Discussions

In the 1st year, the students were required to participate in two types of discussions for peer interactions. One was the group discussion, in which the students with same role were required to make decisions about evacuation, and the other was the community discussion, in which the students with different roles came together and exchanged their roles' perspectives and made decisions.

All students with specific roles were asked to take part in the group and community discussions three times, respectively. Before the group and community discussions, the instructor presented information about Hurricane Smith, including its path, category, and additional related facts.

Each student was assigned to one of three communities, Deerfield Beach of Florida, Hilton Head of South Carolina, or Morehead City of North Carolina, with

one of seven specific roles. Table 3.2 displays the role that each student was assigned for their group and community discussions. The intention of the role-based group discussions was to support students' reasoning process (Cohen, 1994; Herrenkohl, et al., 1999).

Table 3. 2.

The Roles of the Communities in the 1st Year

Group	Responsibility
Mayor/City Council	This group can make important decisions about the issues the community encounters.
School System	This group includes the school board from the school district of the community.
Emergency Services	This group includes ambulance workers, police, fire personnel, and health care workers.
Infrastructure Services	This group includes electricity, water, drainage, and road workers, and communication service providers.
Chamber of Commerce	This group includes local small business owners (for example, hardware store owners, gas station owners, local restaurants) and the local governing council.
Disability Advocates	This group includes people with deep roots in the community who might not want to leave, people with disabilities, senior citizens, and single-parent households with young children, among others.
Media	This group includes local radio, newspaper, and television personalities. **Note**: This group will be responsible for facilitating the community discussion and reporting out to the class.

Five to six students comprised a group for the group discussions, and more than 30 students with seven roles took part in each of the community discussions.

There was only one mission: What should our community do to protect itself against Hurricane Smith? To deal with the issue within a community, the students took part in six discussions: three group discussions and three community discussions. To support the two types of discussions, the instructor and six instructional designers developed the procedural question prompts that guided the procedure for decision-making, step by step. The procedural question prompts were embedded in the Group Discussion Chart (see Appendix A) and the Community Discussion Chart (see Appendix B).

Table 3.3 shows the procedural question prompts in the Group and Community Discussion Charts.

Table 3.3. Procedural Question Prompts in Group and Community Discussion Charts in the 1st Year

Procedural Question Prompts of Group Discussion Charts	Procedural Question Prompts of Community Discussion Charts
1. List below the dangers and impacts associated with Hurricane Smith in its current 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? 4. Why did you make the decision? List	1. What are the most important things that you will need to keep in mind as you make decisions? 2. List below the dangers and impacts associated with Hurricane Smith in its current location. 3. What is the most important issue identified by each group in your community?

your reasons and the data that you used as evidence.	4. Which issue is the most important to consider? Why? 5. What is your decision? 6. Why did you make the decision? List your reasons and the data that you used as evidence.

During each discussion, the students were asked to answer the procedural question prompts. The main purpose of using the procedural question prompts for the discussions was to direct students' efforts to complete a specific task and to provide a structure for their decision making process (Ge, 2005; Land & Hannafin, 1999).

Individual Report

The students were asked to submit their individual reports (see Appendix C) after they were engaged in the discussions. This individual report was designed in order for the students to display the critical thinking skills they gained throughout Hurricane Smith, in the process of making their final decision about what their community should do to protect itself against Hurricane Smith. Therefore, the individual report asked for them to utilize six categories of critical thinking: 1) identifying decisions, 2) evaluating decisions, 3) providing their own decision, 4) justifying their own decision, 5) presenting supporting data/evidence, and 6) integrating other perspectives.

2nd Year

For the 2nd year, the Hurricane Smith Module was modified in several aspects. Based on overall observations and reflections on the 1st year implementation, the instructor and the instructional designers agreed to refine the designs and to make changes in the flow of learning activities.

Table 3.4.

Summary of Design Modifications in the 2nd year

Design Principles	1st Year (Fall 2007) Findings	2nd Year (Fall 2008) Modifications
Authentic Task	Real Data Use in a specific context → Students were interested in the task because it was based on a real hurricane case and had specific and concrete data to consider the impact of hurricanes in the real world.	Same as the 1st year
Peer Interaction	Students were engaged in too many different processes to make decisions adequately, and they indicated an insufficient understanding of what a hurricane is and what is required of their role within a certain community.	A need for more individual preparation in order for improved peer interaction: - Reducing the steps for community decision making (two community discussions, instead of three community discussions). - Instead of role based group work discussion, students were asked to consider

		several important pieces of information and aspects of the hurricane in their individual studies.
Question Prompts	Students failed to show concrete reasoning behind their decision making of whether or not the community should evacuate to protect itself against the hurricane.	A need for elaborative question prompts: - Procedural question prompts were effective in supporting the structure to make a decision. - Elaborative question prompts were added in the process of individual preparation and group discussions

The 1st design and implementation raised several issues. The main issue was related to the answers to the procedural question prompts demonstrated in the Group and Community Discussion Charts. Some of groups omitted their answers and did not provide their decision and reasoning. Furthermore, although they gave answers to the procedural question prompts, most answers yielded doubts about whether the students used the resources made available for hurricane learning. Another issue was related to the number of discussions required for students to take part in. Students met for discussion six times with their classmates who had the same roles. We doubted if the six-time iteration was effective, because the decisions handled only the task of whether the community should evacuate or not.

Based on these issues, Table 3.4 shows the design modification for the second iteration. The main modification was made in refining two design principles: peer interaction and question prompts.

Among the issues raised in the first implementation, individual preparation (Cohen, 1994) was emphasized. Instead of having three different group discussions designed to provide interaction with other peers with the same role, the decision for the 2nd year's design was to create an "Individual Worksheet" which required students to prepare their community discussions by understanding three important aspects, the hurricane, the community, and their roles in a certain community. Therefore, the overall learning flow for the Hurricane Smith Module was modified, as illustrated in Figure 3. 3 below:

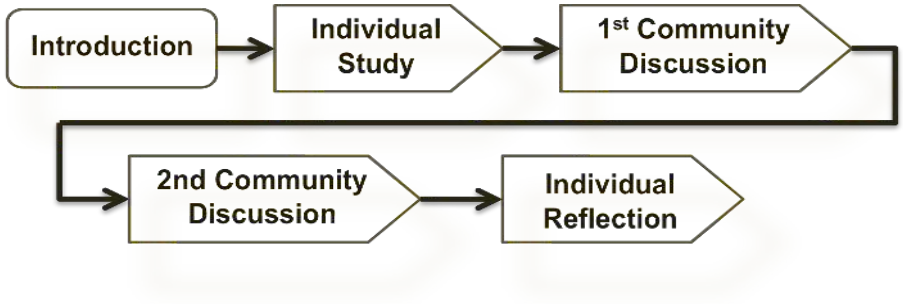

Figure 3.3. Flow of Learning Activities in the 2nd year

Secondly, one of the modifications was related to using question prompts. In the 1st year, only procedural question prompts were embedded in both the Group and Community Discussion Charts, with the purpose of supporting the process of decision-making. Instead of using only one type of question prompt (procedural

question prompts), elaborative question prompts were added in the Individual Worksheet and the Community Information Organizer. The purpose of implementing elaborative question prompts was to help student identify and understand important information to be considered in order to make an educated decision about evacuating.

Individual Worksheet

The Individual Worksheet (see Appendix D) was newly designed and developed to give students an opportunity to prepare for their discussions (Cohen, 1994). Since the students' activities for the discussions of the 1st year showed an unclear understanding of the hurricane itself and the community, there was a need to support students' understanding of what the hurricane is and how the hurricane would impact their community.

The Individual Worksheet consisted of the following three parts:

- Understanding the Hurricane
- Understanding the community with regard to hurricane evacuation
- Understanding their specific administrative role

Since the above were important aspects in thinking about the Hurricane's impact on each community, the focus of the Individual Worksheet helped students understand and construct basic knowledge in order to take part in the community discussion.

To help students understand the Hurricane, there were several questions that the students should be able to answer. The following question prompts were used to elaborate their understanding of a hurricane and its impact:

- How does the size of the hurricane influence evacuation?
- How strong should the wind be in order for you to evacuate?
- What differences does time of hurricane impact make (night vs. day)?
- How does the direction of the hurricane impact your planning?
- How would the duration of the hurricane impact your evacuation plans?

Based on their understanding, the next step was to understand basic information about the community. Although the information packet for each community was uploaded in ANGEL so that students could access a lot of basic information and characteristics about the community, the elaborative questions in the Individual Worksheet only focused on essential information needed to consider the Hurricane situation. Therefore, there were only a few questions related to information about whether the community should evacuate or not. The elaborative questions for understanding the community were related to the following three topics:

- Geographical location
- Population
- Evacuation route

The next task was to understand the specific administrative roles. Compared to the 1st year's design, the second design eliminated two of the seven original roles,

because the two roles, School System and Disability Advocates, did not affect the process of the group decision making. The roles were also eliminated based on the design decision that too many roles might hinder the community discussion.

There were two main questions to elaborate students' understanding about their specific roles:

- What important information related to the hurricane should the specific role identify?
- What and how should the specific role consider and recommend for the community?

The above two questions varied according to specific roles, as seen in Table 3.5 below.

Table 3.5.

The Roles of the Communities in Fall 2008

Role	The points that the role should identify as important
Emergency Services	• Hospitals • Fire stations and locations • Location of shelters and how many people can be accommodated in each shelter • How could the hurricane impact the availability of these different facilities?
Infrastructure Services	• How does the size of the hurricane influence evacuation? • How strong should the wind be in order for you to evacuate? • What difference does time of hurricane impact make? • How does direction of hurricane impact your planning? • How would the duration of the hurricane impact your evacuation plans?

	• How does location of the hurricane impact the usability of roads or transportation facilities?
Media	• History of hurricane impact in the area of the community • General information about preparing for hurricanes • Hurricane watch updates including how to deal with time of impact • What should the town and services prepare for as being most likely to happen?
Chamber of Commerce	• Distribution of population (residents vs. tourists) • Age (children vs. older population) and mobility (disabled, sick, very feeble, etc.) • Distribution of residential areas (high concentration vs. low concentration, proximity to areas with high exposure to hurricane, etc.) • Who would you recommend be evacuated first and why? Are there specific challenges related to evacuation of a specific segment of the population?
Mayor and City Council	• Cost of complete evacuation • Cost of evacuating specific residents and facilities (what are the areas and populations most likely to be affected, and how much would it cost to evacuate those specific areas? • What should your plan of action be for evacuation? What information do you need to make a decision about evacuation?

By reflecting on the results of the 1st year's group and community discussions, it was suggested that procedural question prompts, which provide a structure to make a decision, were not sufficient to help students consider their role and the impacts of the hurricane. Before following the decision making structure, an elaborative strategy whereby students identify important facts and information related to the community and emergency situation was needed to consider the impact of the hurricane on their community and to make a decision. Therefore, elaborative question prompts (Ge, 2005) were added in the Individual Worksheet. In particular, each type of elaborative question prompt was developed for each group with a specific role

respectively. For example, the group with infrastructure services of a community was asked to identify important aspects that should be considered in an emergency situation such as the population, demographic information, emergency shelters, dangerous areas, evacuation roads, hospitals, etc.

Community Information Organizer

Compared with the 1st design and implementation, in the 2nd year the students were required to take part only in community discussions, not in group discussions. They were expected to bring their understanding of Hurricane Smith, their community, and their specific roles into the community discussion. As with the 1st year, they took part in the community discussions twice, whenever new weather information about the Hurricane was released. After focusing on the weather information, the students were asked to participate in the decision making process with the Community Information Organizer (see Appendix E).

This Community Information Organizer was similar to the Community Discussion Chart in the 1st year, providing guidance and structure for decision making. However, compared to the procedural question prompts in the Community Discussion Chart, the questions of the Community Information Organizer combined procedural and elaborative prompts, which means that the goal of all questions were to make decisions, and each question was contextualized to reflect and elaborate their understanding of the hurricane, community, and various roles within a community.

Table 3.6 displays the questions used at each decision point in the Community Information Organizer.

Table 3. 6. Questions Combining Procedural and Elaborative Prompts in the Community Information Organizer

Questions combining procedural and elaborative prompts
• When is the possible time of impact? • What direction is the hurricane moving in? • What is the estimated strength of the hurricane? • What are the estimated dangers and potential damage to facilities and residents? • What is your decision? • Why did you make this decision? Remember that evacuation comes at a cost of shutting down all businesses, etc., while not evacuating means possible harm to community and facilities. Explain your decision. • At this point, write a five- line information bulletin that will explain to residents what action they should take for the hurricane. The bulletin will be released to all radio stations, news channels, and weather channels on TV to inform the residents of the area what the community plan is and why that is the best plan to following to do. Make sure to tell the residents why you are making these decisions and what might be possible future scenarios might be possible. • What are some of the consequences of your final decision on the community? What might happen in the next few days?

Individual Report

As with the first design and implementation, the students were required to reflect on their learning activities by writing their individual reports. The material for the individual report was modified as the group work activities were changed. In the 1st year, the students made their final decision about evacuation based on their group and community discussions, but the 2nd year's students made their final decision based only on their community discussion activities with their individual worksheets.

Data Collection

The data set came from the implementation of the Hurricane Smith Module within the introductory geoscience course, *Earth 101 - Natural Disaster*, at the Pennsylvania State University. Data was collected during two semesters, Fall 2007 and Fall 2008.

The focus of this study was to explore the evidence of how students' critical thinking was enhanced throughout the module. Norris (1985) suggests that students' written essays or assignments could be suitable data to evaluate their critical thinking, and there have been several studies analyzing students' written documents to evaluate critical thinking (Anderson, et al., 2001; Guiller, et al., 2007; Zohar & Nemet, 2001). Thus, this study collected several types of written documents that the students of the 1st and 2nd years had submitted. During the 1st year's implementation, the Group and Community Discussion Charts, and the Individual Report were collected. During

the 2nd year's implementation, the Individual Worksheet, the Community Information Organizer, and the Individual Report were collected.

To investigate the first research question, "What changes are visible in group decision making and reasoning as represented in group worksheets in the 1st and 2nd years?," the Community Decision Charts of the 1st year and the Community Information Organizer of the 2nd year were collected. During the Hurricane Smith Module, each group for each community was asked to make the decisions throughout the group work process and then had to submit it. As mentioned earlier, these two types of documents consisted of the question prompts, which helped the group to decide whether the community should evacuate or not.

With regard to the second research question, "What differences in level of critical thinking are evident in the group reports and individual reports between the 1st and 2nd years?" the individual reports of the 1st and 2nd years were the artifacts to be collected. The individual report was designed to show critical thinking along with the individual's final decision. The students were required to submit their reports after they took part in the Hurricane Smith Module.

To answer the third research question, "What differences are evident in the individual and group worksheets and individual reports between the students with higher and lower levels of critical thinking in the 1st and 2nd years?", individual cases were selected and their written documents were collected. This research question had the intentions of tracing back the individual student's preparation and group discussions during the Hurricane Smith model and identifying patterns between the students with lower and higher levels of critical thinking. Therefore, data collection

was purposeful and selective for each case. The following data analysis section presents a more detailed description about sampling, data collection, and data analysis for the third research question.

Data Analysis

To examine the impact of the two-year design on the students' group decision-making and individual critical thinking, this study employed quantitative and qualitative data analysis techniques. The data analysis is presented here in detail with accordance to each research question.

Analysis of change of group decision making in the 1st and 2nd years

To identify whether there were changes on group decision making between the 1st and 2nd year classes, the three community decision points of each year were analyzed with the quantitative analysis method.

In each year, the students were asked to make decisions, whether their community (one of three communities) should evacuate in preparation for Hurricane Smith, during their group activities. The decisions were made three times in the 1st year and twice in the 2nd year, as soon as the Hurricane information was announced and updated.

Data analysis was conducted according to each community since the decisions were contextualized in each community since there were three

communities, which differed in effects of hurricane and their characteristics in geography, population, and infrastructure.

For analysis of change of group decision making between the 1st and 2nd years, the community decision points were analyzed and compared with accordance to each community.

Analysis of changes of group reasoning in the 1st t and 2nd years

To investigate changes in group reasoning, the reasoning section of the Community Discussion Charts in the 1st year and the Community Information in the 2nd year were analyzed.

In order to analyze the content of written data, students' reasoning, latent content analysis (Tashakkori & Teddie, 1994), which identifies themes or patterns that emerged during the data analysis, was used.

Three steps were carried out throughout the latent content analysis. The first step was creating tables for the reasoning parts in an Excel spreadsheet. All answers to the reasoning section and the decisions were imported to the table, for each community.

In the second step, data in the table was reviewed and noted with several comments. Then themes began to emerge in the reasoning.

According to the themes, a table with decision, reasoning, and themes by each community and each year were created. After all of the tables were created, the reasoning of each community of the 1st year was compared with that of the 2nd year, based on the themes.

Analysis of Differences in Level of Critical Thinking Demonstrated in Individual Reports between the 1st and 2nd Years

To investigate whether there were differences in levels of critical thinking between the 1st and 2nd years, individual reports from the 1st and 2nd years' implementation were analyzed. To analyze the individual reports, written documents with qualitative characteristics, this study used the *a priori* approach (Miles & Huberman, 1994), in which themes and categories had already been established. In this study, there were six categories of critical thinking established by reviewing literature: 1) identifying decisions, 2) evaluating decisions, 3) providing their own decisions, 4) justifying their own decision, 5) presenting supporting data/evidence, and 6) integrating other perspectives.

Originally, the scoring rubric for grading critical thinking was developed through the Critical Thinking Project by Washington State University (http://www.ctlt.wsu.edu, 2006) with the purpose of fostering critical thinking skills in undergraduates across a university's curriculum. In this study, the scoring rubric was adopted and modified in order to grade students' critical thinking skills based on six categories represented in the individual reports of the two years.

While modifying the rubric, it was important to validate it within the context of the Hurricane Smith Module. To ensure validity of the scoring rubric, content-related evidence and construct-related evidence were specially considered by the design team, the six instructional designers and the instructor. According to Moskal and Leydens (2000), content-related

evidence refers to the extent to which a student's responses to a given assessment instrument reflects that student's knowledge of the content area that is of interest, and construct-related evidence is the evidence that supports that an assessment instrument is complete and only measuring the intended construct, like reasoning or problem solving. Since the six categories for critical thinking in science had already been established for ensuring the construct validity, the rating scales of "emerging," "developing,, and "mastering" were developed to assess the quality of each category for critical thinking in science. With the constructs and the rating scales, the content validity, which means situating the content of the Hurricane Smith Module, was established by stating what "mastering," "developing," and "emerging" indicate in the rating for each category. For example, in the category of "identifying decisions," "mastering" is explained as "clearly recognizes and summarizes the embedded and implicit danger and impact of Hurricane Smith, and identifies integral relationships essential to analyzing this issue." However, "emerging" is represented as "fails to provide any introduction to important issues raised in either discussion or only presents one of the issues." At the middle of the rating scale, "developing" is represented as "clearly identifies issues raised in group and community discussions" and "may summarize the most important questions raised in both groups and provide one's own perspectives." To sum up, "mastering" is stated as fully representing each category of critical thinking. Table 3.7

shows the scoring rubric for grading critical thinking, modified by the design team.

Two instructional designers, including the researcher, were involved in scoring the 1st and 2nd years' individual reports. In regards to scoring the reports with a rubric, two issues on reliability, interrater reliability and intrarater reliability, were considered, as suggested by Moskal and Leydens (2000). To ensure the interrater reliability, the two raters scored 30 individual reports of each year to reach a consensus on scoring each category by making anchor papers, which illustrate the nuances of the scoring rubric, as Moskal and Leydens (2000) suggest. For example, to score "identify decisions appropriately from group and community discussions," the concepts of "role," "context," "hurricane," and "community locations and information" were added to clarify what students identify in the decisions from group and community discussions. Therefore, if the student clearly summarized his or her role, community location, the characteristics of hurricane, and so forth, s/he would get the highest score, "mastering," and if the student partially summarized the issues from the group and community discussions, s/he would be scored at the "developing" level. In addition, if the student failed to provide any of this information, s/he would obtain an "emerging" score. With the anchor papers, the raters underlined and discussed the sentences and paragraphs in order to clarify which part reflected specific categories of critical thinking. Throughout several face-to-

face meetings, the two raters reached a consensus on how to score each category of critical thinking represented in the individual reports.

To ensure intrarater reliability, which refers to the concept that a given rater changes over time according to the rater's situation, the raters always referred to the scoring rubric and the anchor papers when grading each individual report.

The scores ranged from 1 to 6 in each category, based on the indication of the rubric. Each category was scored, and then the sum of the six categories was calculated.

Table 3.7 Scoring Rubric for Grading Critical Thinking

1. Identifies decisions appropriately from group and community discussions					
Emerging		Developing		Mastering	
1	**2**	**3**	**4**	**5**	**6**
· Fails to provide any introduction to important issues raised in either discussion or only presents one of the issues.		· Clearly identifies issues raised in group and community discussions. · May summarize the most important questions raised in both groups and provide own perspective.		· 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**
· Either they are offersing group/community decision or · oOffers own evaluation without any reference to group or community discussions (or Ddoes not offer own perspective without any reference to group/community discussions). · Does not provide reasoning or evidence to support evaluation.		· Provides own evaluation based on group and community discussions. · Acknowledges differences/similarities with group and community perspectives (e.g.: provides agreement/disagreement but no/insufficient reasoning)		· 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 decision					
Emerging		Developing		Mastering	
1		**2**		**3**	
· Offers an unclear or simplistic solution or position (decision). · Presents position based on group/community discussions without any indication of own consideration.		· Offers generally clear solution/position, although gaps may exist. · Presents own position such that it includes some original thinking that acknowledges, refutes, synthesizes or extends assertions from group/community, although some aspects may have been adopted.		· Offers a solution/position that demonstrates sophisticated, integrative thought and is developed clearly. · Presents position in such a way that it demonstrates ownership for constructing knowledge or framing original questions, while integrating and acknowledging other influences.	

4. Presents arguments to justify own solution/decision		
Emerging	Developing	Mastering
1	**2**	**3**
· Fails to present justification for own solution. · No argument is constructed for why this is the best solution.	· Presents and justifies own solution without addressing other views, or does so superficially. · Argument is stated, but it is vague or general and does not address pertinent issues.	· Clearly presents and justifies own solution while qualifying or integrating contrary views (additional) or interpretations. · Arguments are well constructed, and supported with persuasive reasoning.
5. Presents supporting evidence/data		
Emerging	Developing	Mastering
1	**2**	**3**
· No evidence is provided, or evidence to support the argument is weak or irrelevant. · Fails to provide any data/context within the solution.	· 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.	· Evidence to support the argument is strong and relevant. · Considers context, data, and evidence in discussion of own solution.
6. Integrates perspectives from group and community into proposed solution		
Emerging	Developing	Mastering
1	**2**	**3**
· 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. · No Analysis.	· 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.	· 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.

Analysis of the Effects of Prior Group Discussion and Individual Preparation on the Level of Critical Thinking

This qualitative analysis was an examination of what we can see from following an individual student's engagement in group activities and his/her final individual report, with the intent of reporting on any patterns that emerge with specific attention to high scoring and low scoring students. For this analysis, the multiple-case study design was used.

The Multiple-Case Study Design

The previous research questions (the first and second questions) focused on investigating and comparing students' learning activities during the class, and the levels of critical thinking after the class, respectively. Those two research questions contributed to understand what occurred in the students' learning process and outcomes by employing the three design principles in large general science courses for undergraduate students.

The third research question, "What differences are evident in the individual and group worksheets and individual reports between the students with higher and lower levels of critical thinking in the 1st and 2nd years?", aimed to understand how the designs of the 1st and 2nd years worked to enhance critical thinking in a real class. To explore this question, the multiple-case study, for which more than two cases were selected and compared, was used. The logic of the use of the multiple-case study is for replication, either by: 1) predicting similar results (literal

replication), or 2) predicting contrasting results (theoretical replication), relying on the development of theoretical framework (Yin, 2008, p. 54).

In particular, this multiple-case study used an embedded design in order to reflect the two different contexts in which the two different designs had been implemented. Figure 3.4 illustrates the embedded design, modified from Yin's (2008, see p. 46), for this multiple-case study.

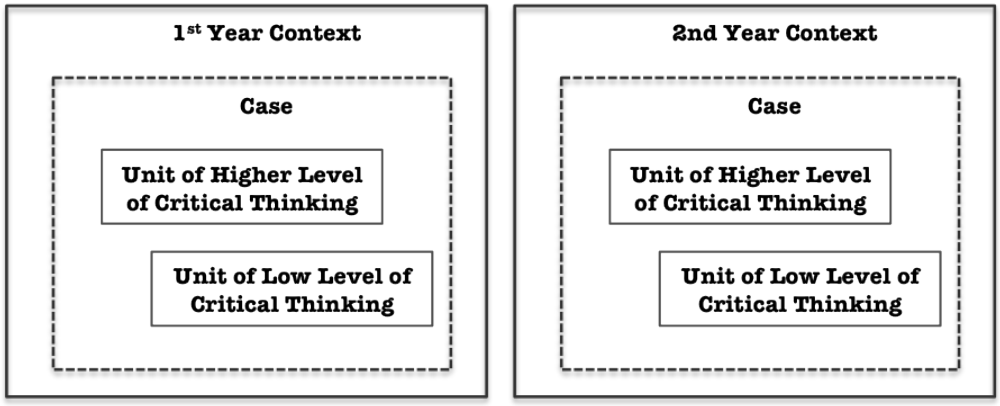

Figure 3.4. Embedded Multiple-Case Study Design

Sampling and Data Collection

In qualitative studies such as a case study, selective sampling is usually used to maximize the representation of cases (Sake, 2000). Although Yin (2008) points out that there is no logic in sampling in the multiple-case study, he suggests that three to four cases might be needed for each of the replications. He also emphasizes the importance of representation of each replication in the multiple-case study.

Based on the embedded multiple-case study design, this study employed a "two-tail" design in which cases from both extremes have been deliberately chosen (Yin, 2008) as a sampling strategy. Therefore, this multiple-case study called for four units reflecting the two contexts, the 1st and 2nd years, and high and low levels of critical thinking for literal and theoretical replications. Therefore, four groups of cases, by 2 x 2, were needed for the units of cases.

By carefully reviewing the results of the second question, differences in the levels of critical thinking in each year, two individual students representing each separate unit were selected as the cases. Therefore, eight individual students were the total cases for this multiple-case study.

The next step was to collect data for each case. For the 1st year's case, data came from each student's group and community discussion charts, and the individual report. For the 2nd year's case, data came from each student's individual worksheet, community information organizer, and the individual report. All types of data were written documents reflecting each student's learning activities and levels of critical thinking.

Data Analysis Strategies and Technique

The main approach to data analysis involved a detailed analysis using the three strategies suggested by Yin (2008), relying on theoretical propositions, developing a case description, and using both qualitative and quantitative data. First, these multiple cases focused on tracing back to evidence of each individual student's

learning demonstrated in the worksheets in order to compare against and explain the relationship between the learning activities during the class and the levels of critical thinking after class, with the proposition that the two designs worked to enhance critical thinking. Next, according to each embedded unit, the evidence of the cases' learning demonstrated in each worksheet and critical thinking represented in individual reports will be described. In particular, the *pattern match technique* was used in describing and comparing across the cases, since this multiple-case study has a certain type of outcome, critical thinking, and the investigation focuses on how and why the levels of critical thinking occurred in each case (Yin, 2008). By using the pattern match technique, the data collected was organized to support plausible explanations about the relationship between the learning activities and critical thinking. Lastly, in this multiple-case study, the quantitative data from scoring the critical thinking was used to label each case's level of critical thinking and the qualitative data from individual reports and worksheets was analyzed to answer why and how he or she gained levels of critical thinking.

With these data analysis strategies and the pattern match technique for this multiple-case study, the researcher followed several steps to analyze the data: reading and jotting notes down on each case's written documents; emerging and identifying patterns; labeling concepts; organizing the patterns; and re-identifying the themes and patterns.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the results of the two-year design experiment based on data analysis for the following research questions:

1. What changes are visible in group decision making and reasoning as represented in group worksheets in the 1st and 2nd years?
2. What differences in level of critical thinking are evident in individual reports between the 1st and 2nd year?
3. What differences are evident in the individual and group worksheets and individual reports between the students with higher and lower levels of critical thinking in the 1st and 2nd years?

In response to the first research question, the results of the group decision making and reasoning process over two years will be reported first. By employing qualitative data analysis, the kinds of decisions that the students made and the rationale behind their decisions will be described and compared; after that, the findings will be discussed. In the second section, the results of levels of critical thinking from the two years will be presented and compared, and the findings will be discussed. In the last section, the results of the multiple-case study will be reported and discussed.

Profile of the Participants

This chapter begins by comparing the profiles of the participants of the two-year period. Since the major interest of this study is to explore how the design experiment impacted the students' critical thinking, examining if the target populations were homogeneous was an important issue to address before performing data analysis.

Although over 150 students were enrolled in the Earth 101 course, 176 students in Fall 2007 and 174 students in Fall 2008, only the students who took part in the group work activities and who submitted their individual reports were included in data analysis. With this criterion, 130 students were the subjects included in data analysis each year.

Table 4.1.

Summary of Participants' Profiles

		1st Year	**2nd Year**
		N (Percent)	**N (Percent)**
Gender	Male	61 (46.9%)	70 (53.8%)
	Female	55 (42.3%)	60 (46.2%)
	N/A	14 (10.8%)	0 (0%)
	Total	130 (100%)	130 (100%)
Race	White	102 (78.5%)	112 (86.2%)
	African-American	6 (4.6%)	1 (0.8%)
	Asian	1 (0.8%)	5 (3.8%)

	Hispanic	4 (3.1%)	3 (2.3%)
	Other	3 (2.3%)	1 (0.8%)
	N/A	14 (10.8%)	8 (6.2%)
	Total	130 (100%)	130 (100%)
Year	First Year	2 (1.5%)	5 (3.8%)
	Sophomore	38 (29.2%)	26 (20.0%)
	Junior	14 (10.8%)	19 (14.6%)
	Senior	60 (46.2%)	70 (53.8%)
	N/A	16 (12.3%)	10 (7.7%)
	Total	130 (100%)	130 (100%)
College	Agricultural Sciences	1 (0.8%)	2 (1.5%)
	Arts and Architecture	8 (6.2%)	6 (4.6%)
	Business	22 (16.9%)	32 (2.5%)
	Communications	27 (20.8%)	18 (13.8%)
	Earth and Mineral Sciences	2 (1.5%)	2 (1.5%)
	Education	7 (5.4%)	6 (4.6%)
	Engineering	2 (1.5%)	7 (5.4%)
	Health and Human Development	8 (6.2%)	12 (9.2%)
	Information Science Technology	2 (1.5%)	6 (4.6%)
	Liberal Arts	28 (21.5%)	24 (18.5%)
	Science	6 (4.6%)	2 (1.5%)
	N/A	17 (13.1%)	13 (10%)
	Total	130 (100%)	130 (100%)
The Number of Science	1	1 (0.8%)	1 (0.8%)

Courses Taken in High School	2	6 (4.6%)	5 (3.8%)
	3	28 (21.5%)	40 (30.8%)
	4	64 (49.2%)	56 (43.1%)
	5	15 (11.5%)	14 (10.8%)
	6	1 (0.8%)	2 (1.5%)
	7	0 (0%)	0 (0%)
	8	0 (0%)	2 (1.5%)
	N/A	15 (11.5%)	10 (7.7%)
	Total	130 (100%)	130 (100%)
Experience in Earth Science Courses	Yes	91 (70.0%)	85 (65.4%)
	No	36 (28.5%)	36 (27.7%)
	N/A	2 (1.5%)	9 (6.9%)
	Total	130 (100%)	130 (100%)

Table 4.1. indicates that the participants of the two years were almost homogenous in their demographic characteristics and prior experiences in science courses. The demographic summary of the participants displays the numbers and percentages of gender, race, school year, college affiliations, science classes in taken high school, and amount of experience in earth science courses. These results indicate that the variables of demographics and science class experience will not be a barrier to analyzing the data or interpreting the results.

The distribution of gender presents that there were 61 male (46.9%) and 55 (42.3%) female students in the 1st year, and 70 male (53.8%) and 60 female (46.2%) students in the 2nd year. The distribution of race indicates that the majority of the

students were white, 102 (78.5%) in the 1st year and 112 (86.2%) in the 2nd year. In the school year, almost half of the students were seniors, 60 (46.2%) in the 1st year, and 70 (53.8%) in the 2nd year, and there were few 1st year students, 2 (1.5%) in the 1st year, and 5 (3.8%) in the 2nd year.

Only 8 (6.2%) students in the 1st year and 4 (3%) students in the 2nd year had science-related majors and were enrolled in the College of Earth and Mineral Sciences and the College of Science, respectively. This result shows that most students who took part in this study were non-science major students.

All students in the 1st and 2nd years indicated that they had taken more than one science course in high school; most students said they took 3 or 4 science courses during high school. Also, more than half of the students, 91 (70.0%) in Fall 2007 and 85 (65.4%) in Fall 2008, said they had previously taken an earth science course.

Comparison of Group Decision Making and Reasoning

To answer the first research question, *"What changes are visible in group decision making and reasoning in the 1st and 2nd year?",* the researcher collected and analyzed the decision points and reasoning from the Community Discussion Charts in the 1st year and the Community Information Organizer in the 2nd year.

Although there were changes in designing the learning activities of the Hurricane Smith Module, the main task of the students in both years was making decisions about whether their community should evacuate from Hurricane Smith and providing reasons for why they made their decisions.

Each of the students was assigned to one of the communities among Deerfield Beach, FL; Hilton Head, SC; and Morehead City, NC, and then engaged in the discussion process to make decisions within the community context.

This section presents and compares the decisions and reasoning between the two years along with each community. Originally, each year had 5 groups for each city, but some groups did not submit their group worksheets. Thus, these groups were not the subjects of data analysis in this study. For data analysis, 10 group discussion charts of the 1st year and 12 community information organizers of the 2nd year were analyzed. Table 4.2. displays the number of groups analyzed, along with each community.

Table 4.2.

The Number of Groups in Data Analysis

	1st Year	2nd Year
Deerfield Beach, FL	3 out of 5 groups	4 out of 5 groups
Hilton Head, SC	3 out of 5 groups	4 out of 5 groups
Morehead City, NC	4 out of 5 groups	4 out of 5 groups

Comparison of the Decisions

Deerfield Beach, Florida

Table 4.3 summarizes the two years' group decisions of whether Deerfield Beach should evacuate from the Hurricane.

At the first decision point of the 1st year, only one group chose "Do not evacuate" as its decision, and two of them chose "Tell citizens to prepare for evacuation" as their decision. Although there was a "no answer" from one group, the other two groups made their decision of "Evacuate" at the 2nd decision point. In the end, all three made the final decision of "Evacuate."

Table 4.3

Summary of Decisions for Deerfield Beach Between the 1st and 2nd year

Decision	1st Year			2nd Year	
	Decision Point 1	Decision Point 2	Decision Point 3	Decision Point 1	Decision Point 2
Do not evacuate	1/3	0	0	0	0
Keep an eye on data	0	0	0	0	0
Tell citizens to prepare for evacuation	2/3	0	0	0	¼
Tell citizens to prepare for evacuation, but begin to evacuate the elderly				2/4	0
Evacuate	0	2/3	3/3	2/4	¾
N/A		1/3			

In the 2nd year, two of the four groups chose "Tell citizens to prepare for evacuation, but begin to evacuate the elderly," and the others chose "Evacuate" as their decision at the 1st decision point. At the final decision, one of them switched back to "Tell citizens to prepare for evacuation" as their decision, and the others opted for "Evacuate."

Although there was a group who chose "Do not evacuate" at the initial time under Hurricane Smith, most of the groups chose "Tell citizens to prepare for evacuation," or "Evacuate" as their decisions after the weather information had been released, in both the 1st and 2nd year. In addition, all groups in the 1st year and three of the four groups in the 2nd year made the final decision of "Evacuate" for Deerfield Beach.

These results show that there were similarities in the group decisions for Deerfield Beach between the 1st and 2nd years.

Hilton Head, South Carolina

Table 4.4 presents the summary of the group decisions for Hilton Head over the two-year period.

In the 1st year, the three groups reached a consensus by choosing "Keep an eye on data" at the 1st decision point and "Evacuate" at the final decision point. At the 2nd decision point, two of the groups made the decision of "Tell citizens to prepare for evacuation," and the other one chose "Evacuate" as its decision. There

was a flow through the decision points, from "Keep an eye on data" to "Evacuate," in the 1st year.

In the 2nd year, three of the four groups made the decision of "Tell citizens to prepare for evacuation," and the remaining group made a mixed decision of "Tell citizens to prepare for evacuation + Evacuate." Except for this group, all of the other groups made the final decision of "Evacuate."

Table 4.4

Summary of Decisions for Hilton Head Between the 1st and 2nd year

Decision	2007			2008	
	Decision Point 1	Decision Point 2	Decision Point 3	Decision Point 1	Decision Point 2
Do not evacuate	0	0	0	0	0
Keep an eye on data	3/3	0	0	0	0
Tell citizens to prepare for evacuation	0	2/3	0	¾	0
Tell citizens to prepare for evacuation + Evacuate	0	0	0	¼	¼
Evacuate	0	1/3	3/3	0	¾

These results show that there were similarities and differences in group decisions between the 1st and the 2nd years. First, like the groups for Deerfield Beach, those for Hilton Head displayed a pattern through the decision points, choosing "Evacuate" as their final decision, from "Tell citizens to prepare for evacuation". Second, at the initial decision point, all three groups of the 1st year made the decision

of "Keep an eye on data," not considering evacuation, but all four groups of the 2nd year made the decision of "Tell citizens to prepare for evacuation" related to considering evacuation.

Morehead City, North Carolina

Table 4.5 presents the summary of the group decisions for Morehead City between the 1st and 2nd years.

Table 4.5

Summary of Decisions for Morehead City Between the 1st and 2nd year

Decision	2007			2008	
	Decision Point 1	Decision Point 2	Decision Point 3	Decision Point 1	Decision Point 2
Do not evacuate	1/4	0	0	0	0
Keep an eye on data	3/4	¾	0	4/4	3/4
Tell citizens to prepare for evacuation	0	0	¼	0	1/4
Evacuate	0	0	2/4	0	0
N/A	0	¼	1/4	0	0

At the first decision point of the 1st year, all four groups did not consider evacuation, indicated by their decisions of "Keep an eye on data," and "Do not evacuate." At the 2nd decision point, three of them made the decision of "Keep an eye on data," like the 1st decision, and the other group did not provide any decision.

Their final decisions were, “Tell citizens to prepare for evacuation” and “Evacuate,” much different from the first and second decision points

In the 2nd year, all four groups chose “Keep an eye on data” as their first decision, and three of the groups kept this decision as their final decision. Only one of them made the final decision of “Tell citizens to prepare for evacuation.”

These results from descriptive data analysis show several findings. First, there was a difference in the final decision between the 1st and the 2nd year. In regards to evacuation of the community, in the 1st year, all of the groups, except one which did not provide a decision, made the decisions of “Tell citizens to prepare for evacuation” and “Evacuate.”. However, most groups in the 2nd year, three out of the four groups, made the final decision of “Keep an eye on data,” and did not consider evacuation. Second, at the initial time when the weather information had first been released, the first decision of both the 1st and 2nd years showed a consensus on not considering evacuation, by choosing “Keep an eye on data” and “Do not evacuate.”

Comparisons of Reasoning for Decisions

What kinds of reasoning were provided to make the decisions for each community under the Hurricane Smith context? Was there any change in reasoning between the 1st and 2nd year? In order to respond to these types of questions, the reasoning portions of the Community Discussion Charts in the 1st year and the Community Information Organizers in the 2nd year were analyzed.

For data analysis, all answers in the reasoning parts for the Community Discussion Charts in the 1st year and the Community Information Organizers in the

2nd year were transcribed in an Excel sheet, and then the researcher carefully read all the groups' rationales to analyze and synthesize their reasoning. Table 4.6. presents the five categories of their reasoning with definitions and examples.

Table 4.6

Categories of Reasoning for Decisions

Category	Definitions/Subcategories	Example
Hurricane	Referring to the effects of the Hurricane on the community Referring to the characteristics of the Hurricane	Flooding, Storm, Wind
Community	Considering the characteristics of the community within the Hurricane situation	Geographical location, Economy of the community, Population of the community like the portions of elderly and disabled people, Road restriction, Tourism, Hurricane history of the community
Forecast	Referring to the weather, information and forecast	Hurricane path, Warning zone vs. no warning zone, Watch zone vs. no watch zone
Evacuation	Considering the factors related to how to evacuate; the amount of time it takes to evacuate	Time to evacuate, Route to evacuate, Cost to evacuate, Shelter in evacuation, Available hospitals
Other Considerations	Considering impacts of the Hurricane	Panic People's lives

Although each group in both years provided many concerns regarding their decisions made about the Hurricane Smith situation, the concerns consisted of references to five main categories. For example, some of the groups referred to "flooding" and the "storm," and others referred to "wind" to emphasize the fact that Hurricane Smith was approaching so that they provided the reasoning to support their decision. Thus, in this study, those terms of "flooding," "storm," "wind," and "hurricane path" consist of "Hurricane itself," which means that the groups considered "Hurricane" among the many concerns and factors that the community should consider to make the decision related to evacuation. To describe and compare the reasoning of the 1st and 2nd years, the categories of Table 4.5 will be used along with the communities.

Deerfield Beach, Florida

Table 4.7 displays the reasoning to make the decisions for Deerfield Beach in the 1st year, with the themes of Table 4.5

Table 4.7

Reasoning for the Decisions for Deerfield Beach in the 1st Year

Group & Decision Points		Decision	Reasoning	Categories of Reasoning
A	Decision Point1	Tell citizens to prepare for evacuation	Strong winds, flooding, late at night (11 pm)	**Hurricane**
	Decision Point 2	Evacuate	Tornadoes, flooding, winds, late at night	**Hurricane**

	Decision Point 3	Evacuate	Storm 10-15 ft, flooding (10-15 inches of rain), early in morning (11:15 am)	**Hurricane**
B	Decision Point 1		There is flooding, but the storm might lose strength	**Hurricane**
	Decision Point 2	N/A	N/A	**N/A**
	Decision Point 3	N/A	N.A	**N/A**
C	Decision Point 1	Tell citizens to prepare for evacuation	It is 11 pm, we were issued a warning, so we were to stock up on supplies in churches	**Forecast**
	Decision Point 2	Evacuate	N/A	**N/A**
	Decision Point 3	Evacuate	Location on coast where there can be flooding	**Community Hurricane**

Table 4.7 shows that most of the reasoning to support the group decisions for Deerfield Beach referred to the effects and characteristics of hurricanes, such as the storm, wind, and flooding. Although Group C was concerned about the location of Deerfield Beach, the category of "community," each group did not refer to any of the other categories, like "forecast," "evacuation," and "other concerns." This result shows that the groups did not reflect on various factors in order to make the decisions and highly depended on the effects of the hurricane itself.

In addition, there was no reasoning at some decision points in Groups B and C, and the other examples of reasoning were too short to support their decisions.

Compared to the reasoning of the 1st year, those of the 2nd year tend to be long and concrete, and had several categories to consider. Table 4.8 presents the reasoning for the decisions for Deerfield Beach in the 2nd year.

Table 4.8

Reasoning for the Decisions for Deerfield Beach in the 2nd Year

Group & Decision Points		Decision	Reasoning	Categories of Reasoning
A	Decision Point 1	Evacuate	Deerfield Beach is practically in the center of the warning zone. The storm surge is higher than the elevation of Deerfield Beach. The winds are at 155 mph.	**Forecast Hurricane**
	Decision Point 2	Evacuate	Since we had always evacuated or we are not going beach on that the hurricane is still coming directly toward us.	**Hurricane**
B	Decision Point 1	Evacuate the elderly and ask tourists to leave town. Do not evacuate the general population	It will take longer to get disabled people out, and tourists will clog up needs if a real evacuation is needed	**Evacuation**
	Decision Point 2	Tell citizens to prepare for evacuation	We knew the storm was moving heavily towards us, but since city the extremely able population res--. Evacuation of the residing people will not take an extremely long time. The hurricane turned slightly. So we were hoping it would turn more.	**Hurricane Community Evacuation**
C	Decision Point 1	Tell citizens to prepare for evacuation (but begin to evacuate the elderly because it would take them longer and there is such a high percentage of senior citizens in the town	We decided to begin to evacuate the elderly because the community of Deerfield has 38% elders, and it would take longer to evacuate them. The rest of the community will begin to prepare for evacuation. We're going to send the elderly west along 96 to a city called Kissib, which is about 3 hrs. west because it gets them out of the warning area	**Community Evacuation**
	Decision Point 2	Evacuate	We decided to evacuate the rest of the community. We are going to move them towards the panhandle	**Evacuation Forecast**

			of Florida b/c it appears that the storm could move more north + possibly avoid this area.	
C				
	Decision Point 1	Evacuate	We choose to evacuate early because alrn wgh the storm has not hit me FL coast, we need extra home to evacuate	**Evacuation**
	Decision Point 2	Evacuate	We're continuing to evacuate North because the storm is moving up the coast to the Carolinas. People's lives would be in too much danger if the evacuation was called off because of severe winds and the sea level rising.	**Evacuation Other Considerations Hurricane**

All categories were found in the reasoning to make decisions for Deerfield Beach in the 2nd year. Instead of focusing on the hurricane itself, the groups of Deerfield Beach in the 2nd year frequently considered how to evacuate and the characteristics of the community.

In addition, at the single decision point, most of the groups considered more than two categories. For example, for the 1st decision, Group A indicated two categories, "forecast" referring to "Deerfield Beach is in the center of the warning zone," and the effect of hurricane, mentioning "storm" and "winds."

Thirdly, one of the characteristics of Deerfield Beach, a large portion of elderly people, was referred to when considering decision making in Groups B and C.

Lastly, most of the groups considered time and route for evacuation when making their decisions.

These results lead to two findings in comparing the reasoning of the groups for Deerfield Beach between the 1st and 2nd years. First, the reasoning of the 2nd year was more concrete than that of the 1st year. Second, the groups of the 2nd year

considered various factors when making their decision within the Deerfield Beach context.

Hilton Head, South Carolina

To make the decisions for Hilton Head, the groups of the 1st year mainly considered two categories, "hurricane" and "community," although Groups B and C referred to the category of "forecast." Table 4.9 presents the reasoning for the decisions for Hilton Head in the 1st year.

Table 4.9 Reasoning for the Decisions for Hilton Head in the 1st Year

Group & Decision Points		Decision	Reasoning	Categories of Reasoning
A	Decision Point1	Keep an eye on data	Don't want to lose tourism dollars, 11 pm at night	**Community**
	Decision Point 2	Evacuate	One road leading off the island, 8 pm at night, flood will make roads dangerous	**Community Hurricane**
	Decision Point 3	Evacuate	Will be flooded, 8 am, need to get people out as quickly as possible, we're an island	**Hurricane Community**
B	Decision Point 1	Keep an eye on data	Hurricane not close enough to affect us, we have time to monitor hurricane	**Forecast**
	Decision Point 2	Tell citizens to prepare for evacuation	Some effects of hurricane	**Hurricane**
	Decision Point 3	Evacuate	Hilton Head will flood, wind damage will also be severe	**Hurricane**
C	Decision Point 1	Keep an eye on data	It's just a hurricane watch, route not really known yet	**Forecast**
	Decision Point 2	Tell citizens to prepare for	Storm is heading north, tornadoes are occurring in path	**Hurricane**

	evacuation		
Decision Point 3	Evacuate	Getting hit by hurricane, heavy rain, strong winds	**Hurricane**

Group A considered tourism and geographical characteristics, along with the impacts of the hurricane, which is different from the other groups focusing on the hurricane itself. Groups B and C did not provide any reasoning considering the characteristics of the community, such as population, geographical location, or economy. Compared to the groups for Deerfield Beach in the 1st year, those for Hilton Head mentioned several categories to be considered when making a decision, but "evacuation" was not mentioned.

However, the reasoning of the groups for Hilton Head in the 2nd year provided all categories to be considered when making their decisions.

Table 4.10

Reasoning for the Decisions for Hilton Head in the 2nd Year

Group & Decision Points	Decision	Reasoning	Categories of Reasoning
A			
Decision Point 1	Keep an eye on data	We are only keeping an eye on data because it costs a lot to evacuate a whole island, and we are only on a watch and are not positive about the path of the hurricane.	**Evacuation Forecast**
Decision Point 2	Evacuate	Due to the geographic characteristics of Hilton Head (island), it makes evacuation difficult. Also, people from the south will begin evacuation, which will drastically reduce evacuation speed.	**Community Evacuation**

B	Decision Point 1	Tell citizens to prepare for evacuation	A high proportion of our population is elderly, so it is best to give them ample time to evacuate. Additionally, because Hilton Head is an island, it is better to evacuate early; thus, this will avoid the risk of attempting to evacuate when a major escape route has sustained damage.	**Community Evacuation**
	Decision Point 2	Tell citizens to prepare for evacuation	The elderly will take a long time to evacuate, and there is only one main road to leave the island. Congestion of I-95.	**Community Evacuation**
C	Decision Point 1	Tell citizens to prepare for evacuation + evacuate	Direction of hurricane made us think that it would not hit us, but the possibility was there, we relocated the elderly + hospitalized because they make up 25 % of the population. Flooding is a major issue in Hilton Head.	**Forecast Community Hurricane**
	Decision Point 2	Tell citizens to prepare for evacuation	Direction of the storm changed from north → northwest, still danger of major flooding; intensity of hurricane; shelters and hospitals are closed.	**Forecast Hurricane Evacuation**
D	Decision Point 1	Tell citizens to prepare for evacuation (and evacuate the tourists)	There is only one road in and out of the Island, and it is a relatively small one; on the contrary, there is a dense population.. Many people do not live there, so they would have no place to take shelter besides their hotels, which would not be safe since the majority of tourist spots are on the beach.	**Community Evacuation**
	Decision Point 2	Evacuate	The evacuation time is high, + the loss economically speaking doesn't outweigh the potential loss of life due to the striking of the hurricane.	**Evacuation Community Other**
E	Decision Point 1	Do not evacuate, keep an eye on data, tell citizens to prepare for evacuation	The strongest path of the storm has not arrived yet. We told people to get prepared for the storm and keep an eye on the data and not to evacuate yet.	**Hurricane**
	Decision Point 2	Evacuate	The storm is closer and is heading in our direction. We need to get all of the people out since we are an island; it is necessary to evacuate.	**Hurricane Community**

As shown in Table 4.10, most of the students' reasoning in the 2nd year reflected on the characteristics of Hilton Head community with regard to how to evacuate, instead of frequently mentioning the characteristics of the hurricane itself, like the storm, flooding and wind. For example, Groups A and D emphasized "geographical characteristics of Hilton Head" as an island with a limited evacuation route, and Groups B and D considered "elderly people" and "tourists," reflecting on the characteristics of Hilton Head. In addition, most reasoning contained considerations about evacuation with the characteristics of the community. For example, Group B provided their reasoning based on their consideration of the long evacuation time for the elderly.

Like the above community, Deerfield Beach, the groups for the Hilton Head community in the 1st year provided shorter, more basic rationales than those in the 2nd year. The groups for Hilton Head in the 2nd year tended to provide complex reasoning, which contained more than two categories at each decision point.

Morehead City, North Carolina

The reasoning for the decisions for Morehead City in the 1st year showed that the groups were mainly concerned about the community and forecast, instead of the hurricane and evacuation. Like the groups of the other communities in the 1st year, at some decision points, there was no decision or reasoning; additionally, their other examples of reasoning were too short to provide the actual reason why they made the decisions.

Table 4.11

Reasoning for the Decisions for Morehead City in the 1st Year

Group & Decision Points		Decision	Reasoning	Categories of Reasoning
A	Decision Point1	Keep an eye on data	Don't want to lose tourism dollars, 11 pm at night	**Community**
	Decision Point 2	N/A	N/A	**N/A**
	Decision Point 3	N/A	N/A	**N/A**
B	Decision Point 1	Do not evacuate	No need to evacuate, keep tourists happy	**Community**
	Decision Point 2	Keep an eye on data	N/A	**N/A**
	Decision Point 3	Tell citizens to prepare for evacuation	N/A	**N/A**
C	Decision Point 1	Keep an eye on data	Storm do not hit NC	**Forecast**
	Decision Point 2	Keep an eye on data	Weather maps	**N/A**
	Decision Point 3	Evacuate	Storm heading north	**Forecast**
D	Decision Point 1	Keep an eye on data	At this point – not close enough	**Forecast**
	Decision Point 2	Keep an eye on data	N/A	**N/A**
	Decision Point 3	Evacuate	N/A	**N/A**

Table 4.12 presents the reasoning for the decisions for Morehead City in the 2nd year.

Similar to the groups for Morehead City in the 1st year, the aspects of forecast and community were frequently used to support the decision in the 2nd year. However, the other aspects of evacuation, hurricane, and other concerns were referred to when making the decisions, although only two aspects were mentioned for the decisions in the 1st year. Moreover, the groups for the Morehead City community in the 1st year tended to omit any kind of reasoning at the 2nd and 3rd decision points.

Table 4. 12

Reasoning for the Decisions for Morehead City in the 2nd Year

Group & Decision Points		Decision	Reasoning	Categories of Reasoning
A	Decision Point 1	Keep an eye on data	Outside tropical storm warning + watch	**Forecast**
	Decision Point 2	Keep an eye on data	Has a history of not-so-strong storms. Not in hurricane watch area yet.	**Community Forecast**
B	Decision Point 1	Keep an eye on data	We divided up to keep an eye on data. We're just outside the Hurricane watch zone and forecasters cannot 100% predict that the Hurricane will even head our way or hit us directly. However, the strength of the storm could be dangerous if we are on in its path. We feel that we still have ample time for evacuation, if need be.	**Forecast Hurricane**
	Decision Point 2	Keep an eye on data	Monitors of data will be made --- and we will tell the elderly and hospitals to be prepared. We are on the edge of the watch zone, so we still have a few days to prepare. Therefore, we can start evacuation and still have time to evacuate 3000 people.	**Evacuation Community Forecast**
C	Decision Point 1	Keep an eye on data	Right now, the city is just barely in the watch zone. We did not want to cause panic so we are not ordering	**Forecast Other concerns**

			an evacuation--just asking the town to be prepared.	
	Decision Point 2	Keep an eye on data	Since we were only in the "Hurricane Watch" region, we decided it was take too expensive to evacuate citizens at this point.	**Forecast Evacuation**
D				
	Decision Point 1	Keep an eye on data	Morehead City is still too far away from the Hurricane to make any decision on evacuation.	**Hurricane**
	Decision Point 2	Tell citizens to prepare for evacuation	The hurricane is getting closer. We need to start preparing our citizens for evacuation. It is still too far away to call for full evacuation, but if residents make sure, it might be a good idea to start heading there.	**Hurricane Community**

These results lead to two findings in comparing the two years' group reasoning. First of all, like the previous findings from the group reasoning, the groups of the 2nd year referred to more aspects to be considered in decision making for Morehead City than those of the 1st year. Second, this finding is also similar to the previous findings. The groups of the 2nd year tended to provide more concrete and elaborate reasoning than those of the 1st year.

Summary of Findings to Research Question 1

To answer the first research question, "*What changes are visible in group decision making as represented group worksheets in the 1st and 2nd years?",* the following qualitative data was analyzed in this section:

- 3 decision points and reasoning of the Community Discussion Charts in the 1st year

- 2 decision points and reasoning of the Community Information Organizer in the 2nd year

To investigate the visible changes in decisions and reasoning between the 1st and 2nd years, the written data from the group work was described and compared along with each community. These descriptive and comparative results revealed three findings.

First, although each community and the hurricane information were same between the two years, the decisions were slightly different. Although there is no correct answer regarding the decision of whether the community should evacuate from the hurricane, it was evident that the decision making is different at each decision point, according to each community and each year.

Secondly, with regard to the reasoning to support the decisions, the groups of the 2nd year considered several categories in making the decisions, opposed to those of the 1st year. The groups of the 1st year tended to highly depend on the superficial information about the hurricane itself, like the storm, flooding, and wind, to make their decision, but those of the 2nd group frequently used several categories, like "hurricane," "community," "evacuation," "forecast," and "other considerations," related to considering evacuation to support their decisions.

Thirdly, the groups of the 2nd year provided more concrete and elaborate reasoning for their decisions, compared to those of the 1st year. Although the groups of the 1st year provided only statements, referring to the "storm," "flooding," "tourists," and so on, without any implication about their reasoning, those of the 2nd

year provided more elaborated notions by using several important categories which should be considered in the hurricane situation. Overall, the groups of the 1st year tended to show superficial and common sense- based reasoning, but those of the 2nd year showed situated and concrete reasoning.

Lastly, the groups of the 1st year tended to omit reasoning at some decision points. Specifically, the groups for Deerfield Beach and Morehead City in the 1st year did not provide any reasoning at some decision points. However, no group omitted reasoning in the 2nd year.

Differences in Levels of Critical Thinking in Individual Reports

Comparison of Levels of Critical Thinking Between the 1st and 2nd years

To examine what differences were evident in the levels of critical thinking demonstrated in individual reports between the students of the 1st and 2nd years, quantitative data analysis was used. The researcher and another instructional designer graded the level of critical thinking by using the scoring rubric presented in Chapter 3. Among all participants in both years, 156 students in the 1st year and 155 students in the 2nd year, only 130 students' individual reports in each year were fully scored since some of students had failed to submit the reports or others had submitted make-up papers instead of individual reports. The total score that students could gain in their individual report was 36 points, with a total of 6 points in each of the six categories. After grading was completed, independent t-tests were run to compare

critical thinking between the students of the two years. To examine what differences were evident between the students with higher and lower levels of critical thinking, the top 25 % and lower 25% students were selected across the two years and then independent t-tests were run.

Comparison of Levels of Critical Thinking Between the Students of the 1st and 2nd Years

To examine what differences were evident in critical thinking between the students of the two years, independent t-tests were run. Table 4.13 presents the results of the t-test, showing the differences in critical thinking between the top 25%, lower 25%, and total students of the 1st and 2nd years.

Table 4.13

Independent t-test in *Critical Thinking Between 1st and 2nd Years*

	1st Year			2nd Year			T	Sig	Cohen d
	N	M	SD	N	M	SD			
Top 25%	32	34.38	1.792	32	33.94	1.564	1.041	.302	.261
Lower 25%	32	14.19	3.316	32	17.81	2.978	**-4.601**	**.000****	**1.149**
Total	130	23.32	7.742	130	25.45	6.311	**-2.432**	**.016 ***	**.302**

* p < .05 level, ** p < .01 level

The t-test result was not statistically significant (t= 1.041, p> .05) between the top 25% students of the two years. The 1st year's top 25% students (M= 34.38, SD = 1.792) represent a higher level of critical thinking opposed to the 2nd year's top 25% (M= 33.94, SD = 1.564). However, there was a statistically significant difference between the lower 25% students of the two years (t = 14.601, p< .01). The 2nd year's lower 25% students (M=17.81, SD=2.978) represented increased levels of critical thinking than those of the 1st year (M=14.19, SD=3.316).

In total, the t-test result was statistically significant (t = -2.432, p< .05). The students of the 2nd year (M = 25.45, SD = 6.311) scored higher than those of the 1st year (M = 23.32, SD = 7.742).

Comparison of Levels in the Categories of Critical Thinking Between the Students of the 1st and 2nd Years

The researcher further investigated the t-test results of the categories for critical thinking in order to examine what kinds of categories in critical thinking were different between the top 25%, lower 25%, and total students of the two years. Each of the categories of critical thinking can be evaluated according to the following levels: emerging (1-2 points), developing (3-4 points), and mastering (5-6 points).

Identifying Decisions

Table 4.14 shows the results of the independent t-tests, examining whether there were differences in "identifying decisions," one of the categories in critical thinking in this study, between the top 25%, lower 25%, and total students of the two years.

Table 4.14.

Independent t-test results in *Identifying Decisions Between the 1st and 2nd years*

	1st Year			2nd Year			t	Sig	Cohen d
	N	M	SD	N	M	SD			
Top 25%	32	5.69	.738	32	5.94	.354	-1.729	.089	.432
Lower 25%	32	3.88	1.519	32	3.94	1.294	**- .177**	**-.860**	**.043**
Total	130	4.65	1.340	130	4.57	1.170	.492	.623	0.064

* p < .05 level **p < .01 level

In identifying group decisions, the students of the 1st year (M = 4.65, SD = 1.340) scored slightly higher than those of the 2nd year (M = 4.57, SD = 1.170). The total students of the two years were rated between "developing" and "mastering" in "identifying decisions." The t-test result had no significant difference between the two years' students (t = .492, p> .05).

Among the categories of critical thinking, the students in both years scored higher in "identifying decisions" than the other categories. Although the top 25% students of the 2nd year (M = 5.94, SD = .354) scored higher than those of the 1st year

(M = 5.69, SD = .738), there was no statistically significant difference between the two groups. Both top groups were definitely rated as "mastering" in "identifying decisions," which clearly recognized and summarized the embedded and implicit danger and impact of Hurricane Smith.

However, between the lower 25% students of the two years, there was a statistically significant difference ($t = -.860$, $p < .05$). The lower 25% students of the 2nd year (M = 3.94, SD = 1.294) demonstrated higher levels of critical thinking than those of the 1st year (M = 3.88, SD = 1.519). Both groups were rated as "developing" in "identifying decisions," which clearly identified issues raised in group and community discussions and might summarize the most important questions raised in both groups and in providing one's own perspective.

Evaluating Decisions

Table 4.15 shows the results of the independent t-tests, examining whether there were differences in "evaluating one's decisions," one of the categories in critical thinking in this study, between the top 25%, lower 25%, and total students of the two years.

In evaluating group decisions, there was no statistically significant difference between the total students of the 1st year and those of the 2nd year ($t = -1.786$, $p > .05$), although the students of the 2nd year (M = 4.34, SD = 1.138) performed better than those of the 1st year (M = 4.05, SD = 1.416). Students in both years were rated as "developing," since they provided their own evaluation based on group and community discussions without sufficient reasoning.

Table 4.15.

Independent t-test results in *Evaluating One's Decisions Between the 1st and 2nd Years*

	1st Year			2nd Year			t	Sig	Cohen d
	N	M	SD	N	M	SD			
Top 25%	32	5.74	.672	32	5.69	.738	.354	.724	.071
Lower 25%	32	3.00	1.459	32	3.63	.942	**-2.036**	**.046***	-.513
Total	130	4.05	1.416	130	4.34	1.138	-1.786	.075	0.226

* p < .05 level **p < .01 level

Between the top 25% students of the two years, no statistically significant difference was not found (t = .354, p> .05), although the 1st year's top 25% students (M = 5.74, SD = .672) scored higher than students of the 2nd year (M = 5.69, SD = .738). However, there was a statistically significant difference in critical thinking between the lower 25% students of the two years (t = -2.036, p< .05). Between the two groups, the 2nd year students demonstrated higher levels of critical thinking than the 1st year students.

Providing One's Own Decision

Table 4.16 shows the results of the independent t-tests, examining whether there were differences in "providing one's own decision," one of the categories in critical

thinking in this study, between the top 25%, lower 25%, and total students of the two years.

Table 4.16.

Independent t-test results in *Providing One's Own Decision Between the 1st and 2nd Years*

	1st Year			2nd Year			t	Sig	Cohen d
	N	M	SD	N	M	SD			
Top 25%	32	5.75	.672	32	5.75	.672	.000	1.000	**0**
Lower 25%	32	1.81	.931	32	3.25	1.218	**-5.304**	**.000****	**-1.328**
Total	130	3.89	1.676	130	4.63	1.365	**-3.895**	**.000****	**0.484**

* p < .05 level **p < .01 level

In providing one's own decision, the t-test result was significantly different between the total students of the two years (t = -3.895, p< .01). The total students of the 2nd year (M = 4.63, SD = 1.365) significantly outperformed those of the 1st year (M = 3.89, SD = 1.676) in providing their own decisions. The means of the total students of both years were identified as "developing," because the solutions/positions they offered were general and gaps may have been present in their explanations.

The result of the t-test, examining differences in "providing one's own decision" between the lower 25% of the two years, shows that there was a significant difference (t = -5.304, p<.01). Between the two groups, the 2nd year (M = 3.25, SD

=1.218) significantly performed better in providing their own solutions than the 1st year did (M=1.81, SD = .931). Specifically, in rating, a shift was made in providing their solutions across the year. Although the lower 25% students of the 1st year were rated as "emerging," which means that they offered unclear or simplistic solution or positions, those of the 2nd year were evaluated as "developing."

However, no significant difference was found between the top 25% students of the two years (t= .000, p> .05), as they obtained the exact same score on their solutions across the two years (M = 5.75, SD = .672). In presenting their decisions, the top 25% students of the two years offered solutions/positions that demonstrated sophisticated, integrative thought and were developed clearly.

Arguments and Justification for One's Own Decision

Table 4.17 shows the results of the independent t-tests, examining whether there were differences in "arguments and justification for one's own decision," one of the categories in critical thinking in this study, between the top 25%, lower 25%, and total students of the two years.

In presenting arguments for justification, the t-test result was significantly different between the total students of the two years (t = -2.688, p< .01). The total students of the 2nd year (M =4.31, SD = 1.483) scored better than those of the 1st year (M = 3.77, SD = 1.737). Both groups were rated as "developing" in "presenting arguments for justification," which means that one presents and justifies his/her own solution without addressing other views, or does it superficially.

Table 4.17.

Independent t-test results in *Arguments and Justifications for One's Own Decision Between the 1st and 2nd Years*

	1st Year			2nd Year			t	Sig	Cohen d
	N	M	SD	N	M	SD			
Top 25%	32	6.00	.000	32	5.94	.354	1.000	.321	.240
Lower 25%	32	1.88	.871	32	2.69	.965	**-3.536**	**.001****	**.881**
Total	130	3.77	1.737	130	4.31	1.483	**-2.688**	**.008****	**0.334**

* p < .05 level **p < .01 level

The statistically significant difference was also found between the lower 25% students of the two years (t = .001, p< .01). Between the lower 25% students, the 2nd year students (M = 2.69, SD = .965) significantly performed better in presenting arguments for justification than the 1st year students (M = 1.88, SD = .871). Both groups were rated as "emerging" in "presenting arguments for justification," which indicates that they failed to present justification for their own solution.

However, although the top 25% students performed well in this category, i.e., both groups were rated as "mastering," which means that they provided clearly presented and justified solutions with qualified and integrated views on the Hurricane Smith situation, no statistically significant difference was found across the two years (t = 1.000, p> .05). Examining actual scores, it is evident that the top 25% students of

the 1st year (M = 6.00, SD = .000) showed a slightly higher score than those of the 2nd year (M = 5.94, SD = 354).

Presenting Supporting Data/Evidence

Table 4.18 shows the results of the independent t-tests, examining whether there were differences in "presenting supporting data/evidence," one of the categories in critical thinking in this study, between the top 25%, lower 25%, and total students of the two years.

Table 4.18.

Independent t-test results in *Presenting Supporting Data/Evidence Between the 1st and 2nd Years*

	1st Year			2nd Year			t	Sig	Cohen d
	N	M	SD	N	M	SD			
Top 25%	32	5.56	.840	32	4.94	1.134	**2.505**	**.015***	.621
Lower 25%	32	1.63	.942	32	2.06	1.190	-1.631	.251	-.400
Total	130	3.40	1.772	130	3.51	1.615	-.512	.609	0.065

* p < .05 level **p < .01 level

There was no statistically significant difference in presenting supporting data/evidence between the total students of the two years (t = -.512, p>. 05),

although the 2nd year students (M = 3.51, SD = 1.615) scored higher than the 1st year students (M = 3.40, SD = 1.772). Both groups were rated as "developing" in presenting supporting evidence data, which means that there was evidence to support the argument but it was not always important.

Between the lower 25% students of the two years, no statistically significant difference was not found (t = -1.631, p> .05), although the 2nd year group (M = 2.06, SD = 1.19) was better in this category of critical thinking than the 1st year group (M = 1.63, SD = .942) in presenting supporting data and evidence. Both groups were rated as "emerging" in presenting supporting data/evidence, which means that no evidence was provided to support their argument or they failed to provide any data/evidence.

However, there was a statistically significant difference between the top 25% students of the two years (t = 2.505, p< .05). Interestingly, the 2nd year group (M = 4.94, SD = 1.134) showed lower scores than the 1st year group (M = 5.56, SD = .840) in presenting supporting data/evidence. A shift was made in rating across the year. Although those of the 1st year were rated as "developing," the top 25% students of the 1st year were categorized as "mastering," which means that they considered context, data, and evidence in the discussion of their final decision.

Integrating Other Perspectives

Table 4.19 shows the results of the independent t-tests, examining whether there were differences in "integrating other perspectives," one of the categories in

critical thinking in this study, between the top 25%, lower 25%, and total students of the two years.

Table 4.19.

Independent t-test results in *Integrating Other Perspectives Between the 1st and 2nd Years*

	1st Year			2nd Year			t	Sig	Cohen d
	N	M	SD	N	M	SD			
Top 25%	32	5.63	.793	32	5.69	.738	-.326	.745	-.078
Lower25%	32	2.06	1.016	32	2.25	.672	**-4.601**	**.000****	**-.221**
Total	130	3.55	1.694	130	4.09	1.512	**-2.704**	**.007****	**0.336**

* p < .05 level **p < .01 level

In integrating other perspectives, the result shows that there was a statistically significant difference between all the students of the 1st year and those of the 2nd year (t = -2.704, p < .01). The students of the 2nd year (M = 4.09, SD =1.512) performed better in this category of critical thinking than those of the 1st year (M = 3.55, SD = 1.694). Both groups were rated in the "developing" category in "integrating other perspectives," which means that they began to relate alternative views to qualify analysis.

Between the lower 25% students of the two years, a statistically significant difference was found (t = -4.601, p< .01), showing the 2nd year group (M = 2.25, SD

= .672) scored better than the 1st year group (M = 2.06, SD =1.016) in "integrating other perspectives." Both groups were rated as "emerging" in "integrating other perspectives," which means that they dealt with a single perspective or failed to discuss their group and community perspectives when presenting their final decision.

However, between the top 25% students of the two years, there was no statistically significant difference ($t = -.326$, $p > .05$) in "integrating other perspectives," indicated by showing similar mean scores across the two years. Both groups were rated as "mastering" in "integrating other perspectives," which means that they addressed other perspectives and additional diverse perspectives drawn from information to qualify their analysis.

Summary of Findings to Research Question 2

To investigate the second research question, "*What differences in levels of critical thinking are evident in individual reports between the 1st and 2nd years?*," independent t-tests were run. This subsection presents a discussion of the results.

The statistical t-test results indicate that the students of the 2nd year showed higher levels of critical thinking in science than those of the 1st year. The lower 25% students of the 2nd year also showed increased levels of critical thinking in science than those of the 2nd year. Between the total and the lower 25% students of the two years, there were statistically significant differences in critical thinking. However, between the top 25% students of the two years, the 1st year students were slightly higher than the 2nd year students in critical thinking, although there was no statistically significant difference.

Second, the students of the 2nd year performed significantly better in three categories of critical thinking: 1) providing one's own decision, 2) argument and justification for one's own decision, and 3) integrating other perspectives. Although the students of the 2nd year scored higher in two categories of critical thinking, "evaluating decisions" and "presenting supporting data/evidence," there were no significant differences between the two groups. With regard to the category of critical thinking, "identifying decisions," there was no significant difference between the two groups, although the students of the 1st year performed better than those of the 2nd year.

Third, among the three categories which did now show significant differences between the students of the 1st and 2nd years, the students of both years scored more than 4 in the two categories of "identifying decisions" and "evaluating decisions," but in the category of "presenting supporting data/evidence," those of both years scored less than 4.

Fourth, the top 25% students of the two years did not show any statistically significant differences in these five categories of critical thinking: 1) identifying decisions, 2) evaluating decisions, 3) providing one's own decision, 4) argument and justification for one's own decision, and 5) integrating other perspectives. Only in "presenting supporting data/evidence" was a statistical significant difference found, revealing that the top 25% students of the 1st year performed better than those of the 2nd year. Overall, although the top 25% students of the 2nd year scored higher than those of the 1st year, in the five categories of critical thinking, there were no differences.

Lastly, the lower 25% students of the two years students showed statistically significant differences in these four categories of critical thinking: 1) evaluating decisions, 2) providing one's own solutions, 3) arguments and justification for one's own decision, and 4) integrating other perspectives.

Summary of Comparisons of Critical Thinking

By comparing levels of critical thinking of students of the 1st and 2nd years, it was found that the students of the 2nd year demonstrated higher levels of critical thinking than those of the 1st year. This finding implies that the 2nd year design, which employed procedural and elaborative question prompts and peer interaction with individual preparation, was more effective in enhancing students' critical thinking in a large undergraduate class context.

Moreover, among the six categories of critical thinking, the students of the 2nd year performed better in: 1) providing one's own decision, 2) arguing and justifying one's own decision, and 3) integrating other perspectives, than those of the 1st year. This finding implies that the two types of question prompts and use of peer interaction with individual preparation helped the students to construct their own decision and solution with appropriate arguments and justification, and integrate similar and different perspectives into their own beliefs.

It was evident that there were changes in critical thinking demonstrated in the individual report between the lower 25% students of the two years. Overall, the lower 25% students of the 2nd year demonstrated increased levels of critical thinking, by gaining better scores in these four categories of critical thinking: 1) evaluating

decisions, 2) providing one's own decision, 3) arguments and justification for one's own decision, and 5) integrating other perspectives. This finding implies that the two types of question prompts and use of peer interaction with individual preparation were effective for the lower level students to evaluate group decisions, provide their decisions, argue and justify their decisions, and integrate other perspectives.

However, there were few differences in critical thinking among the top level students of the two years. Both groups showed higher levels in each category of critical thinking. It was evident that the design change did not highly impact or cause any improvement in their critical thinking. A difference was only found in one category of critical thinking, presenting supporting data/evidence. The 2nd year's top level students showed a statistically significant difference opposed to the 1st year students, although there were no differences among the total and the lower level students of the two years. This result implies that the design change in the 2nd year helped the top level students to use data and evidence in order to make their final decision in their individual reports.

The Multiple-Case Study Results

To investigate why there were differences in levels of critical thinking between these two years, an in-depth, multiple-case study was conducted. For this multiple-case study, eight cases were studied and compared. As mentioned in Chapter 3, the embedded and two-tail design was used for sampling and data collection. This section presents the sampling strategy and procedure, a brief introduction of the eight cases, and the results of cross-case comparison.

Sampling Strategy and Procedure

To investigate the third research question, *"What differences are evident in the individual and group worksheets and individual reports between the students with higher and lower levels of critical thinking in the 1st and 2nd years?",* an embedded and two-tail design for the multiple-case study was used for sampling and data analysis.

For embedded design, used if the cases are situated in specific contexts that are different, the cases were selected from the 1st and 2nd years respectively. For two-tail design for sampling, used to maximize the differences among the cases, higher and lower levels of critical thinking were used as the criterion. Specifically, for the two-tail design for sampling, the statistical results of the previous section were referred to. In order to define what the higher and lower levels of critical thinking mean for this multiple-case study, the researcher went back to the descriptive

statistics of each category of critical thinking. The statistical results indicate that there are differences in: 1) providing decision, 2) arguments and justification of one's own decision, and 3) integrating other perspectives, but there were no differences in: 1) identifying one's decisions, 2) evaluating one's own decisions, and 3) presenting supporting data/evidence. In addition, among the three categories that did not show significant differences in levels of critical thinking, the students of the both years performed well in "identifying one's decisions" and "evaluating one's decisions," with their means of higher than 4 out of 6. This result of the two categories of critical thinking does not support maximizing the differences within each year and between the two years, because most of the students in both years performed well in the two categories. In the other category, "presenting supporting data/evidence," the means of the students in both years was less than the other three categories. Therefore, this category was not appropriate to maximize the difference in level of critical thinking because overall the score was poor in both years. To maximize the differences between the higher and lower levels of critical thinking, the researcher decided to use only the three categories that showed significant differences between the two years as the criterion, instead of using the sum of all the categories of critical thinking.

Therefore, in this multiple-case study, a case with higher levels of critical thinking is defined as a student with 6 out of 6 in each of the three categories. On the other hand, a case with lower levels of critical thinking is defined as a student with 1 out of 6 in each of the three categories.

Based on the embedded and two-tailed design for sampling as mentioned above, this multiple-case study has 4 units by each year and the level of critical thinking. The following defines each unit:

- **High-1st yr**: Higher level of critical thinking representing 6 out of 6 in each category of: 1) providing one's own decision, 2) arguments and justification for one's own decision, and 3) integrating other perspectives, in the 1st year.
- **Low-1st yr**: Lower level of critical thinking representing 1 out of 6 in each category of: 1) providing one's own decision, 2) arguments and justification for one's own decision, and 3) integrating other perspectives, in the 1st year.
- **High-2nd yr**: Higher level of critical thinking representing 6 out of 6 in each category of: 1) providing one's own decision, 2) arguments and justification for one's own decision, and 3) integrating other perspectives, in the 2nd year.
- **Low-2nd yr**: Lower level of critical thinking representing 1 out of 6 in each category of: 1) providing one's own decision, 2) arguments and justification for one's own decision, and 3) integrating other perspectives, in the 2nd year.

Each unit has two individual students, and each individual is considered to be a case. Therefore, a total of eight cases were selected as the result of the definition of each unit for this multiple-case study.

The data sources for the cross-case comparisons were the written documents that the students had submitted. For the cases for High-1st yr and Low-1st yr, the available data was the group and community discussion charts and individual reports.

For the cases for High-2nd yr and Low-2nd yr, the individual worksheets, the community information organizer, and individual reports were collected.

Overview of the Case

Table 4. 15 above gives an overall description of each case with the unit, a brief profile, its community and role, school year, and major during the Hurricane Smith Module, and levels of critical thinking demonstrated in the individual report. The unit is indicated in brackets. A pseudonym is used to protect the identity for each case.

Table. 4.20

Profile of the Eight Cases

Name	Unit	Community /Group	Gender	Major	School Year	Level of Critical Thinking					
						Identifying Decisions	Evaluating Decisions	Providing One's Own Decisions	Argumentation & Justification	Presenting Supporting Data/Evidence	Integrating Other Perspectives
Paula	High-1st yr	Deerfield Beach/Infrastructure Services	Female	Spanish	4	6	6	6	6	6	6
Alice		Hilton Head/Infrastructure Services	Female	Art	4	6	6	6	6	6	6
Sue	Low-1st yr	Hilton Head/Disability Advocates	Female	Journalism	4	5	2	1	1	1	1
Jim		Morehead City/Chamber of Commerce	Male	Elementary Education	4	3	3	1	1	1	1
Jane		Morehead City/Mayor and City Council	Female	Advertising	4	6	5	6	6	6	6
Julie	High-2nd yr	Deerfield Beach/Emergency Services	Female	Marketing	2	6	6	6	6	6	6
Kristen	Low-2nd yr	Deerfield Beach/Media	Female	Finance	4	3	1	1	1	3	1
Joe		Hilton Head/Emergency Services	Male	RPTM	2	4	3	1	1	1	1

Case 1 (High-1st yr), Paula, who demonstrated higher levels of critical thinking in her individual report, was a 1st-year student attending the College of Liberal Arts. She participated in the 1st year's Hurricane Smith Module. In each of the six categories of critical thinking, she scored 6 out of 6, which means that she demonstrated the highest level of critical thinking. She took the role of the Infrastructure Services for one of the groups for Deerfield Beach with another peer.

Case 2 (High-1st yr), Alice, was a senior student majoring in Arts and attended the Hurricane Smith Module in the 1st year. She demonstrated a perfect score, 6 out of 6, in each category of critical thinking. She performed the role of the Infrastructure for Hilton Head with another peer.

Case 3 (Low-1st yr), Sue, who demonstrated lower levels in the three categories of critical thinking, was a senior student who majored in journalism. She took part in the Hurricane Smith Module of the 1st year. Although she was defined as a case with lower levels of critical thinking, she had a higher score in one of the categories of critical thinking; she received 5 out of 6 in identifying group decisions. She was a member of the Disability Advocates group for Hilton Head with another peer.

Case 4 (Low-1st yr), Jim, was majoring in Elementary Education. He was a senior student when he attended the Hurricane Smith Module of the 1st year. He was defined as a case with lower levels of critical thinking, since he scored 1 out of 6 in each of the three categories. He performed the role of the Chamber of Commerce for Morehead City, with two peers.

Case 5 (High-2nd yr), Jane, received perfect scores, 6 out of 6, in five categories of critical thinking, except in evaluating decisions. She was a senior student majoring in advertising when the Hurricane Smith Module was implemented in the 2nd year. She was a member of the Mayor and City Council group in Morehead City.

Case 6 (High-2nd yr), Julie, was a sophomore student majoring in marketing when she attended the Hurricane Smith Module in the 2nd year. She was selected as a case with higher levels of critical thinking since she demonstrated a perfect score in every category of critical thinking in her individual report. She was a member of Emergency Services for Deerfield Beach.

Case 7 (Low-2nd yr), Kristen, was a senior student majoring in finance. She took the role of Media Group for Deerfield Beach. She participated in the Hurricane Smith Module in the 2nd year. She was selected as a case with lower levels of critical thinking, since she scored 1 of 6 in each of the three categories of critical thinking. She also scored 3 and 1 (out of 6) in the two categories of identifying one's decisions and evaluating one's decisions.

Case 8 (Low-2nd year), Joe, was a sophomore student in the Department of Recreation, Park, Tourism, and Management. He performed the role of Emergency Services for Hilton Head when the Hurricane Smith Module of the 2nd year was implemented. He demonstrated lower levels of critical thinking by scoring 1 out of 6 in each of the three categories.

The Results of Cross-Comparison

The purpose of this cross-case comparison over the multiple cases is to explore what differences in the individual and group worksheets and individual reports were evident between the two years. Therefore, the focus of the cross comparison was to find out evidence showing the similarities and differences represented in the cases' group discussion (1st year), individual worksheets (2nd year), and individual reports (1st and 2nd years) over the 4 units.

During the cross-case comparison over the four units, four major themes emerged to elaborate on the similarities and differences; 1) understanding of assigned role, 2) linking roles to make decisions, 3) answers to the question prompts, 4) use of data and sources. The subsequent sections present these four themes with evidence, as well as provide trends across artifacts for high performing students in both years.

Understanding of Assigned Role

Understanding of assigned role was a unique pattern found during the cross-case comparison over the multiple cases. It was evident that all of the students with higher levels of critical thinking perceived and defined what their role is and what they should do for the hurricane situation for their communities, as opposed to those with lower levels of critical thinking.

1st Year's Cases

Paula (High-1st yr) engaged in her group discussion by defining her role in Infrastructure. Her group discussion chart with her peers defined its role as "our function is that we're responsible for all the infrastructure in Deerfield Beach, meaning the roads, utilities, and necessities that the community needs in terms of surviving in Deerfield and evacuating." In her individual report, she began with what she did with her role to make her own decision for her community as follows:

> It is my job to ensure that Deerfield Beach, FL is as best prepared as possible to prevent injuries and damages from hurricane in the future. I was part of the infrastructure group, so we were largely in charge of roads (transportation routes), utilities, and getting necessities to the community.

The above excerpt shows her clear perception on her role and what she should do for her community to protect itself against the Hurricane Smith situation.

Alice (High-1st yr), who also assumed the same role as Paula for Morehead City, clearly stated the function and priorities of her role in her group discussion chart as follows:

> My purpose is to make sure that all roadways and bridges are functioning and maintained. Also, [another part of my job is] to make sure all routes and important roads are labeled and designated. We must make sure all roadway signals are working.
> Priorities are specifying important routes and roadways, functioning signals, clear roadways, and maps and information to citizens.

Although Paula focused on roads, utilities and necessities for her community as a member of the Infrastructure Services group, Alice was concerned about

congestion during the evacuation because Hilton Head, her community, had only one road to evacuate from the hurricane, with the same role.

> The Infrastructure Services group was especially concerned with preparing citizens for evacuations because there is really only one main roadway out of Hilton Head, and it would experience high congestion during an evacuation.

It was evident that Paula and Alice recognized what their role was and what they should do to prepare for the Hurricane in their community context.

In contrast to Paula and Alice, Sue and Jim (Low-1st yr) demonstrated their role superficially, if at all, in both their group discussion charts and individual reports.

For example, Jim, one of the members of the Chamber of Commerce for Morehead City, his group stated his role as "regulating business and trade in the city of Morehead" in his group discussion chart. However, his group did not provide what he had done with his role for his community in his individual report.

Sue, in the role of Disability Advocate, recognized the function of her role as having "no function, we just need to be taken care of" in her group discussion chart. In addition, she did not mention anything about what she had done in her individual report, which can be seen in her words below:

> During the Hurricane, I was the head of the Disability Advocate Group. As such, I was extra cautious about how to proceed in dealing with the Hurricane.

Among the cases of the 1st year, the cases with higher critical thinking (High-1st yr) focused on what their roles were and what they had done for their community

in their group discussion charts and individual reports, rather than those with lower levels of critical thinking (Low-1st yr).

2nd year's Cases

Julie (High-2nd yr), who took the role of Emergency Services member for Deerfield Beach, showed how seriously she recognized her role in her individual worksheet. In the section of understanding the specific administrative role, she provided detailed answers to "hospitals," "fire stations and locations," "location of shelters and how many people can be accommodated in each other" and "other considerations" that she should identify as a member of Emergency Services for her community under the hurricane situation. She elaborated on the locations of hospitals, fire stations, shelters, and other places, in Deerfield Beach, where the residents should be guided under an emergency situation and provided how to get to them with attached maps indicating the locations in her individual worksheet. She just began by stating, "I was an Emergency Services representative from the Deerfield Beach area of southern Florida," in her individual report, and then focused on where the residents of Deerfield Beach should go for evacuation and how to get to there with the attached route for evacuation.

Jane (High-2nd yr) also stated what she should do in her role for her community in her individual report as follows:

> I represent the Mayor and City Council of Morehead City. My job was to evaluate the total cost of evacuation (if necessary) as a result of Hurricane Smith. I also responsible for identifying any other possible dangers that could come from the

> hurricane aside from the obvious, and from collecting this information I was to inform the community of appropriate measures to take. I estimated key businesses and venues that would have to shut down and then analyzed the results on the economy cost-wise. I identified the specific roads and highways that would act as an evacuation route and the cost/time constraint that would come along with packing those roads with traffic.

As a member of the Mayor and City Council group of Morehead City, she listed her responsibilities, evaluating the total cost of evacuation, identifying possible dangers from the hurricane, and so on. Her perception of her role demonstrated in her individual report was complex and elaborative enough to show what she should do. Her individual worksheet also showed a complete understanding about her role. She calculated the cost of complete evacuation with the list of considerations, and the cost of evacuating specific residents and facilities as "around $30 million."

Compared to Jane and Julie (High-2nd yr), Joe and Kristen (Low-2nd yr) rarely mentioned their role in their individual reports. Moreover, although the responsibilities of their role were stated, they were not concrete or failed to situate them into their community and hurricane context.

Joe (Low-2nd yr) briefly mentioned his role as a member of Emergency Services in his individual report. Although he stated the goal of his role as "I have to try and keep the people and the tourists safe," he did not provide what he should do when Hurricane Smith was coming to his community. In addition, he skipped the questions about the locations that an Emergency Services representative should identify for evacuation in his individual worksheet. He only answered the question of "location of shelters," but the answer was superficial, stating that "shelter should be

west from the storm." This contrasted with Julie, who provided detailed answers to the locations that Emergency Services should be able to identify, namely routes and maps to hospitals, shelters, and fire stations for her community, Deerfield Beach.

In the case of Kristen (Low-2nd yr), who took the role of Media Group member for Deerfield Beach, she answered questions related to understanding her specific role in her individual worksheet. She listed the history of hurricanes and their categories but answered superficially the question of "how to deal with time of impact" by stating "people should stay inside their houses regardless of what time or day it is." In her individual report, there was no mention about what her role was and what she had done for her community in this role.

Like the cases of the 1st year, it was evident that the cases with higher level critical thinking (High-2n yr) clearly stated what their roles were and what they had done with these roles in their individual worksheets and individual reports.

Comparisons cross the Years

The pattern, in which the cases with higher levels of critical thinking focused on their specific roles, was evident across the year. Paula and Alice (High-1st yr), and Jane and Julie (High-2nd yr) tended to state and confirm their role taking. However, Sue and Jim (Low-1st yr), and Kristen and Joe (Low-2nd yr) rarely mentioned their specific roles.

Regarding role taking, Paula and Alice (High-1st yr) defined their role in their group discussion charts and showed what they had done during group and community discussions through their individual reports. Jane and Julie (High-2nd yr)

provided detailed answers to the questions of understanding their specific roles in their individual worksheets and then showed what they had done during community discussions through their individual reports. Although different question were used in identifying their specific roles, which students should took through the Hurricane Smith Module, between the two years, the cases with higher levels of critical thinking in the 1st year (High-1st yr) defined and identified their responsibilities and functions in their group discussion charts, and those in the 2nd year (High-2nd yr) identified the most important aspects to perform their roles through their individual worksheets.

However, the cases with lower levels of critical thinking (Low-1st yr and Low-2nd yr) tended to provide superficial answers to the questions related to their roles, in the group discussion charts of the 1st year and the individual worksheets of the 2nd year, and resulted in not presenting what they had done with their roles in their individual reports.

Linking Roles to Decisions

The second theme from the results of the cross-case comparison was found in the cases' individual reports, where students were required to make their final decision as a result of their participation in group discussions and individual preparation. A pattern exists among the cases with higher levels of critical thinking (High-1st and High-2nd). Their serious role taking was used as a basis for making their final decision in their individual reports.

1st Year's Cases

Alice (High-1st yr), as a member of Infrastructure Services for Hilton Head, presented her own decision based on her role by being "concerned with preparing citizens for evacuations" in her individual report.

> The storm surge, especially one of this height, could have the possibility to damage the roadways and bridges, causing extreme difficulties for evacuation. Therefore, evacuating before the storm gets too close is vital for the safety of all people.

Paula (High-1st yr), as a member of Infrastructure Services for Deerfield Beach, presented a concrete evacuation plan as her final decision as follows:

> My final decision on the Hurricane Smith evacuation plan is that early evacuation is the best option there is. This is due to the topography and population/age group data given above, but it also has to do with the geography and transportation routes of Deerfield Beach, FL.
>
> … Evacuating early and using Route 869 to go west (at a hotel base in Sarasota that we already have an agreement with) is the best plan because it gets everyone out in time, before they are trapped in their homes without base necessities, and it also avoids the path of most storms.

She indicated the route for evacuation based on the map of Deerfield Beach and insisted that it should avoid the path of the storms.

However, Sue (Low-1st yr) did not link her role, Disability Advocate, to making her final decision in her individual reports:

> I suggest that a careful eye should be kept on the data, and a warning for the people to prepare for evacuation should be put out as early as possible, probably earlier than we did in the Hurricane Smith situation. That way, if evacuation is necessary, the people are prepared.

From the above excerpt, it was evident that she did not take care of people with disabilities in her community, Hilton Head, and made a superficial decision. Instead of making his own final decision, Jim (Low-1st yr) referred to his group and community decisions as follows:

> Our group and community decision to evacuate was unanimous; it is the best possible solution to get our people out of danger and into safer grounds. We have prepared an evacuation route due West and have many places where everyone can stay and have plenty of food and water.

Like Sue, Jim did not reflect on his role when making his decision. Although he had the role of Mayor and City Council, he neither showed how safely the residents should evacuate, nor which route should be used for evacuation.

2nd Year's Cases

Julie (High-2nd yr) linked her role taking with her own decision in her individual report. Her final decision focused on "evacuation route," reflecting her effort on performing the role of Emergency Services. She attached several resources from web sites, indicating the shelters, hospitals, and evacuation routes for Deerfield Beach, in her individual worksheet. These efforts showed how seriously she took her role under the task of making a decision about whether her community should evacuate or not. Based on the influence of her role, her final decision was as follows:

> I would evacuate the rest of the city of Deerfield Beach. Once again, knowing the path of the hurricane, I would send them to the panhandle of Florida, which is the same place that my (role) group decided to send them. In particular, I would send them to the Panama City region of Florida. Using major highways such as Routes 75

> and 95, to allow for more efficient traffic flow, this evacuation route would take no more than nine hours.

In the above excerpt, Julie indicated a specific site for relocation and exact routes to get there, which she had identified in her individual worksheets and community discussion.

In the case of Jane (High-2nd yr), she raised an impressive criterion for evaluating decisions based on her role, City Mayor and City Council, in her individual report as follows:

> During Hurricane Smith's journey toward our city, the council was responsible for making certain decisions at key points throughout the hurricane's course. We observed that the hurricane was heading toward Florida, and it appeared to be heading mostly inland and had downgraded from a Category 4 hurricane to a Category 3. Therefore, we decided to keep watching the radar and analyzing the data. As the mayor, I sent out a press release of appropriate measures for the community to take in order to guard themselves against strong winds, fire, power outages, and possible flooding. We did not evacuate because we estimated the total cost of evacuation to be around 1 billion dollars or more. The median household income in Morehead City is $28, 737, and we are aware that we aren't the wealthiest of communities--the financial hit of evacuation would have been disastrous.

This consideration, cost and financial issue about evacuation for her community, was based on the answers to questions related to "cost of complete evacuation" and "cost of evacuating specific residents and facilities" in her individual worksheet. Before making her final decision, she presented several issues related to evacuation as a Mayor and City Council group member as follows:

> We are now faced with the problem of possibly having to evacuate 7,691 people out of Morehead City, with 1,598 of those people aged 65 or older. We are going to be directly hit by the hurricane with winds ranging from 111 to 130 mph and a storm surge of 9 to 12 ft. We are forced to evacuate being so close to the coast, and we are going to encounter inevitable flooding and damage to small structures/buildings.

In her final decision, she pointed out available resources for evacuating her community as follows:

> Our final decision is to call all available help to Morehead City for evacuation. This help includes flying in people from the US Army Corps of Engineers via the Carven Regional Airport to assist the elderly and the most immobile people to safety.

Also, with her final decision, she provided a reason why her community should evacuate, based on what she had identified in researching her community as a member of the Mayor and City Council group:

> Still, many of the homes in Morehead City are valued at around $106,400, meaning they are generally smaller in structure and will most likely be destroyed according to the wind's speeds.

Her primary concern was related to the characteristics of most of the homes' structure. She thought that they would be destroyed if the hurricane hit.

Joe (Low-2nd yr) did not make any clear decision linked to his role, a member of Emergency Services crew, in his individual report. He ended his individual report as follows:

> There must be more advantages to evacuating too early rather than too late. If you evacuate too early you might lose time at work, or spend more money on a place to stay in another city. If you evacuate too late, this could even mean losing your life.

> At the time a decision needs to be made; you will never know if it is the right one. All you can do is take the information you have, and do what you feel is right. This is what the emergency service crew did for Hilton Head Island, and we came out of it very strong.

In the above excerpt, it is evident that he just made a superficial decision of what his community should do to protect itself against the hurricane. He did not indicate any names of shelters or hospitals that a member of the Emergency Services team should be able to identify in his decision.

In the case of Kristen (Low-2nd yr), she did not provide her final decision. Instead, she ended her individual report with an inaccurate direction of the hurricane, as follows:

> We have never witnessed a hurricane like this and still think that we made the right decision and still support that decision. With this experience in our past, we will continue to develop our technology to become more sufficient in predicting hurricane tracks. We will also look much closer when a hurricane appears on the same track as Hurricane Smith's because we now know that it is possible to switch directions.

Including the above statement, there was no evidence to link her role to making decisions and other arguments or justifications in her individual report.

Comparison cross the Years

Compared to the cases with lower levels of critical thinking (Low-1st yr and Low-2nd yr), those with higher levels of critical thinking (High-1st yr and High-2nd yr)

developed more sophisticated decisions in their individual report, based on their serious role taking.

Sue and Jim (Low-1st yr) and Kristen and Joe (Low-2nd yr) tended not to provide their final decisions in their individual reports. Instead, they just identified previous group and community discussions in their individual reports.

However, Paula and Alice (High-1st yr), who represented Infrastructure Services for their community, showed evidence of how their specific roles affected their final decisions, by identifying and indicating evacuation routes and some limitations.

Julie and Jane (High-2nd yr) showed evidence of how they linked their role taking to making their final decision, by indicating the places where people should go for evacuation with the road numbers to get there.

To sum up, the cases of lower levels of critical thinking failed to use their roles in making their final decision so it resulted in superficial decisions or just referred to their group and community's decisions. However, the cases of higher levels of critical thinking clearly linked their roles to making their final decisions and some argumentation and justifications in both years.

Answers to the Question Prompts

The third theme was found in the group discussion charts of the 1st year and the individual worksheets of the 2nd year, since both sheets required students to

answer the questions related to the decision-making process and understanding important aspects of the hurricane situation.

Although different questions were used in the two types of sheets, a pattern was found regarding this theme, answers to the question prompts, in both sheets between the cases with higher and lower levels of critical thinking.

1st Year 's Cases

Table 4. 21

Example of Answers to Procedural Question Prompts at Decision Point 3 in the 1st Year

	Paula (High-1st yr)	**Jim (Low-1st yr)**
List below the dangers and impacts associated with Hurricane Smith in its new location	Storm is moving west /northwest. There is a heavy surf advisory (big saveswaves). All the way is mass. Rainfall of 5-10 inches. Still expecting to hit towards our area. Now the scope of the hurricane and where it is going to hit is all the way up in the north. There could be lots of lost property and possessions.	-High winds -High tides -Flooding -Hail
What do you think are the most important dangers/impacts to address from the list above? Why are they important?	- People getting trapped due to the flooding (water) and tornadoes that are in our area; - Getting people basic necessities in the process of evacuating, like how to get food/water when we're moving from the area; - Being able to move to an area that will have room for us and want to have hurricanes in warning.	All of these dangers are most important. They can damage businesses, homes, beaches, etc.

Paula's group (High-1st yr) listed more than three dangers and impacts to the question, "*List below the dangers and impacts associated with Hurricane Smith*," and "*What do you think are the three most important dangers/impacts to address from the list above?",* at each group decision point. The answers of her group to the question used more shaped sentence to point out the dangers and impacts of the hurricane on her community.

However, Jim's group (Low-1st yr) only listed and provided simple answers to those two questions. Table 4.17. displays and compares Paula's answers to the two question prompts with those of Jim.

Paula's answers are related to why the current hurricane would be dangerous and what they should consider to protect the community from the Hurricane. However, Jim's simple answers only contained some common sense about the hurricane and its effects.

In the case of Alice (High-1st yr), she listed answers to all the questions, although each of her answers was shorter than that of Paula. She listed the dangers and impacts associated with Hurricane Smith, and made decisions three times backed with several reasons. For the reasons of why she made the decision, she frequently referred to "weather report," which was provided to students as an available resource in class, and focused on the hurricane's path and category. For example, at Decision Point 3, she chose "evacuate" as her decision and supported her reasoning with "hurricane warning category 4," "heavy winds/high surge/heavy rains/flooding," and "single roadway out, so need to handle so much traffic." These answers seemed to be reasonable to support her decision.

However, Sue (Low-1st yr) did not make reasonable answers to the question of *"Why did you make the decision?",* although she answered all the questions in her group discussion charts. Her answers to the reasoning portion of Decision Point 3 were "to get us out to safety" and "we also need assistance" to support her third decision of "evacuate."

2nd Year 's Cases

Julie and Jane (High-2nd yr) did not skip any questions in their individual worksheets. The individual worksheet consisted of three parts: 1) understanding the hurricane, 2) understanding the community, and 3) understanding the specific administrative role, to elaborate on students' basic understanding related to dealing with the hurricane situation. With this individual worksheet, Julie and Jane (High - 2nd yr) tended to provide more detailed answers to all the questions than Kristen and Joe (Low-1st yr) did.

For example, in response to the question of *"How strong should the wind be for you to evacuate?",* Julie answered, "Around 111 mph," and provided wind strengths, storm surges, and possible damages of all the hurricane categories. However, Kristen (Low-2nd yr) just answered, "111 mph to evacuate homes," to the same question without any further information about the characteristics of the hurricane category.

In the case of Joe (Low-2nd yr), he skipped several questions related to understanding his role, Emergency Services, and only provided shorter answers to the

questions of understanding his community, by answering "south" to "geographical location," and "33,862" to "population."

In contrast to Joe, Jane (High-2nd yr) provided much detailed information to the questions of "understanding her community," by answering, "Morehead City is on a peninsula bordered on the south by the inland waterway; east by Newport; North by Calico Creek on the east coast." Also, she detailed her specific role, as a Mayor and City Council group member, with the questions related to understanding her role. She listed several costs related to evacuation, as "costs will be asking abnormally high if the hurricane destroys grocery stores," and "costs will total about $40 million," with considerations of businesses and services in her community.

In the case of Julie (High-2nd yr), she also elaborated on her role with the questions related to understanding her specific role. As a member of Emergency Services, she identified the locations of hospitals, shelters, and schools, which could be used in emergency situations. Specifically, with lists of the locations with routes and capacities, she attached the maps indicating the locations of hospital, shelters, and schools of Deerfield Beach, from her own search on the Internet.

Comparison Cross Years

All the cases with higher levels of critical thinking provided rich and clear answers to the question prompts of the individual and group worksheets. It was evident that the cases with higher levels of critical thinking (High-1st yr and High-2nd

yr) used the question prompts to expand their knowledge about the Hurricane and their community.

However, the cases with lower levels of critical thinking (Low-1st yr and Low-2nd yr) sometimes omitted answers or provided simple or unreasonable answers to the question prompts.

In the 1st year, Paula and Alice (High-1st yr) followed the procedure to make decisions by answering all the questions in detail. On the other hand, Jane and Julie (High-2nd yr) elaborated their understanding by answering all the questions with further information and resources.

Among the cases of lower levels of critical thinking, Sue and Jim (Low-1st yr) provided short and unreasonable answers to the questions related to supporting their decisions, and Kristen and Joe (Low-2nd yr) provided shorter answers to the elaborative questions.

Use of Data and Sources

The last theme, use of data and sources, was found in the group discussion charts (1st year), individual worksheets (2nd year) and individual reports (1st and 2nd years).

Although there were several resources available during the Hurricane Smith Module, and students were encouraged to use data and sources inside and outside of class, there was an evident pattern in using data and sources across the cases.

1st Year 's Cases

Alice and Paula (High-1st yr) explained the reasoning of why they made the decisions with data and sources. In the case of Alice (High-1st yr), she clearly stated where the information that she was using came from in her individual report:

> Hurricane Smith was a Ccategory 4 hurricane, which has very damaging effects. An example of a Ccategory 4 hurricane is Hurricane Andrew, which hit Florida and Louisiana in 1992 and caused over 26 billion dollars of damage (Supplemental Information, p.3). Another reason for evacuation to occur during a Category 4 hurricane is that a Category 4 hurricane comes with "extreme damage" as defined by the Saffir-Simpson Scale of Hurricanes (Supplemental Information, p. 5). Also, as Hurricane Smith moved northward, it came closer to the shores of Hilton Head, and the closer the hurricane is to the coast, the greater the danger of the storm surge. The storm surge could actually cause more damage than the winds because they can reach up to 18 feet in height (Supplemental Information, p. 6). There are some very real dangers to the storm surges of hurricanes; for example, over 6000 people were killed as a result of a storm surge in 1900 from the Galveston Hurricane (Supplemental Information, p. 11). Another example is more recent one from Hurricane Hugo in 1989; this storm produced a 20 foot storm surge (Supplemental Information, p. 11) .

She used the supplemental information provided in class in order to justify her final decision, "evacuate," in her individual report. In her group discussion chart, she clarified where her data and sources came from to support her decision. For example, at Decision Point 1, her decision was "keep an eye on the data" with the reasons of "the hurricane track is westward" and "the hurricane is still very far away" according to information from a weather report provided in class.

Paula used hurricane data, a transportation sheet, a geographical map, and a road map to provide the reasons of "we're going to the west coast of Florida where

they don't have warnings," "we will look at the different modes of transportation available--trains, airplanes, and buses," "we don't want people to get stuck in any area and want to look at shelters," and "because of tornadoes there could be a lot of damage and buildings and trees falling," at Decision Point 3 in her group discussion chart. To support her final decision in her individual report, she attached a map, indicating the evacuation route, from the information packet for Deerfield Beach.

However, Sue and Jim (Low-1st yr) did not use data or sources to support their reasoning or decisions in either their group discussion charts or individual reports. There were no citations or references in their group discussion charts and individual reports.

2nd Year's Cases

Compared with the group discussion charts in the 1st year, there was no request to write data and sources in the individual worksheet in the 2nd year. However, it was evident that Jane and Julie (High-2nd yr) searched and studied several data and sources for the Hurricane Smith Module. For example, Jane cited several websites containing information of what a hurricane is. From these sites, she clarified categories, characteristics, and impacts of a hurricane. In addition, by using community information uploaded in ANGEL, she calculated the exact cost of evacuation and possible loss from the Hurricane. Following are excerpts from her individual report:

> We did not evacuate ourselves against strong winds, fires, power outages, and possible flooding. We did not evacuate because we estimated the total cost of

> evacuation to be around 1 billion dollars or more. The median household income in Morehead City is $28,737, and we are aware that we aren't the wealthiest of communities-- the financial hit of evacuation would have been disastrous.
>
> We are not faced with the problem of possibly having to evacuate 7,691 people out of Morehead City, with 1,598 of those people aged 65 or older. We are going to be directly hit by the hurricane with winds ranging from 111 to 130 mph and a storm surge of 9 to 12 ft.

Although Jane did not cite any source for the above excerpts, it was evident that she used the packet for her community that was provided in class because she indicated exact numbers related to the cost of evacuation, population, and storm and surges of the hurricane. In her individual worksheet, she cited references when answering questions. For example, she used the website, http://www.nhc.noaa.gov, to answer the question of "*How strong should be the wind be for you to evacuate?"*

Julie (High-2nd yr) cited two websites to justify why evacuation is needed for her community:

> Based on the information provided at Decision Point Three, there is not much that I would change about my community's decisions on evacuation from Hurricane Smith. According to the Saffir-Simpson Hurricane Scale, a Category 4 hurricane can have winds from 131 – 155 MPH, which has the force to destroy mobile homes, collapse roofs, and blow down entire trees and signs.
>
> According to the NOAA Cyclone Report, Hurricane Charley, a similar Category 4 hurricane hat hit the southwestern coast of Florida, caused catastrophic wind damage. Death associated with this hurricane included, just to name a few: two who were in a mobile home that was destroyed by the heavy winds, a man who died as a result of a tree falling onto a building he was in, and a girl who died as a result of an airborne van blowing into the vehicle she was driving (http://www.nhc.noaa.gov). The winds and flooding associated with Category 4 hurricanes are at levels prompting evacuation.

From the data she cited, she clarified why her community should evacuate from the Category 4 hurricane with historical cases.

However, Kristen and Joe (Low-1st yr) did not use any data or sources available in class in their individual worksheets and reports.

Trends across artifacts for high performing students in both years

The theme of trends across artifacts was found between the students of higher levels of critical thinking of both years. It was evident that the students with higher levels of critical thinking in the 2nd year aligned the reasoning of their individual worksheets with those of their individual reports. Otherwise, there was little evidence that the students with higher levels of critical thinking in the 1st year used reasoning based on their group discussion charts in their individual reports. Jane (High-2nd yr) showed aligned reasoning between her individual worksheet and individual report. As a member of the Mayor and City Council group in Morehead City, she was concerned with the cost of evacuation in both her individual worksheet and individual report. In her individual worksheet, she tried to estimate the cost of complete evacuation considering shutting down schools, hospitals, and households as follows:

> Cost will be asked high if the hurricane destroys grocery stores. The cost will be around 1 million dollars.
> Costs about 12 million toward cost of 4-lane highways. (Including this) the total will be about 40 million dollars.

> Around 30 million dollars (with the most expensive being the households. Transportation costs to get them out of there).

In her individual report, she was continuously concerned with the cost of evacuation:

> I estimated key businesses and venues that would have to shut down and then analyzed the result on the economy cost-wise.
> We did not evacuate because we estimated the total cost of evacuation to be around 1 billion dollars or more.

Besides the cost of evacuation, Jane clearly showed the route for evacuation in both her individual worksheet and individual report. In her individual worksheet, she designated I-70 toward Goldsboro. In her individual report, she insisted that the residents should take I-70 toward Goldsboro, too.

Julie (High-2nd yr) continuously recognized how the size of the hurricane would influence evacuation in her individual worksheet and individual report. As a member of Emergency Services in Deerfield Beach, she wrote down how the size of the hurricane would influence evacuation in her individual worksheet as follows:

> Category 1: 74-95 MPH. storm surge 4-5ft. no damage to buildings. Damage to signs.
> Category 2: 96-110 MPH. surge 9-8 ft. roofing, door, window damage.
> Category 3: 111-130 MPH. surge 9-12 ft. evacuation of low-lying residents.
> Category 4: 131-155 MPH. surge 13-18 ft. homes destroyed. Evacuate residents up to homes from shore
> Category 5: > 155 MPH. surge 18 ft. 5-8 mile shoreline evacuate.

Based on information of how the size of the hurricane would influence on storm, surge, and wind, the reasoning for making the decision of evacuation in her individual report is as follows:

> I knew that a Category 4 hurricane could cause a great deal of damage and is a force of nature with which man cannot reckon.
> According to the Saffir-Simpson Hurricane Scale, a Category 4 hurricane can have winds from 131-155 MPH, which has the force to destroy mobile homes, collapse roofs, and blow down entire trees and signs. Also, Category 4 hurricanes can have a storm surge of 13-18 feet above normal. Therefore, it is recommended that due to flooding, areas as far as six miles inland be evacuated as soon as possible (http://www.nhc.noaa.gov). At Decision Point One, the hurricane was already a Category 4 hurricane that was expected to arrive at the Deerfield Beach area within one to two days. In my opinion, a Category 4 hurricane is an extremely dangerous force that should not be taken lightly.

Although Jane and Julie (High-2nd yr) clearly showed alignments in making their decision for evacuation between the two artifacts, individual worksheet and individual report, Alice and Paula (High-1st yr) supported their final decisions in their individual reports by referring to other supplemental information, not their group discussion charts. Alice (High-1st yr) made her final decision as follows:

> My final decision for the Hurricane Smith evacuation plan is to be sure not to evacuate too soon because of all of the damaging effects an unnecessary evacuation can have, but to be sure to keep a watchful eye on all of the data because not evacuating can also have terrible consequences.

To support her final decision, she referred to the cases of Hurricane Andrew and Hurricane Galveston from the supplemental information that had been distributed

during the Hurricane Smith Module. The main reasoning for her final decision was based on other supplemental information, not the reasoning of her group discussion charts. In her group discussion chart, her group just provided the category of Hurricane Smith and its possible effects as the reasoning for her decisions.

The case of Paula (High-1st yr) is similar to Alice. Her final decision focused on the evacuation route as a member of Infrastructure Services in Deerfield Beach.

> My final decision on the Hurricane Smith evacuation plan is that early evacuation is the best option there is. This is due to the topography and population age group data given above, but it also has to do with the geography and transportation routes of Deerfield Beach, FL.

To support her final decision, she used several maps from the course website, but she did not mention any reasoning coming from her group discussion chart.

Comparison Cross the Years

It was evident that the cases with higher levels of critical thinking (High-1st and High-2nd) highly depended on data and sources when they provided the answers and decisions in the worksheets and individual reports. Instead, the cases with lower levels of critical thinking (Low-1st yr and Low-2nd yr) just provided their answers or decisions superficially without supporting data and sources.

An interesting finding was that the 2nd year's cases with higher levels of critical thinking (High-2nd yr) provided data and sources with exact numbers, opposed to the 1st year's (High-1st yr). Jane and Julie (High-2nd yr) showed the exact numbers for population, surge, storm, and flooding of the hurricane, and available

routes for evacuation. Alice and Paula (High-1st yr) provided the numbers about the characteristics of the hurricane, but they did not indicate the exact numbers related to their communities, like population, household income, cost of evacuation, and the route numbers.

Summary of Findings to Research Question 3

From the qualitative data analysis, the cross-case comparison raised four themes in explaining and comparing the differences between the students with higher and lower levels of critical thinking that were evident in individual worksheets and group discussion charts and individual reports.

First, the cases with higher levels of critical thinking (High-1st yr and High-2nd yr), focused more on their role within their community context, than those with lower levels of critical thinking (Low-1st yr and Low-2nd yr).

Second, the cases with higher levels of critical thinking (High-1st yr and High-2nd yr) linked their roles and responsibilities to making their final decisions in individual reports. It was evident that their role taking was a basis to expand the categories of critical thinking, evaluating their decisions, providing their own decisions, and justifying their decisions.

Third, the cases with higher levels of critical thinking (High-1st yr and High-2nd yr) made the answers to the procedural (1st year) and elaborative (2nd year) question prompts in detail and clearly. However, the cases with lower levels of critical thinking (Low-1st yr and Low-2nd yr) tended to omit the answers, and their answers tended to be abstract and superficial.

Fourthly, there were differences in using data and sources among the cases. The cases with higher levels of critical thinking (High-1st yr and High-2nd yr) cited and referred to data sources in their group discussion charts, individual worksheets, and individual reports. They especially tended to refer to the sources introduced or provided in class. Between the years, the 2nd year's cases with higher levels of critical thinking provided more elaborate data, by referring to exact numbers of community population, household income, and the characteristics of hurricane, than the 1st year's cases did.

Next, the 2nd year's cases with higher levels of critical thinking provided aligned reasoning between the two artifacts, individual worksheets and individual reports. However, the 1st year's cases with higher levels of critical thinking did not use the same reasoning in the two artifacts, group discussion charts and individual reports. Instead of using the reasoning of the group discussion charts, the 1st year's cases with higher levels of critical thinking used other reasoning from supplemental information for the Hurricane Smith Module in order to support their final decisions in individual reports. Otherwise, the 2nd year's cases with higher levels of critical thinking directly linked their reasoning of their individual worksheet to those of their individual reports.

Finally, among the cases, it was evident that there were clear differences between the cases with higher and lower levels of critical thinking (High-1st yr and High-2nd yr vs. Low-1st yr and Low-2nd yr), rather than between the two years (1st year vs. 2nd year).

Chapter 5

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Summary of Findings and Discussion

The purpose of this study was to explore how to enhance students' critical thinking in an introductory undergraduate science course. As a design experiment, this study aimed to design, develop, implement, and refine learning activities, and investigate how the learning activities worked in fostering students' critical thinking in a large- size classroom context.

For two years, the Hurricane Smith Module, one of the modules in the geoscience course, was designed and refined by using three design principles with the goal of fostering critical thinking. Critical thinking in science consisted of six categories, reflecting the learning activities of the Hurricane Smith Module: 1) identifying decisions, 2) evaluating decisions, 3) providing own decision, 4) argument and justification for own decision, 5) presenting supporting data/evidence, and 6) integrating other perspectives.

With the purpose of enhancing critical thinking in the large classroom, three design principles--authentic task, question prompts, and peer interaction--were employed as the results of a literature review. These design strategies were associated with the learning activities of the Hurricane Smith Module for two consecutive years. Based on reflection and observation of the instructor and the instructional designers on the 1st implementation, changes were made in using specific design strategies to foster students' critical thinking.

With regard to the use of question prompts, the students of the 2nd year were provided with procedural and elaborative question prompts, while those of the 1st year only received procedural question prompts embedded in the Group and Community Discussion Charts.

Second, uses of peer interaction differed between the 1st and 2nd year students. Instead of being engaged six times in two types of discussions, group and community discussions, the students of the 2nd year were required to take part in a community discussion twice and to prepare for the discussion by learning about and understanding important aspects of dealing with the hurricane situation. For individual preparation, elaborative question prompts were embedded in the Individual Worksheet.

In both years, the students were asked to submit their individual reports, which showed their levels of critical thinking after performing all learning activities of the Module.

To investigate how the two different designs worked in a large-size classroom, this study described and compared the group decision-making and reasoning represented in the worksheets for group discussions, level of critical thinking demonstrated in individual reports, and the effects of the prior group discussion and individual preparation on levels of critical thinking. The findings and discussion are summarized below, according to the three research questions:

1. *What changes are visible in group decision making and reasoning as represented in group worksheets in the 1st and 2nd years?*

The results from the descriptive and comparative analysis on the Community Discussion Charts of the 1st year and the Community Information Organizers of the 2nd year, which demonstrated the decision making process as to whether the community should evacuate or not, indicate that there were changes in patterns of reasoning between the two years (although the decision making process showed a similar pattern in each community).

It was evident that the groups engaged in decision-making for communities of the 2nd year showed more concrete and shaped reasoning than those of the 1st year. The groups of the 1st year not only tended to omit the question, but they also provided inadequate, superficial reasoning as to why they made their decision. For example, in the 1st year, Group A, which took part in the discussions for Morehead City, neither made a decision nor provided any reasoning at the 1st and 2nd decision points. Although Group B of the same community made all three decisions, the decisions were not associated with any reasoning. However, the groups of the 2nd year in this study demonstrated concrete reasoning in supporting their decisions. These results supported the design decision of using elaborative question prompts and individual preparation for the modification of the 2nd year's implementation of the Hurricane Smith Module. Several examples of previous research studies report the same problem in using question prompts. Students sometimes omit questions or answer superficially (Green & Land, 2000), and ignorance of question prompts results in lack of attention to important aspects of what they should be learning (Ge & Land,

2003). For effective use of question prompting, Ge & Land (2004) emphasize the role of prior knowledge and peer interaction to help students make up for a lack of knowledge.

During the data analysis of the groups' reasoning, five categories associated with the issues students considered for evacuation emerged: hurricane, communities, evacuation, forecast, and other considerations. Among these categories, students' reasoning in the 1st year highly relied on the one category of "hurricane," instead of considering several categories like "evacuation," "community," "forecast," and "other considerations related to making evacuation decisions." Groups of the 1st year tended to focus on the effects of hurricane, like the storm, surge, and flooding, as the reasoning behind why they made their decisions. However, groups of the 2nd year tended to refer to the five categories impartially and demonstrated more complex reasoning when they made decisions about evacuation. For example, Group B for Morehead City of the 2nd year made their decision based on the categories of "evacuation," "community," "forecast," and "hurricane" and provided the following explanation:

> We divided up to keep an eye on the data. We're just outside the Hurricane watch zone and forecasters cannot 100% predict that the Hurricane will even head our way or hit us directly. However, the strength could be dangerous if we are on in its path. (At Decision Point 1)
>
> We feel that we still have ample time for evacuation if need be. The data will be monitored --- and we will tell the elderly and hospitals to be prepared. We are on the edge of the watch zone, so we still have a few days. Therefore, we can start evacuating and still have time to have 3000 people_(At Decision Point 2)

However, Group C for the same community of the 1st year made their decision based solely on one category, "forecast," and provided the justification that the "storm did not hit NC" and "the storm was heading north." Based on the numbers of the categories used in the reasoning process, it can be concluded that the 2nd year design, which had embedded the elaborative question prompts in the community information organizer, helped students to elaborate their rationale in making the evacuation-related decisions for each community. On the other hand, it can also be concluded that the 1st year design, which had employed only the procedural question prompts in the community discussion chart, was not effective to elaborate on students' reasoning. These results also support the previous studies that elaboration question prompts were effective in knowledge building (King, 1992; King & Rosenshine, 1993) and problem solving (Ge, 2005; Ge & Land, 2004).

2. *What differences in levels of critical thinking are evident in individual reports between the 1st and 2nd year?*

There was a significant difference in critical thinking demonstrated in individual reports between the students of the 1st and 2nd years. The students of the 2nd year demonstrated higher levels of critical thinking than those of the 1st year. In addition to this result, between the lower 25% students of the two years, there was a significant difference in critical thinking, while no significant difference was found between the top 25% students of the two years. This result yields the conclusion that the 2nd year's design worked better in enhancing critical thinking than that of the 1st year.

With regard to the six categories that make up critical thinking, statistical significant differences between the total students of the 1st and 2nd years were found in: 1) providing one's own decision, 2) argumentation and justification for one's own decision, and 3) integrating other perspectives. However, there were no differences in the other three categories: 1) identifying one's decision, 2) evaluating one's decision, and 3) presenting supporting data/evidence. Among the lower level students of the two years, statistical significant differences were found in: 1) evaluating decisions, 2) providing one's own decision, 3) argumentation and justification for one's own decision, and 4) integrating other perspectives. However, between the top level students of the two years, there was a statistically significant difference only in "presenting supporting data and evidence."

Based on these statistical results, it can be concluded that the 2nd year's design contributed to improving the three categories. Given the 1st year design, the students of the 1st year demonstrated overall lower levels in four categories: 1) providing one's own decision, 2) argumentation and justification for one's own decision, 3) presenting supporting data/evidence, and 4) integrating other perspectives, by scoring below 4 out of 6, in their individual reports. However, the two categories related to group discussion, "identifying one's decision" and "evaluating one's decision," scored above 4 out of 6 in the 1st year. Among the categories demonstrated in lower levels, there was improvement in the three categories in the 2nd year. This improvement in the three categories implies that the design strategies employed in the 2nd year, elaborative question prompts and individual preparation, helped the students construct their own decision about the

hurricane situation, provide arguments and justification for their final decision, and integrate other perspectives into their own position.

However, in demonstrating their group discussion by identifying and evaluating, no significant difference was found.

To sum up, these results might be explained with the characteristics of the 1st and 2nd years' design. The flow and focus of the 1st year's design was to encourage peer interactions with three types of decision making in role-based group discussions and community discussions, and the procedural question prompts were to support the group decision making process. However, in the 2nd year, the students were required to complete individual worksheets embedded with elaborative question prompts so they received individual preparation for community-based group discussions. Although the number of group discussions was reduced in the 2nd year, the students of the 2nd year demonstrated similar levels in the categories of identifying one's decisions and evaluating one's decisions.

The three categories, which demonstrated statistically significant differences, needed "elaboration," so the reason as to why the 2nd year's design worked better than the 1st year's is obvious. However, although Ge & Land (2004) and King (1992) point out the importance of combining the elaborative question with students' prior knowledge in order for them to benefit from learning activities, there was neither significant difference nor improvement in "presenting supporting data/evidence," one of the categories of critical thinking, between the students of the two years.

Specifically, it can be concluded that the 2nd design worked better with the lower level students by showing the significant differences in overall critical thinking

and its four categories. On the other hand, although the top level students of the 2nd year performed better that those of the 1st year, there was a statistical significance only in one category, "presenting supporting data and evidence."

3. *What differences are evident in the individual and group worksheets and individual reports between the students with higher and lower levels of critical thinking in the 1st and 2nd years?*

The results of the multiple-case study explain what made students demonstrate higher levels of critical thinking, especially in the three categories in individual reports. During the cross-case comparison, four themes, 1) understanding of one's assigned role, 2) linking roles to make decisions, 3) answers to the question prompts, and 4) use of data and sources, were raised in explaining the different patterns between the students with higher and lower levels of critical thinking. Also, a trend was visible across artifacts for high performing students in both years,

An interesting result is associated with the understanding of one's assigned role for peer interaction in this study. All cases with higher levels of critical thinking demonstrated how much more seriously they took their role seriously within their community setting, compared with the cases with lower levels of critical thinking. They revealed a clear definition and perception on what they should do in their roles for their community. Although the role was randomly assigned and did not have as much information as a job description had, the cases with higher levels of critical thinking focused on understanding their assigned roles in performing their individual

work and group discussions. It was evident that the students with higher levels of critical thinking associated their understanding of assigned roles with providing their own decision, and argumentation and justification, by expanding their understanding about the hurricane and community. For example, Jane, a case who took the role of Mayor and City Council and demonstrated higher levels of critical thinking in the 2nd year, made her final decision, "keep watching the radar and analyzing data," for Morehead City, as arguing that financial loss would be more at that point when Hurricane Smith was just heading out but its category was decreased from 4 to 3. Her final decision was based on her role and the data she had collected about the hurricane and her community.

Besides an understanding of one's assigned role, the students who exhibited higher levels of critical thinking demonstrated hard work during the prior group discussions and individual work on the hurricane, community, and their specific roles, compared to students demonstrating lower levels of critical thinking. They tended not to ignore answers to the elaborative and procedural question prompts in the Group Discussion Charts and the Individual Worksheets. In addition, they frequently referred to data from the resources provided during the Module and other related websites. These results support the finding of the first research question.

Between the higher level groups in both years, two different patterns were found. First, the cases with higher levels of critical thinking in the 2nd year used data and sources more exactly than those of the 1st year. They tended to demonstrate the exact numbers of population of their community, road numbers for evacuation routes, locations of shelters, hospital, and schools, and so on. This result is interpreted as an

effect of the elaborative question prompts used in the 2nd year's design, because the questions were intended to help the 2nd year students to understand key pieces of information associated with planning for evacuation and encourage them to seek out vital sources of information on the Internet.

Second, the 2nd year's cases with higher levels of critical thinking provided aligned reasoning between the two artifacts, individual worksheets and individual reports. However, the 1st year's cases with higher levels of critical thinking did not use the reasoning of their group discussion charts in making their final decisions in individual reports.

From the above findings of the three research questions, this study concludes that the 2nd year's design, which employed elaborative question prompts and individual preparation, worked better in enhancing group reasoning and critical thinking in the large undergraduate general science course, than the 1st year's design, which used only procedural question prompts and group discussions without individual preparation.

Implications for Instructional Design

From the findings of this two-years' design experiments, three design principles, confirmed as design strategies fostering higher order thinking, were associated with the learning activities in which the undergraduate students were

required to take part. The results of this study drew several implications regarding the use of the three design principles.

Table 5. 1
Summary of Differences in Critical Thinking Associated with Design Changes

Design Changes between the 1st and 2nd Years	Changes in Critical Thinking in Science based on the results of t-test
Peer Interaction - Reducing the steps for community decision making - Instead of role-based group work discussion, students were asked to give several pieces of information and provide aspects of the hurricane in their individual studies **Question Prompts** - Elaborative question prompts were added in the process of individual preparation and group discussions	1. The students of the 2nd year demonstrated higher levels of critical thinking than those of the 1st year. The 2nd year's design contributed to improving these three categories: 1) providing one's own decision, 2) argumentation and justification for one's own decision, and 3) integrating other perspectives. 2. The lower 25% students of the 2nd year had significantly higher levels of critical thinking than those of the 1st year. The 2nd year's design contributed to improving the four categories in the lower 25% students: 1) evaluating decisions, 2) providing one's own solutions, 3) arguments and justification for one's own decision, and 4)

integrating other perspectives.

3. The top 25% students of the 2nd year demonstrated better scores in levels of critical thinking than those of the 1st year. The 2nd year's design contributed to improving the category, *presenting supporting data/evidence*.

4. The design changes worked better with the lower 25% students than with the top 25% students.

Use of Question Prompts

First of all, it is evident in this study that question prompts can scaffold students' reasoning and critical thinking. Specially, the combination of procedural and elaborative question prompts reveals positive effects on scaffolding students' critical thinking in this study. Although several studies have highlighted the positive effects of question prompts (Ge, 2005; Ge & Land, 2003; King, 1992, King & Rosenshine, 1993), this study specifically suggests how two types of question prompts can be embedded in scaffolding students' learning in a large classroom context. For group discussions, procedural question prompts were used. On the other hand, the elaborative question prompts were mainly used to support individual preparation for group discussion, and they resulted in positive effects on helping

students to construct their own understanding so that they provided and justified their own decision and integrated other perspectives. The 1st year students frequently ignored or answered the procedural questions embedded in the group discussion charts poorly, as Green and Land (2000), and Ge and Land (2004) point out, and demonstrated insufficient reasoning. However, the 2nd year design employing the elaborative questions to their individual and group worksheet helped solve this problem by using question prompts. These results imply that each type of question prompt has a specific function so instructional designers should carefully use them by reflecting on the learning context. Ge and Land's study (2004) supports this implication by presenting which type of question prompt can be used in scaffolding ill-structured problem-solving. For example, they present that elaborative question prompts can be used in the process of problem representation, generating solutions, and making justifications, and reflection prompts can support the process of monitoring and evaluating. In addition, with regard to considering students' characteristics, procedural question prompts are more useful for novice students, not for students with prior knowledge (Ge & Land, 2004).

Individual Preparation for Peer Interaction

There have been many studies on examining the effects of peer interaction on students' learning. Some of these studies report positive effects and others reveal no effects of peer interaction and small group learning. However, Cohen (1994) argues that studies on group learning should move from the general question of effectiveness of group learning to conceptualizing conditions under which the use of group

learning in classrooms can be productive because there are too many variables affecting the effect of group learning and peer interaction. Cohen referred to three factors suitable for supporting peer interaction: task instructions, student preparation, and teacher's role. Among these factors, this study reveals the positive effects of individual preparation on productive peer interaction.

In this study, the 1st year's design did not incorporate individual preparation for peer interaction, represented as group and community discussion. The 1st year students without individual preparation produced superficial reasoning in the Group and Community Discussion Charts and revealed lower levels of critical thinking in their individual reports, compared to students in the 2nd year. These results show that individual preparation before peer interaction facilitates productive discussions and results in positive effects on students' learning. Similarly, Ge and Land (2003) argue that cognitive supports, like prior learning or elaboration by using question prompts, can improve the effects of peer interaction in solving ill-structured problems.

In this study, individual preparation was designed to elaborate their understanding by identifying important aspects related to the task, decision-making in a hurricane situation, of group discussion. The results of comparison of the two years' designs support the positive effects of employing individual preparation before group discussion. This design strategy can help improve students' learning, especially in a large classroom context, where there are too many students, which makes peer interaction difficult but needed none-the-less. .

Assigned Roles and Peer Interaction

An interesting finding is how assigned roles for peer interaction contributed to students' critical thinking. Although a research question regarding how assigned roles contributed to support students' learning was not posed, the results of the multiple-case study show that an understanding of students' assigned roles gave opportunities for students to construct and situate their understanding in a certain context.

The students who demonstrated higher levels of critical thinking revealed that they took their roles seriously by defining and accounting for what they should do within their community and constructed their own understanding to make their own decision. Their individual reports showed that they developed their critical thinking during the community decision making process, by identifying and evaluating group decisions, providing and justifying their own decisions, and integrating other perspectives based on their role taking. It was evident that taking their roles seriously enabled them to elaborate their understanding about the hurricane and to develop unique perspectives on what they should do with their role in handling the hurricane situation. Moreover, given several roles in a group, each student can perform his or her role self-directly and be involved in an audience role that can question and comment on other peers' roles (Herrenkohl, et al., 1999).

This interesting finding suggests that an understanding of one's assigned role may be essential to facilitate active student participation and peer interaction, to develop his or her own perspective, and to think critically.

Use of Student Centered Design Principles in a Large Classroom Context

This study also shows how to design a large general science course offered to undergraduate students. There are several studies on restructuring the large classroom for students' active learning (McGreger, 2000; Smith, 2000) and applying advanced design principles (Gupta, 2003; Kronberg & Griffin, 2000; Yuretich, 2003). Most of these have emphasized the importance of active learning, student-centered learning, and fostering higher thinking skills in large-size undergraduate level science courses. However, those studies have some limitations due to lack of empirical evidence and conducting short-time period studies.

This study shows how to develop learning activities for a large science course by using the three advanced design principles and how students can benefit from the use of these principles with empirical evidence. With regard to authentic task, this study used a real case and real data in order to help students link their real life experience to a specific scientific phenomenon. Based on an overall observation of the instructional designers, the authentic task, the Hurricane Smith Scenario, and the three real communities, worked appropriately enough to help them integrate their real life and scientific knowledge and concepts on hurricane for the two years. Question prompts were refined and improved over the two years for the large classroom setting. As an important scaffolding strategy, the 1st year design employed just procedural question prompts expected to elicit students' active answers. However, the procedural question prompts were proved to be an insufficient strategy to help the group reasoning process in a large classroom setting, so elaborative

question prompts were added in the 2nd year. Peer interaction through group discussion was one of the design principles.

The above information on the two-year design experiment summarizes how the design principles were used in a large classroom context. The mixed approach of using design principles can contribute to increased effectiveness in large size science courses on students' learning, especially in fostering higher order thinking.

Although the designs of this study are the subjects to be refined and improved, those three design principles are appropriate to inform how to design a large classroom setting, especially a class with the purpose of facilitating students' active learning and developing higher order thinking.

Limitations of This Study and Suggestions for Future Study

This study aims to understand a large classroom context by designing and implementing learning activities for two years, with the methodology of design experiment. However, in conducting this study, some limitations were found.

First, there was a time constraint for a design experiment. As a design experiment, this study needed to iterate the learning activities several times, in order to find out empirical evidence and to refine the learning activities suitable for the large classroom. However, for two years, this design experiment was conducted only twice, which means that the learning activities still need to be refined and situated in the introductory geoscience course where a large number of students are enrolled. Based on the findings of this study, further studies are needed to improve the learning

activities with the purpose of fostering students' reasoning and critical thinking, by developing refined strategies for each design principle. This study refined the 2nd design by adding elaborative question prompts and using individual preparation before peer interaction, and these modifications resulted in positive effects on students' reasoning represented in the group worksheets and levels of critical thinking demonstrated in individual reports. However, there are other design strategies and conditions for the design principles to be more productive and effective. For example, with regard to question prompts, this study only used two types of question prompts, and they were embedded in a print format worksheet. In future studies, several types of question prompts, like reflection, monitoring, or activity question prompts, can be made available with various formats, like discourse, or embedded in technology. On the other hand, with regard to peer interaction, additional conditions, like task instruction, use of a facilitator, or a means of interaction, might be available to enhance active and productive interactions.

Second, in this study, three design principles--authentic task, question prompts, and peer interaction--were employed to enhance students' critical thinking. However, only two design principles--question prompts and peer interaction--were examined by comparing two years' results of group reasoning and individual critical thinking since there were modifications on the use of two design principles. This study did not show how authentic task influenced the students' reasoning and critical thinking and the combination and relationship among the three design principles, although students revealed a situated understanding from the Hurricane Smith scenario with real data in their individual report and group worksheet. Therefore,

future studies need to focus on how authentic task impacts students' learning and its relationship with other design principles.

Third, this study examined and compared the results of the two years, not by using an experimental design, in order to understand the real classroom setting. It was assumed that all of the participants had similar prior knowledge on earth science and similar characteristics as non-science major students. There were no pre-tests on earth science knowledge, reasoning, or general critical thinking skills before the students took part in this study. If future study conducts and compares the results of pre-tests and post-tests, more insight about how to design and prepare for the large science course will be available.

Fourth, further case studies are needed for an in-depth understanding of how design works for each student with regards to collecting more data, even though he or she demonstrated higher or lower levels of critical thinking. In this study, the multiple-case study was conducted to track how the students' prior group discussion and individual preparation influenced their critical thinking. Each individual with higher or lower levels of critical thinking was a case, and their written documents were the subjects to be analyzed, without interviews or observation. For a more robust case study and generalization, more evidence from interviewing and observing cases will be needed.

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Appendix A. Group Discussion Chart in Fall 2007

*Community Name:*_____
*Group Designation:__<insert group name here>*_____

<insert group name> discussion chart

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

Priorities:

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

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

----------Third 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 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)**

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

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

Appendix B. Community Discussion Chart in Fall 2007

Community 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.

----------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?

Appendix C. Individual Report in Fall 2007

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. Your must prepare a final report describing you expert decision regarding Hurricane Smith, which the Mayor will use to inform the Hurricane Evacuation Plan for the community.

In your report, you are asked to 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.

Your Task:

1. In a word document of **2-3** pages (12 pt font), write a report that includes an analysis of the hurricane situation and your suggestions about the evacuation decision. Support your suggestions with data and reasons wherever appropriate.
2. In your report, the Mayor would like you to address the following details:
    (a) **Identity**: identify the group and the community of which you were a part.
    (b) **Group decision**: What was the final decision of your group? Did you agree with that decision? If you or no, explain why, based on the discussions, the data, and your understanding of the situation.
    (c) **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.
    (d) **Your final decision**: What is your final decision as to the Hurricane Smith evacuation plan?
        - 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.
        - Include graphs, diagrams, maps or any data that support your reasoning.
        - Describe examples from the real world and any other

explanations that you think support your decision, if appropriate.

3. Submit a hard copy of your report, specifying group name, your name and email addresses. Also, save your report as a word document with your full name in the title and submit it in the assignment drop box setup in ANGEL course website.

Appendix D. Individual Worksheet in Fall 2008

Name: _____
Group: Emergency Services
Community: Deerfield Beach

Guidelines for this individual activity

This individual worksheet should help you prepare for the group activity and the final report on the evacuation decision for Hurricane Smith. The worksheet will help you think about key pieces of information that you will need as you plan for hurricane evacuation and the impact of hurricane within your community for the group activity.

To complete the individual worksheet, you should:

- Go to the Earth101 Angel site, and find resources for your specific community (there are three folders named Deerfield Beach, Hilton Head, and Morehead City)
- Search the Web as well as other resources to find answers to the questions below. Remember that you are going to be the expert in your specific role so use your Internet search skills to make sure that you find good sources of information on the topics below. Make sure that you record all sources and please note that Wikipedia CANNOT be used as a resource.
- Write down answers to each question, and prepare yourself as a spokesperson for the specific administrative role (e.g., emergency services, media, etc.) to which you were assigned.

Remember to bring this worksheet with you to class on Thursday, Oct. 9! You will need to turn this in with the group worksheet.

I. Understanding the Hurricane:

This section is to help you to identify information that should be considered with regards to hurricane evacuation decision.

(a) In general, for hurricane evacuation decision, what information would you need? Find information about the following plus others that you think are important:

- How does the size of the hurricane influence evacuation? (e.g., what is the min. size at which you should consider evacuation?)

- How strong should the wind be for you to evacuate?

- What difference does time of hurricane impact make (night vs. day)?

- How does direction of hurricane impact your planning?

- How would the duration of the hurricane impact your evacuation plans?

(b) What are other natural events that tend to accompany hurricanes and what should you know about their impact and size? (e.g., storm surges, flooding, etc.,) Do some exploration and make a list of these common dangers and how you can address them.

II. Understanding your community with regards to hurricane evacuation:
What information do you need for you to make a decision on hurricane evacuation ***for your community***? First, find this basic information for your community:

(a) geographical location:

(b) population:

(c) evacuation routes:

III. Understanding the specific administrative role:

(a) As an emergency services group member, you should identify the following information plus others that you think might be important:

i) Hospitals (location, how many in number, capacity for dealing with emergency)

ii) Fire stations and locations

iii) Location of shelters and how many people can be accommodated in each shelter

iv) Others (list here and below)

(b) Based on the information in IIIa, how could the hurricane impact the availability of these different facilities? For example, hospitals near the coast would be vulnerable if a hurricane was coming from offshore -- this would mean that you would need to evacuate and find other spots for hospital residents in those areas. Try to make a list of all possible impacts of the hurricane on these emergency services facilities so you can advise your community on how to deal with evacuation, if needed.

Name: _____
Group: Infrastructure services
Community: Deerfield Beach

Guidelines for this individual activity

This individual worksheet should help you prepare for the group activity and the final report on the evacuation decision for Hurricane Smith. The worksheet will help you think about key pieces of information that you will need as you plan for hurricane evacuation and the impact of hurricane within your community for the group activity.

To complete the individual worksheet, you should:

- Go to the Earth101 Angel site, and find resources for your specific community (there are three folders named Deerfield Beach, Hilton Head, and Morehead City)
- Search the Web as well as other resources to find answers to the questions below. Remember that you are going to be the expert in your specific role so use your Internet search skills to make sure that you find good sources of information on the topics below. Make sure that you record all sources and please note that Wikipedia CANNOT be used as a resource.
- Write down answers to each question, and prepare yourself as a spokesperson for the specific administrative role (e.g., emergency services, media, etc.) to which you were assigned.

Remember to bring this worksheet with you to class on Thursday, Oct. 9! You

will need to turn this in with the group worksheet.

I. **Understanding the Hurricane:**

This section is to help you to identify information that should be considered with regards to hurricane evacuation decision.

(a) **In general,** for hurricane evacuation decision, what information would you need? Find information about the following plus others that you think are important:

- How does the size of the hurricane influence evacuation? (e.g., what is the min. size at which you should consider evacuation?)

- How strong should the wind be for you to evacuate?

- What difference does time of hurricane impact make (night vs. day)?

- How does direction of hurricane impact your planning?

- How would the duration of the hurricane impact your evacuation plans?

(b) What are other natural events that tend to accompany hurricanes and what should you know about their impact and size? (e.g., storm surges, flooding, etc.,) Do some exploration and make a list of these common dangers and how you can address them.

II. Understanding your community with regards to hurricane evacuation:
What information do you need for you to make a decision on hurricane evacuation ***for your community***? First, find this basic information for your community:

(d) geographical location:

(e) population:

(f) evacuation routes:

III. **Understanding the specific administrative role:**

(a) As an infrastructures services group member, you should identify the following information plus others that you think might be important:

i) Major roads and access points (where are they located, heading in what

direction and to what cities)

ii) Locations of airports, railway stations, bus stations and exit points (what are their capacities for evacuating people)

(b) Based on the information in IIIa, how does location of the hurricane impact the usability of roads or transportation facilities? For example airports near the path of the hurricane cannot be used for evacuation, so what could be a substitute method for evacuation? Try to make a list of all possible impacts of the hurricane on infrastructure so you can advise your community on how to deal with evacuation, if needed.

Name: _____
Group: Media
Community: Deerfield Beach

Guidelines for this individual activity

This individual worksheet should help you prepare for the group activity and the final report on the evacuation decision for Hurricane Smith. The worksheet will help you think about key pieces of information that you will need as you plan for hurricane evacuation and the impact of hurricane within your community for the group activity.

To complete the individual worksheet, you should:

- Go to the Earth101 Angel site, and find resources for your specific community (there are three folders named Deerfield Beach, Hilton Head, and Morehead City)

- Search the Web as well as other resources to find answers to the questions below. Remember that you are going to be the expert in your specific role so use your Internet search skills to make sure that you find good sources of information on the topics below. Make sure that you record all sources and please note that Wikipedia CANNOT be used as a resource.
- Write down answers to each question, and prepare yourself as a spokesperson for the specific administrative role (e.g., emergency services, media, etc.) to which you were assigned.

Remember to bring this worksheet with you to class on Thursday, Oct. 9! You will need to turn this in with the group worksheet.

I. **Understanding the Hurricane:**
This section is to help you to identify information that should be considered with regards to hurricane evacuation decision.

(a) **In general,** for hurricane evacuation decision, what information would you need? Find information about the following plus others that you think are important:

- How does the size of the hurricane influence evacuation? (e.g., what is the min. size at which you should consider evacuation?)

- How strong should the wind be for you to evacuate?

- What difference does time of hurricane impact make (night vs. day)?

- How does direction of hurricane impact your planning?

- How would the duration of the hurricane impact your evacuation plans?

(b) What are other natural events that tend to accompany hurricanes and what should you know about their impact and size? (e.g., storm surges, flooding, etc.,) Do some exploration and make a list of these common dangers and how you can address them.

II. Understanding your community with regards to hurricane evacuation:
What information do you need for you to make a decision on hurricane evacuation ***for your community***? First, find this basic information for your community:

(g) geographical location:

(h) population:

(i) evacuation routes:

III. **Understanding the specific administrative role:**

(a) As an media group member, you should identify the following information plus others that you think might be important:

i) History of hurricane impact in the area of your community (how many over the years, what strength, what was the impact each time)

ii) General information about preparing for hurricanes

iii) How to deal with time of impact (i.e., night or day)

(b) Based on the information in IIIa and on your research on other hurricanes in this area, what should the town and services prepare for as being most likely? For example, if there was flooding every time a hurricane happened, what would you suggest as being important to consider? Try to make a list of all possible impacts of the hurricane that are important to consider so you can advise your community on how to deal with evacuation, if needed.

Name:_____
Group: Chamber of Commerce
Community: Deerfield Beach

Guidelines for this individual activity

This individual worksheet should help you prepare for the group activity and the final report on the evacuation decision for Hurricane Smith. The worksheet will help you think about key pieces of information that you will need as you plan for hurricane evacuation and the impact of hurricane within your community for the group activity.

To complete the individual worksheet, you should:

- Go to the Earth101 Angel site, and find resources for your specific community (there are three folders named Deerfield Beach, Hilton Head, and Morehead City)
- Search the Web as well as other resources to find answers to the questions below. Remember that you are going to be the expert in your specific role so use your Internet search skills to make sure that you find good sources of information on the topics below. Make sure that you record all sources and please note that Wikipedia CANNOT be used as a resource.
- Write down answers to each question, and prepare yourself as a spokesperson for the specific administrative role (e.g., emergency services, media, etc.) to which you were assigned.

Remember to bring this worksheet with you to class on Thursday, Oct. 9! You will need to turn this in with the group worksheet.

I. **Understanding the Hurricane:**
This section is to help you to identify information that should be considered with regards to hurricane evacuation decision.

(a) **In general,** for hurricane evacuation decision, what information would you need? Find information about the following plus others that you think are important:

- How does the size of the hurricane influence evacuation? (e.g., what is the min. size at which you should consider evacuation?)

- How strong should the wind be for you to evacuate?

- What difference does time of hurricane impact make (night vs. day)?

- How does direction of hurricane impact your planning?

- How would the duration of the hurricane impact your evacuation plans?

(b) What are other natural events that tend to accompany hurricanes and what should you know about their impact and size? (e.g., storm surges, flooding,

etc.,) Do some exploration and make a list of these common dangers and how you can address them.

II. Understanding your community with regards to hurricane evacuation:
What information do you need for you to make a decision on hurricane evacuation ***for your community***? First, find this basic information for your community:

(a) geographical location:

(b) population:

(c) evacuation routes:

III. **Understanding the specific administrative role:**

(a) As a chamber of commerce group member, you should identify the following information plus others that you think might be important:

i) Distribution of population (residents vs. tourists)

ii) Number and location of vulnerable populations – e.g, based on age (children vs. older population), mobility (disabled, sick, very feeble, etc.,)

iii) Distribution of residential areas (high concentration vs. low concentration, proximity to areas with high exposure to hurricane, etc.,)

(b) Based on the information in IIIa, who would you recommend be evacuated first and why? Are there specific challenges related to evacuation of a specific segment of the population? E.g., if you have a lot of tourists in your town at this time, and they are all close to the shore, then you would probably need to think about how to evacuate them in addition to other vulnerable populations. Try to make a list of all possible impacts of the hurricane that are important to consider so you can advise your community on how to deal with evacuation, if needed.

Name: _____
Group: Mayor and City Council
Community: Deerfield Beach

Guidelines for this individual activity

This individual worksheet should help you prepare for the group activity and the final report on the evacuation decision for Hurricane Smith. The worksheet will help you think about key pieces of information that you will need as you plan for hurricane evacuation and the impact of hurricane within your community for the group activity.

To complete the individual worksheet, you should:

- Go to the Earth101 Angel site, and find resources for your specific community (there are three folders named Deerfield Beach, Hilton Head, and Morehead City)
- Search the Web as well as other resources to find answers to the questions below. Remember that you are going to be the expert in your specific role so use your Internet search skills to make sure that you find good sources of information on the topics below. Make sure that you record all sources and please note that Wikipedia CANNOT be used as a resource.
- Write down answers to each question, and prepare yourself as a spokesperson

for the specific administrative role (e.g., emergency services, media, etc.) to which you were assigned.

Remember to bring this worksheet with you to class on Thursday, Oct. 9! You will need to turn this in with the group worksheet.

I. **Understanding the Hurricane:**

This section is to help you to identify information that should be considered with regards to hurricane evacuation decision.

(a) **In general,** for hurricane evacuation decision, what information would you need? Find information about the following plus others that you think are important:

- How does the size of the hurricane influence evacuation? (e.g., what is the min. size at which you should consider evacuation?)

- How strong should the wind be for you to evacuate?

- What difference does time of hurricane impact make (night vs. day)?

- How does direction of hurricane impact your planning?

- How would the duration of the hurricane impact your evacuation plans?

(b) What are other natural events that tend to accompany hurricanes and what should you know about their impact and size? (e.g., storm surges, flooding, etc.,) Do some exploration and make a list of these common dangers and how you can address them.

II. Understanding your community with regards to hurricane evacuation:
What information do you need for you to make a decision on hurricane evacuation ***for your community***? First, find this basic information for your community:

(a) geographical location:

(b) population:

(c) evacuation routes:

III. **Understanding the specific administrative role:**

(a) As a city council member, you should identify the following information plus others that you think might be important:

i) Cost of complete evacuation (what are the different businesses and services that will be shut down and what is the cost to the economy, what does it cost to evacuate all the residents in the town)

ii) Cost of evacuating specific residents and facilities (what are the most likely areas and populations to be affected and how much would it cost to evacuate those specific areas?)

(b) Based on the information in IIIa, what should your plan of action be for evacuation? What information do you need to make a decision about evacuation? How will you decide what are the most important things to think about as you consider either evacuating or staying? E.g., unnecessary evacuation will cost a lot of money but not evacuating in time can result in irreparable harm to residents. Try to make a list of all possible impacts of the hurricane that are important to consider so you can advise your community on how to deal with evacuation, if needed.

Appendix E. Community Information Organizer

Please fill out the following information organizer to help your group plan for the upcoming
activity. Please attach ALL individual worksheets that you used for gathering data related to your specific role.

Community Name:

Names of group members:

What is the population of town?

What are prominent groups of residents in the town?

- Proportion of retired and elderly persons

- Proportion of hospitalized or other physically disabled persons

- Proportion of tourists

- Proportion of able residents

Whom would you evacuate first and why?

What is the location of possible emergency shelters?

- Proximity to areas in danger

- How many can be accommodated in each shelter

- What kinds of facilities (water, food, sanitation) are available in each place?

What are the main roads/ highways used to leave town?

- Where do roads lead?

- How many interstate vs. rural roads are available to leave the town?

- What impact do the number and type of roads have on evacuation speed and time?

- How much traffic can be supported?

What is the location of hospitals and other emergency services?

What are other pertinent issues that might face your particular community/ group in light of a natural
disaster and the need to evacuate:

----------Time release statement 1----------

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

- When is the possible time of impact?

- What is the direction the hurricane is moving in?

- What is the estimated strength of the hurricane?

- What is the estimated danger and damage to facilities and residents?

2. What is your decision?

Community Decision Point 1			
Do not evacuate	**Keep an eye on data**	**Tell citizens to prepare for evacuation**	**Evacuate**

3. Why did you make this decision? Remember that evacuation comes at a cost of evacuating and shutting down all businesses, etc., while not evacuating means possible harm to community and facilities. Explain your decision.

4. At this point, write a 5 line information bulletin that will explain to residents what action they should take for the hurricane. This bulletin will be released to all radio, news, and weather channels on TV to tell the residents of the area what the community plan is and why that is the best thing to do. Make sure to tell the residents why you are making these decisions and what might be possible future scenarios (based on the information in #1)

5. What are some of the consequences of your final decision on the community? What might happen in the next few days?

----------Time release statement 2----------

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

- When is the possible time of impact?

- What is the direction the hurricane is moving in?

- What is the estimated strength of the hurricane?

- What is the estimated danger and damage to facilities and residents?

2. What is your decision?

Community Decision Point 2			
Do not evacuate	**Keep an eye on data**	**Tell citizens to prepare for evacuation**	**Evacuate**

3. Why did you make this decision? Remember that evacuation comes at a cost of evacuating and shutting down all businesses, etc., while not evacuating means possible harm to community and facilities. Explain your decision.

4. At this point, write another update 5 line information bulletin that will explain to residents what action they should take for the hurricane. This bulletin will be released to all radio, news, and weather channels on TV to tell the residents of the area what the community plan is and why that is the best thing to do. Make sure to tell the residents why you are making these decisions and what might be possible future scenarios (based on the information in #1)

5. What are some of the consequences of your final decision on the community? What might happen in the next few days?

Appendix F. Individual Report in Fall 2008

Individual Report

You have been appointed as Special Aide for Disaster Management and Evaluation within the office of the Mayor of your specific community. The Mayor would like you to evaluate the community's hurricane decision (at decision point 2) and propose your own solution/decision based on the latest information about the hurricane (decision point 3). The Mayor would like you to prepare a report that he will then use to coordinate hurricane evacuation for the community.
In your report (2 pages, approx. 750 words, double spaced, 12 point font), please address the questions below. You should support your suggestions with data and reasons wherever appropriate.

- **Identity**: Identify the community of which you were a part and your specific role within the community.
- **Community decision**: What was the final decision of your community at decision point 2? Did you agree with that decision at that point? Whether yes or no, explain why, based on the community discussions, the data about the hurricane, and your understanding of the situation.
- **Evaluate community decision**: Now that you have new information presented at decision point 3, how would you evaluate your community's decision at decision point 2? Do you still agree or disagree with their decision and why? Or would you change your evaluation and why? Provide data and reasoning as appropriate.
- **Your final decision**: Based on the new information on hurricane location provided at decision point 3, what is your final decision as to what the community should do (i.e., evacuation, do not evacuate, etc.,)?
    - Explain why your decision is the best possible 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.
    - Describe examples from the real world and any other explanations that you think support your decision, if appropriate.
    - Describe alternative solutions/decisions that might be considered, and explain the advantages and disadvantages associated with those plans.
    - Include graphs, diagrams, maps or any data that support your reasoning for all decisions.

Save your report as a Word document with your name as the title of the document.

Make sure to save your document as a .doc and NOT as a .docx document. In the document, make sure to specify your name and email address and the word count. Submit the word document in the assignment drop box set up on the ANGEL course website.

Note: Make sure to correctly cite and include all resources and references at the end of your report. You may NOT use Wikipedia as a reference source.

VITA
SUHYUN YOO

Education

Ph. D. Program of Instructional Systems, The Pennsylvania State University, PA, December 2011

MS. Educational Technology, Seoul National University, South Korea, 1999

BS. Ethic Education, Seoul National University, South Korea, 1993

Work Experience

World Campus of Penn State University, University Park, PA, January 2008 – 2011, Instructional Production Specialist and Graduate Assistant

The Institute for Research in Training and Development of Penn State University, University Park, PA, August 2006 – May 2007, Graduate Assistant

Center for Teaching & Learning in Kyunghee University, South Korea, August 2004 – December 2004, Senior Researcher

Kyobo Life Insurance, South Korea, March 2003 – April 2004, HRD Specialist

Institute of Asia-Pacific Education Development, Seoul National University, South Korea, March 2001 – December 2002, Research Assistant

Education Research Institute, Seoul National University, South Korea, April 1996 – August 1999, Research Assistant

Baeksuck Middle School, South Korea, March 1995 – February 1996, Teacher

Myungduck Foreign Language High School, South Korea, March 1994 – February 1995, Teacher