A QUALITATIVE STUDY OF CREATIVE THINKING USING EXPERIENTIAL LEARNING IN AN AGRICULTURAL AND LIFE SCIENCES COURSE

A Dissertation

by

CHEHRAZADE ABOUKINANE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2007

Major Subject: Agricultural Education

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Approved by:

Chair of Committee, Kim E. Dooley
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ABSTRACT

A Qualitative Study of Creative Thinking Using Experiential Learning in an Agricultural and Life Sciences Course. (December 2007)

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Chair of Advisory Committee: Dr. Kim E. Dooley

The purpose of this study was to explore whether creativity can be nurtured in an experiential learning environment at the college level. The study investigated how well process-based creativity models and construct-based creativity models reflected creative behavior in an experiential and team-based learning environment.

The research design included field observations, focus group interviews, student questionnaires, and portfolio assessments. Study participants were selected students from Texas A&M University's College of Agriculture and Life Sciences.

Findings indicated that both process-based and construct-based creativity models are good indicators of creative behavior.

Torrance's creativity dimensions that emerged among students included problem awareness, ability to produce and consider many alternatives, ability to put ideas into context, ability to use humor, kinesthetic responsiveness, and ability to break through boundaries. Treffinger's creativity dimensions included sensitivity to problems, tolerance of congruity, fluency, good research and management skills, cognition, memory, analysis, application, openness to experience, confidence, independence in inquiry, willingness to

respond, and readiness for transformations. Dacey's constructs included sensitivity to problems, divergent thinking, convergent thinking, openness, independence of judgment, self guidance, and playfulness. Jackson and Messick's constructs included analysis, intuition, openness, and reflection.

Study findings also indicated that all steps of the Osborn and Parnes process-based creativity model were fully utilized in the experiential and team-based learning environment.

As part of the effort to seek models of teaching and learning that encourage students to be more creative while solving complex problems in the world of agriculture, findings of this study can be used to determine how creativity can be fostered through experiential and team-based learning.

DEDICATION

For my children Layan and Adam, my husband Mohammed, my sister Kaoutar, my brothers Hisham and Ali, and my inspiration: my parents Khadija and Mustapha.

ACKNOWLEDGEMENTS

My doctoral dissertation was an incredible experience, not just for of the amount of intellectual knowledge I gained, but for the wealth of information I gained about myself and my career in general. Many people helped me through my doctoral research journey, and to them go all my gratitude.

First of all, I would like to take this opportunity to thank Dr. Dooley who has been my academic advisor for three years. I would like to thank her for providing me with every single opportunity to advance in my academic journey. She will always be remembered for her patience, beautiful smile, positive thoughts, and exuberant enthusiasm about my research during the long hours we spent in her office discussing my research and academic career. I thank Dr. Kenimer, Dr. Nash, Dr. Speed, Dr. Longnecker, Dr Lindner, and Dr. Murphy for their valuable contributions to my research and participation in several peer debriefing sessions to discuss my research data, analyses and findings.

I would like to especially thank my deceased father Mustapha, who provided me with unconditional support and love since I was born. I would like to thank my mother Khadija for all the sacrifices she made to provide me with the best education. I would like to thank her for taking care of my children Adam and Layan while I was engaged in my research journey. I would like to thank my husband Mohammed for his mental support and prayers all throughout my research journey. I would like to finally thank my older brothers Hisham and Ali, and sister Kaoutar; without their encouragements, I would have not been in graduate school.

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CHAPTER I

INTRODUCTION

Background of the Study

"Life is becoming constantly more complex in our age of science and technology" (Lancelot, 1944, p.19). As science and technology change, industries are in need of competent agricultural scientists who can face the various technological changes of the future. Agricultural scientists' contributions are highly visible ranging from cultivation and production of plants and animals to the preparation of these products for consumptions for humans, animals, and plants. Hence, educating agricultural scientists has an influence on national welfare, and the preparation of competent and reliable future agricultural scientists should be of paramount importance to educators in academia.

Since learning in Agricultural Education has been both "hands-on" and conceptual in intent (Parr & Edwards, 2004), experiential learning has been used as a foundational model of teaching and learning in Agricultural Education (Knobloch, 2003).

Numerous researchers in Agricultural Education have explored experiential learning (Cheek, Arrington, Carter, & Randell, 1994; Hughes & Barrick, 1993; Randell, Arrington, & Cheek, 1993). Cheek, Carter, and Randell (1994) described experiential learning as practicing in a real situation, modeling appropriate behaviors and procedures,

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This dissertation follows the style and format of the *Journal of Agricultural Education.*

receiving appropriate feedback and reinforcement, and providing a means to apply knowledge in new situations.

One of the main aspects of experiential learning has been identified by Knobloch (2003) as problem solving. This educational practice has been of great interest to many researchers (Langley, Choi, & Rogers, 2005; Kim, 2006) and promoted the exploration of various learning environments, such as team problem solving and creative problem solving. Studies have indicated that team collaboration in problem solving enhances creativity and allows for better outcomes than problem solving when performed individually (McFadzean, 1998; Johnston, James, Lye, & McDonald, 2000). Therefore, this study used a learning environment in which team collaboration and problem solving were implemented to allow creativity to be enriched among students.

Statement of the Problem

Even with the implementation of many appropriate learning and teaching approaches such as experiential learning, Agricultural Education continues to face many challenges that other disciplines endure in higher education as a whole. As Baker and Rudd stated, “Higher education is faced with the challenge of making the educational experience relevant to the demands of society as well as maximizing the use of talents of its stakeholders ”(p.162). Also, according to Boyer (1990), “what we are faced with, today, is the need to clarify campus missions and relate the work of the academia more directly to the realities of contemporary life. We need especially to ask how institutional diversity can be strengthened and how the rich array of faculty talent in our colleges and universities might more effectively be used and continuously renewed” (p. 13). Based on

the educational needs previously listed, questions were raised among some agricultural educators and researchers about how educators proceed with implementing this visioning process, whether there are activities that can enhance this process, if there are any particular steps involved, and how they can be utilized (Baker & Rudd, 2001).

Torrance (1993) assured that creativity is considered to be one of the main elements that will allow universities to create this vision: "No educational reform can succeed and endure unless it is supported by appropriate retooling in the form of methods, instructional materials, assessment procedures, and statements of objectives. This is true in educational reform that requires creativity or is based in part on research" (Torrance, 1993, p. 158).

Torrance has inspired many agricultural educators and researchers since then, and encouraged them to explore options to use creativity in learning and teaching settings (Baker & Rudd, 2001; Friedel & Rudd 2005). The following study explored the use of an experiential learning environment in enhancing creativity among college students.

Research Methods

The sample used in this study was retrieved from a population of an introductory course in Biological and Agricultural Engineering taught at Texas A&M University. The overall objective of the course was to provide freshman and new transfer college students with an engineering design experience. The course also introduced students to basic science and engineering principles they would be exposed to during their freshman and sophomore years. The specific objectives of the course were to:

- Develop students' skills appropriate to open-ended design problems,

- Help the students develop basic competencies in project management, team work and peer evaluation,
- Help the students develop professional skills by directly working with clients from industries, and
- Help the students improve their communication and writing skills by presenting their design solutions in public forums and written reports.

All students enrolled in the introductory course in Biological and Agricultural Engineering were divided into design teams and were assigned a student leader. Student leaders were senior students who were enrolled simultaneously in a more advanced engineering design course and were assigned design topics different in context than the ones they were exposed to in the freshman course. Roles of the student leaders included facilitating the design projects by answering questions related to the design process, and helping resolve conflict which may rise.

Study participants included 14 students who were enrolled in the introductory course in Biological and Agricultural Engineering.

Data were collected in this study using four approaches. The first approach involved observing the students' interactions among themselves and with their class facilitators and professor during a prolonged period of 6 weeks. The second approach involved collecting data while conducting focus group interviews with the students and transcribing their statements. The third approach consisted of gathering documented answers to specific questions that were used as follow up for the focus group interview activity. The fourth approach included analyzing their portfolios which included their final design reports. Hence, data triangulation was used during this study.

To establish trustworthiness in the data collection, processing, and interpretation, four measures were established: (a) credibility, (b) transferability, (c) dependability, and (d) confirmability (Lincoln, & Guba, 1985, p. 290).

Credibility of the study was enhanced by data triangulation, prolonged engagement, persistent observation, and referential adequacy. Transferability was established by providing descriptive details about the research context and assumptions that were made about the research. Dependability was established by the researcher through extensive descriptions of her interpretations of the data, allowing others interested in the study to draw conclusions. Confirmability was established by providing an audit trail (Lincoln & Guba, 1985, p. 368), as a system for checking systemizing, relating, cross-referencing, and prioritizing data.

Data analyses of all four sources (field notes, focus group interviews, portfolios and questionnaire) were based on Miles and Huberman's (1994) flow analysis model. The data analysis consisted of three concurrent flows of activity: data reduction, data display, and conclusion drawing and verification (Miles & Huberman, 1994, p. 10). According to Miles and Huberman (1994), "data reduction refers to the process of selecting, focusing, simplifying, abstracting, and transforming the data that appears in written-up field notes or transcriptions" (p. 10). The data were then displayed in an organized, compressed assembly of information that allowed data interpretation about how creativity was used in an experiential learning environment.

Purpose of the Study

The purpose of this study was to explore whether creativity can be nurtured in an experiential learning environment at the college level.

Results of this study answered the following two research questions:

- How well do construct-based creativity models for determining creative behavior apply to a college level experiential learning environment?
- How well do process-based creativity models for determining creative behavior apply to a college level experiential learning environment?

Significance of the Study

In the broadest sense, agricultural educators continue to seek models of teaching and learning that encourage students to be more creative while solving complex problems in the world of agriculture. Experiential and team-based learning is a useful tool for encouraging students' creativity. Findings of this study help understand how creativity can be fostered through experiential and team-based learning.

Study Limitations

The respondents of this study were limited to the study participants within the whole class of instruction. Full class observation indicates that the sample was representative. This study was not designed to examine the influence of gender, age, or ethnicity in acquiring various creativity traits among students.

Study Assumptions

The following assumptions were made in the conduct of this study:

- Emergence of the creativity behavior exhibited during the experiential learning environment was consistent throughout the course of the study.
- Data collected from focus group interviews and questionnaires reflected honest views and opinions from participants.

Study Delimitations

This study was delimited to students who were enrolled in an engineering design course in the College of Agriculture and Life Sciences at Texas A&M University during the Fall semester of 2004.

Definition of Terms

Active learning: A process whereby learners are actively engaged in the learning process while educators take a more guiding role. Jayawardana, Hewagamage, and Hirakawa (2001) defined active learning by the ability of learners to carry out activities effectively while incorporating them into a process of their own education.

Cognition: It is one of the five operations of the structure of intellect (cognition, memory, convergent thinking, divergent thinking, and evaluation). It means discovery, rediscovery, and recognition (Guilford, 1975 as cited in Dacey, 1985, p. 111).

Confirmability: This criterion is considered one of the major components for establishing trustworthiness in qualitative research. The concept of confirmability is equivalent to the concept of objectivity in quantitative research. It is used to assure that qualitative results can be confirmed by other researchers. A good confirmability technique that is used by researchers is known as the confimability audit and involves the use of an audit trail (Lincoln & Guba, 1985, p. 328).

Creativity: It was defined as the combination of divergent and convergent thinking (Young, 1990). Viewed theoretically, divergent thinking seems to involve the generation of alternatives and unique ideas in the thinking process, whereas convergent thinking involves selecting ideas based on their uniqueness, feasibility, and quality (Kirton, 1987).

Creativity indicator: A tool, trait, or tool used to evaluate creativity among individuals. Examples of creativity indicators include elaboration, originality, and openness (Torrance & Safter, 1999).

Credibility: One of the major criteria that helps establish trustworthiness in qualitative research. Examples of techniques that are used in the qualitative research field to increase credibility include prolonged engagement, persistent observation, and triangulation (Lincoln & Guba, 1985, p. 328).

Dependability: Similar to reliability, stability, consistency, predictability, and accuracy (Kerlinger, 1973, p. 422). Examples of methods that assure dependability include multiple data gathering procedures (triangulation), and stepwise replications, and which involves data gathering on multiple occasions (Lincoln & Guba, 1985, p. 317).

Experiential learning: Type of learning that can be described as practicing in a real situation, modeling appropriate behaviors and procedures, receiving appropriate feedback and reinforcement, and providing a means to apply knowledge in new situations (Cheek, Carter, & Randell, 1994).

Facilitator: "One who guides a discussion, activity, or course. May be the instructor, a guest lecturer, or a student. Not necessarily the same person for all course activities. Facilitator and moderator are, at times, used interchangeably. However, a moderator may be responsible for presiding over the entire course. In an online student-centered environment, faculties facilitate active learning, problem solving, inquiry approaches, and team-based instructional activities or projects" (Sacramento State University Computing, Communication & Media Services, 2007, p. 1).

Flexibility: It is one of Torrance's creativity indicators characterized by lack of tendency to perceive problems from only one perspective (Jausovec, 1994 as cited in Torrance & Safter, 1999, p. 75).

Focus group interviews: Interviews involving a group of individuals who meet to discuss a research problem. It is "an interview style designed for small groups…Focus group interviews also provide a means for collecting qualitative data in some settings and situations where a one-shot collection is necessary" (Berg, 2001, p. 111).

Kinesthetic responsiveness: One of Torrance's creativity indicators that were utilized to measure creativity. "It includes not only manipulative movements but also kinesthetic discrimination, psychomotor coordination, endurance, strength,

flexibility, adaptive motor skills, expressive movement, and interpretive movement" (Torrance & Safter, 1999, p. 189).

Openness: This is a creativity construct that involves a readiness to explore new ideas and avoid premature closure about making decisions (Torrance & Safter, 1999, p. 117). Open-minded individuals are often accepting to external points of views and ideas.

Originality: One of Torrance's constructs that "involves getting away from the obvious and common-place or breaking away from habit-bound thinking. Original ideas are statistically infrequent" (Torrance & Safter, 1999, p. 87).

Persistent observation: A type of observation that lasts throughout the study. The purpose of this technique in qualitative research is to "identify those characteristics and elements in the situation that are most relevant to the problem or issue being pursued and focusing on them in details" (Lincoln & Guba, 1985, p. 304).

Prolonged engagement: Refers to the act of investing enough time in the study in order to learn the culture, test for any misinformation introduced by any distortions, and build trust in the study (Lincoln & Guba, 1985, p. 301).

Qualitative research: It is a generic term used for investigative methodologies which emphasize the importance of analyzing variables and their interactions in a natural setting. In qualitative research, data are gathered through open-ended questions that provide direct quotations. The interviewer is considered as an integral part of the investigation (Jacob, 1988).

Referential adequacy: One of the methods used in qualitative research to enhance credibility. Examples of materials used to assure referential adequacy include archived data, video recorders, audio recorders, or movie cameras which can be used to provide a kind of benchmark against which later data analyses could be tested for adequacy (Lincoln & Guba, 1985, p. 313).

Synthesis: The process of bringing different components of an analysis together in a logical way to make a whole new concept. An example of synthesis is demonstrated in Torrance's Test of Creative Thinking where respondents are asked to bring six sound elements into a coherent image (Torrance & Safter, 1999, p. 158).

Torrance Test of Creative Thinking: A test developed by Torrance in which creativity is measured using the following 17 constructs: problem awareness, ability to produce and consider many alternatives, flexibility, originality, ability to highlight the essence, ability to elaborate, openness, being aware of emotions, ability to put ideas into context, combination and synthesis, ability to visualize richly and colorfully, ability to enjoy work and use fantasy, kinesthetic responsiveness, ability to look at things in different visual perspectives, internal visualization, ability to break though and extend the boundaries and finally, and ability to let humor flow and use it (Torrance & Safter, 1999).

Transferability: This criterion refers to the applicability or transfer of findings to other settings. To assure transferability, the researcher asks if the study findings are transferable to other contexts (Lincoln & Guba, 1985, p. 316).

Triangulation: It refers to the use of multiple investigators, multiple sources of data, multiple methods or multiple theories to confirm emerging findings (Denzin, 1970 as cited in Lincoln & Guba, 1985, p. 305).

Trustworthiness: The quality that allows the researcher to persuade his or her audiences (including self) that the results of the inquiry have a “true value” (Lincoln & Guba, 1985, p. 290).

CHAPTER II

REVIEW OF LITERATURE

Introduction

In discussions on improving education, Padron and Waxman (1999) indicated that many educators and policymakers have encouraged the use of models of teaching and learning that change the role of the teacher as a deliverer of knowledge to a facilitator of more active student learning (as cited in Knobloch, 2003).

Further, Hillison (1996) concluded that from the passage of the Hatch Act in 1887 until the implementation of the Smith-Hughes Act at a later stage, Agricultural Education was known for at least three main characteristics: (a) its strong scientific basis, (b) its tight connection with United States Department of Agriculture, and (c) its educators who have a strong background in scientific laws and principles related to agriculture (as cited in Parr & Edwards, 2004).

Learning in Agricultural Education has been both been both “hands-on” and conceptual in purpose (Parr & Edwards, 2004). Hence, experiential learning has been used as a foundational model of teaching and learning (Knobloch, 2003).

Experiential Learning

Experiential learning has been a fundamental learning practice in Agricultural Education (Cheek, Arrington, Carter, & Randell, 1994; Hughes & Barrick, 1993; Randell, Arrington, & Cheek, 1993).

Knobloch (2003) concluded in a study that there were four tenets of experiential learning in Agricultural Education: a) learning through real-life contexts, b) learning by doing, c) learning though projects, and d) learning though solving problems.

According to Knobloch (2003), four main leaders helped demark experiential learning for agricultural educators in both formal and non formal settings during the 1890s through 1940s: John Dewey, Seaman Knapp, Rufus Stimson, and William Lancelot.

One of Dewey's most important contributions to education was his belief that education should be applied in real life situations (Knobloch, 2003). Dewey emphasized that "education appropriate to the American society must include both the liberal and the practical, both education for work and education for leisure" (Elias & Merriam, 1980; p. 56).

Knapp, as Knobloch quoted him, is considered the father of agricultural extension education. His philosophy can be described as follows: "What a man hears, he may doubt, what he sees, he may doubt, but what he does, he cannot doubt" (Lever, 1952, p. 193). Knapp's concepts helped generate the second pillar or (tenet) in Agricultural Education which was "learning by doing."

Stimson is considered as a leader in shaping Agricultural Education at the high school level (Knoblock, 2003). Stimson believed that project-based learning or active learning motivated students because "this method immediately appeals to the motor instincts and activities of boys and girls of secondary school age" (Stimson, 1919, p. 54). He also commented that the majority of students "learn best by being told and shown on the field of action" (Stimson, 1919, p. 55). Furthermore, Stimson stated that "the pupil

must then be trusted to develop efficiency on his or her own account in one or another field of applied knowledge" (Stimson, 1919, p. 89). Based on Stimson's philosophy derived from all of the above comments, Knobloch extracted the third pillar or tenet of experiential learning in Agricultural Education which is learning through projects or what is often referred to as project-based learning.

The fourth pillar of experiential learning as defined by Knobloch was extracted from Lancelot's philosophy on problem solving. Lancelot implemented Dewey's concept of contextual learning and created the problem solving method of instruction in Agricultural Education (Knobloch, 2003). His book titled *Permanent Learning* was "designed to produce teachers making knowledge function in the lives of their pupils, teachers whose eyes are fixed upon knowledge in action, which is life….The book is unique in its insistence upon *teaching for permanent outcomes* " (Lancelot, 1944, p. v). Lancelot (1944) stated that "It is quite clear that the essential knowledge should be long remembered" (p.17). He also proclaimed that the essential knowledge is the one that is most applied in life, and that it should be taught so that it can be retained as long as needed in order to be utilized appropriately in real life situations (Lancelot, 1944, p. 17). Hence the notion of problem solving was derived from Lancelot's philosophy while being identified as a fourth pillar of experiential learning in Agricultural Education.

As part of effort to improve educational practices and quality in higher education (Baker & Rudd, 2001; Torrance, 1993), several studies investigated the implementation of problem solving (Langley, Choi, & Rogers, 2005; Kim, 2006) in learning environments. This educational practice promoted exploring further types of problem solving in educational settings such as creative problem solving.

Several studies were conducted to study creative thinking in Agricultural Education. Friedel and Rudd (2005) attempted to examine the presence or absence of relationships between student learning styles and student creative thinking. The researchers found no significant relationships between creative thinking ability and learning style, except for a group of learners who scored lower in the creativity constructs of fluency and elaboration. Results of the study also indicated that more research was needed in the area of learning styles and creative thinking.

Baker and Rudd (2001) proposed a model of the creative thinking process for the purpose of serving as a cognitive map for faculty as they seek to promote the creative potential of students. The authors also encouraged further discussion on the creative potential in higher education, and recommended that agricultural faculty in higher education use this study as a foundation to develop a more creative learning environment. Baker and Rudd (2001) also explored in a different study the relationships between critical and creative thinking. Results from this study suggested that the two constructs (critical and creative thinking) are not closely related. The researchers also stated that further research needed to be conducted with different age ranges, genders, and socio-economic backgrounds to confirm the results of this study. Preliminary findings of this study suggested that educators must prepare specific curriculum that stimulates creative and critical thinking separately.

In response to Torrance's and Baker and Rudd's comments on the need to conduct research to explore different avenues where creativity can be utilized in higher education, this study explored how creativity can be nurtured in a particular experiential learning environment. As part of the effort to determine a theoretical base for the

development of an experiential learning environment that supports creativity, this study extended the definition of a simple problem solving technique in a college level course to examine how creativity can be enhanced by an experiential learning environment. This required a throughout review of literature on creativity.

Creativity

A review of the literature outlined several definitions for creativity or creative people. While several creativity scholars defined creativity as a model that includes several constructs or dimensions among individuals (Torrance & Safter, 1999; Treffinger et al., 1992; Young, 1990; Dacey, 1985), others defined creativity as a stepwise process (Parnes, 1975; Osborn, 1963).

Creativity Defined as a List of Constructs

One of the most succinct models of creativity was developed by Jackson and Messick in 1965 (as listed in Dacey, 1985, p. 7). Table 1 provides an outline of the model, including both personal and cognitive traits of creative people, characteristics of the products creative individuals often produce, and the reflexive reactions observers usually have to those products. Each characteristic in Jackson and Messick's model is represented by a row, each with five different aspects.

Table 1
Jackson and Messick's four characteristics of creativity

Traits of the Person		Traits of the Product		
Intellectual Traits	Personality Traits	Product Properties	Standards	Reflective Reactions
1. Tolerance of incongruity	Original	Unusualness	Norms	Surprise
2. Analysis and intuition	Sensitive	Appropriateness	Context	Satisfaction
3. Open-mindedness	Flexible	Transformation	Constraints	Stimulation
4. Reflection and spontaneity	Poetic	Condensation	Summary power	Savoring

[Source: Duke University Press (from Jackson and Messick 1965. Reproduced by Duke University Press with permission)]

Creativity was also described as the combination of divergent and convergent thinking (Young, 1990). Viewed theoretically, divergent thinking involves the generation of alternatives and unique ideas in the thinking process, whereas convergent thinking involves selecting ideas based on their uniqueness, feasibility, and quality (Kirton, 1987).

In his book *Fundamentals of Creative Thinking,* Dacey (1985) provided a complete list of traits which characterizes creative people as summarized in Table 2. According to Dacey, not every highly creative individual will be seen to possess all of these listed traits. However, the more a person possesses or tries to achieve these characteristics, the more she or he improves her or his creativity (p. 40).

Table 2

Dacey's list of characteristics of creative people

1. Are more sensitive to the existence of problems.

2. Have a somewhat greater tendency toward emotional disturbance, but also have more self-control for dealing with this tendency.

3. Are able to think both convergently, solving problems that have only one correct answer and divergently, solving problems that have many possible answers.

4. Demonstrate greater determination and perseverance.

5. Have higher than average intelligence but do not often measure in the "genius" range.

6. Are more open to experience and less defensive about accepting new information.

7. See themselves as responsible for most of what happens to them.

8. Enjoy being playful and childlike, have the ability to "toy" with the environment.

9. Engage more frequently in solitary activities, especially as children.

10. Are more likely to question the status quo.

11. Are more independent of the judgment of others.

12. Are less afraid of their own impulses and hidden emotions.

13. Like to do their own planning, make their own decisions, and need the least training and experience in self-guidance.

14. Do not like to work with others, and prefer their own judgment of their work to the judgment of others. They seldom ask other students or their teachers for opinions.

15. Take a hopeful outlook when presented with complex and difficult tasks.

16. Have the most ideas a chance to express individual opinion is presented. These ideas frequently evoke the ridicule of others.

17. Are most likely to stand their ground in the face of criticism.

18. Are the most resourceful when unusual circumstances arise?

19. Are not necessarily the "best" students.

20. Show an imaginative use of many different words.

21. Are more original. Their ideas are qualitatively different form everyone else's.

[(As cited in Fundamentals of Creative Thinking, 1985, pp. 39-40)]

Torrance's creativity model (Figure 1) takes into consideration three main factors to determine creative behavior: creative abilities, creative skills, and creative motivations. A high level of creative achievement can be reached only from those who have creative motivations, such as some type of commitment, and the skills necessary to allow for creative abilities. People who have a high level of creative abilities and skills may become creative achievers, if the creative motivations can be enhanced. Also, people who have creative abilities and motivations can become achievers if they have the required creative skills (Torrance & Safter, 1999, p. 51).

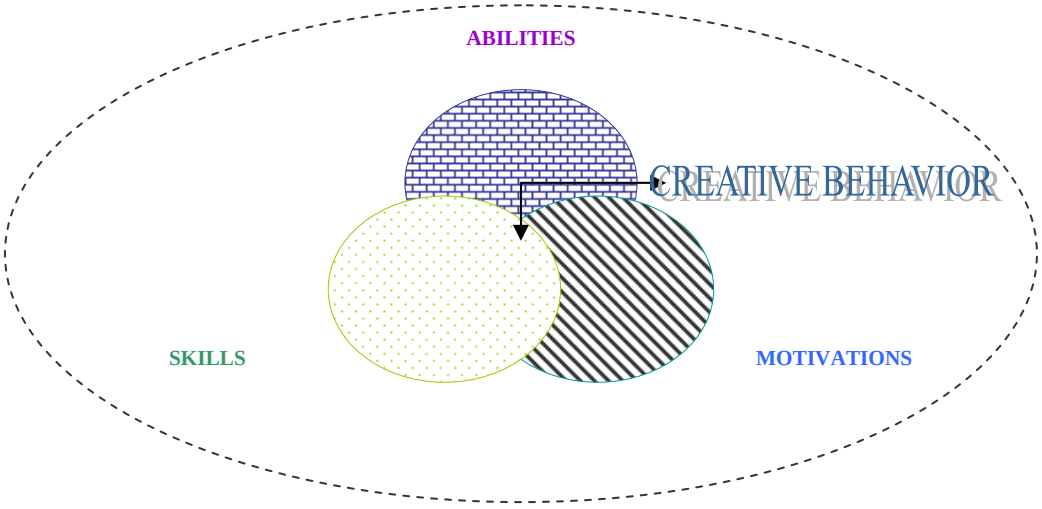

Figure 1. Torrance model for studying and predicting creative behavior.
(Source: *Making the Creative Leap Beyond, By Torrance and Safter, 1999, p. 5)*

The following section identifies some of those creative abilities that Torrance and Safter identified to be the most important: (a) Problem awareness, (b) Ability to produce and consider many alternatives, (c) Flexibility, (d) Originality, (e) Ability to highlight the essence, (f) Ability to elaborate, (g) Openness, (h) Being aware of emotions, (i) Ability to

put ideas into context, (j) Combination and synthesis, (k) Ability to visualize richly and colorfully, (l) Ability to enjoy work and use fantasy, (m) Kinesthetic responsiveness, (n) Ability to look at things in different visual perspectives (o) Internal visualization (p) Ability to break though and extend the boundaries, and finally (q) Ability to let humor flow and use it. The next sections will further define these creative traits.

Creativity occurs following some degree of knowing, perception, and cognitive history (Fearn, 1976, p. 56). Creative thinking does not occur unless there is recognition of a problem and commitment to deal with it (Torrance & Salfter, 1999, p. 52). This concept is often referred to as problem awareness.

Also, there has been considerable demonstration that the more alternatives people produce, the more viable those solutions are likely to be and there is greater chance of success in finding solutions to problems (Osborn, 1983). This construct is often referred to as fluency (Fearn, 1976, p. 58). This concept has also been referred to by Torrance as the ability to produce alternatives (Torrance & Salfter, 1999, p. 57).

Flexibility has also long been recognized as an important component in creative thinking and many researchers have attempted to define it (Torrance & Safter, 1999. p. 74). Flexibility has been defined as the production of ideas from perspectives that are different from the ones associated with a problem (Fearn, 1976, p. 58).

Another creativity construct has been referred to as uniqueness or originality. Originality can be associated often with a novel or unique idea (Fearn, 1976, p. 61). Torrance defined originality as a trait which “involves getting away from the obvious and common place or breaking away from habit bound thinking.” Baron (1969) defined original thoughts or ideas as those that are new to others (Torrance & Safter, 1999, p. 87).

The ability to highlight the essence in problems has also been recognized as one of the main traits of creative thinking. Many creative people fail to solve problems or produce creative products because they lose sight of what is important (Torrance & Safter, 1999, p. 98). Little attention has been given to measurement of the ability to highlight the essence (Torrance & Safter, 1999, p. 99). However, one of the creativity indicators established by Torrance and Ball (1984) in the Torrance Test of Creative Thinking (*TTCT*) is similar to this quality. In this assessment, test takers are urged to think of titles of the pictures they draw. They are urged to think of titles that will highlight the meaning of the picture or help understand a story.

Successful creative problem solving requires that alternatives chosen for execution be elaborated upon and that strategies be developed for their implementation (Torrance & Safter, 1999. p. 108). This concept has been referred to often as the ability to elaborate.

Also, one of the most widely recognized characteristics of the creative person is psychological openness (Rogers, 1979). Often, this concept has been associated with what has been called “premature closure” (Torrance & Saftter, 1999, p. 121). Open thinkers often take time to listen to others and, avoid premature and immediate judgment. One of most important contributions to creativity theory was an emphasis on rules of brainstorming which allows avoiding premature judgment (Osborn, 1963, p. 151).

The Torrance Test of Creative Thinking *(TTCT)* included being aware of emotions as one of the main indicators of creativity. Ideas occur as a result of emotional and irrational factors (Torrance & Safter, 1999, p. 127). De Bono (1975), in the program he developed for schools to use, explained that emotions are more important than

anything else in thinking. He also explained that emotions provide power to the thinking process.

With the approach of the post-industrial society, the need for viewing things in a more universal context has become increasingly more obvious (Torrance & Safter, 1999, p. 140). Several futurists have suggested that there is a strong relationship between motivation for learning and creative accomplishment and the person's images of the future. These include Alvin Toffler (1970), Benjamin Singer (1974), Frederick Polak (1973) and Toffler and Toffler (1993). This concept has been referred to as the ability to put ideas into context.

An additional creativity construct has been referred to as the ability to combine and synthesize. Psychiatrist Silvano Arieti (1976) called creativity "the magic synthesis." Also, there has been a long history of interest in synthesis as one of the higher mental processes considered by educators (Torrance & Safer, 1999, p. 156). A good example is the work of Bloom (1956) who developed taxonomies of educational objectives in the cognitive domain.

Rich and colorful imagery and perceptions have long been recognized by many scholars as the foundation of all creativity (Torrance & Safter, 1999, p. 165). Colorfulness is often associated with positive thinking and is expressed in various forms in creativity assessments. In Torrance's creative thinking model, colorfulness is defined as "exciting in its appeal to sense of taste, touch, smell, sight, and the like. Other descriptive synonyms might be the flavor, earthiness, unreal, spiritual, brilliant, sparkly, spooky, or emotionally appealing" (Torrance & Safter, 1999, p. 167).

Fantasy is included in Torrance's model as one of the major dimensions of creative behavior. The autobiographies of many of the great creative people of history indicate the importance of fantasy in creative achievements (Torrance & Safter, 1999, p. 176). Even practical-oriented professionals such as engineers and scientists of the National Aeronautics and Space Administration (NASA) are using fantasy techniques in their planning for space colonization (Johnson, 1977). The following excerpts from a NASA publication indicate the use of fantasy while describing several possible scenarios involving weightlessness (as cited in Torrance & Safter, 1999):

> An outstanding feature of space is the absence of the sensation of weight. In vessels moving freely in orbit objects exhibit weightlessness; they are said to be in "free fall" or subject to "zero gravity" or "zero g."... A few workers on their lunch break can be seen cavorting in the almost zero-g of the central hub playing an unusual type of ballgame, invented by earlier construction workers…Compared to earth football, the three-dimensional ballgame played in the central hub is much more thrilling. You find that really only the name…is the same since the liberating effects of low gravity and the Coriolis accelerations make all shots longer, faster, and curved, thus completely changing the rules and tactics of the game. (pp. 21-103)

Another dimension in Torrance's model of creative behavior is known as kinesthetic responsiveness. Even though disciplined procedures for creative problem solving and theory of creativity have been given practically no attention to kinesthetic and auditory responsiveness as facilitators (Torrance & Safter, 1999, p. 187), Torrance (1977) and Torrance and Ball (1984) included them as indicators of creative strength. The

figural forms of the *TTCT* which allow production of drawings that show movement and action provide insight on how to evaluate kinesthetic responsiveness.

The ability to look at things from different points of view and see things in different visual perspectives has been regarded as an important characteristic of creative persons (Torrance & Safter, 1999, p. 197). An important element in all the major processes for creative problem solving is a set of deliberate procedures for assisting problem solvers to get new perspectives on the problems under consideration. This is demonstrated in the work of Edward de Bono (1992), for example, in lateral thinking where the search for new and unusual perspectives is implemented. Another good example is Edward de Bono's (1985) *Six Thinking Hats.* This concept reflects de Bono's emphasis on seeing problems in different ways while giving each hat a different color:

- White hat is where thinking is neutral and objective and does not include interpretations and opinions.
- Red hat is where thinking involves some type of feeling and emotion such as intuitions, fear, like, dislike, and taste.
- Yellow hat is where thinking is positive and constructive and includes concerns to put facts into action and cause things to happen.
- Black hat is where thinking is opposite from yellow hat and emphasizes negative assessment. It generally indicates risks and concerns.
- Green hat is where creative thinking is involved and the thinker is in search for alternatives and other avenues to go beyond what is obvious while searching for unique ideas.

- Blue hat is where the thinker is responsible for summarizing and drawing conclusions. The thinker is also responsible for bringing the thinking from all other hats and sets focus, enforces discipline to reach valuable conclusions and findings.

Another dimension of creativity in Torrance's model is known as internal visualization. Internal visual perspectives have been of prime interest for many creativity scholars. This is demonstrated in the work of Osborn (1963; 1983), Parnes (1975), and de Bono (1974). The Osborn-Parnes program contains a wealth of information and procedures on how to "open up" problems. De Bono (1974) also suggested an outstanding procedure for use in talking with children about their problem solving which eventually encourages practice in internal visualization. Internal visualization as an indicator has been developed only recently as part of the *TTCT* (Torrance, Ball & Safter, 1992). This concept is described as the presentation of elements of objects that go beyond exteriors and pay attention to the internal, dynamic working objects, people, machines, and animals (Torrance & Safter, 1999, p. 208). Examples of answers in *TTCT* which include some degree of internal visual perspective include the following: embryo in womb, beans shown underground, and interior of a house.

Combining, synthesizing, seeing things in different perspectives, and all constructs mentioned in previous sections are fundamental factors in creative thinking; however, special abilities sometimes are required to solve complex problems. One of these abilities was identified by Torrance and Safter (1999) as the ability to break through and extend the boundaries. This indicator was also included as one of the new scoring criteria for the figural forms of the *TTCT* (Torrance & Ball, 1984).

Several researchers agree that some sense of humor, sometimes referred to as fantasy, plays a role in facilitating creativity. Moody (1978) defined an individual who has a good sense of humor in a creative sense as one whose creativity results in the production of humorous remarks, stories, jokes, plays, and so forth. Also, Murdock and Ganim (1993) compared theories of humor as related to creativity and found significant interrelationships. Finally, Torrance and Safter (1999) greatly believed that "humor, a sense of humor, and laughter are basically creative and are themselves facilitative of further creativity" (p. 222).

Treffinger, Isaken, and Firestein (1992) developed a model that included both cognitive and affective traits that are used in creative problem solving. The foundation level, often referred to as the first level of Treffinger's model, is based on divergent thinking processes which include the following cognitive skills: fluency, flexibility, originality, elaboration, and cognition and memory. Affective traits at this level include curiosity, willingness to respond, openness to experience, risk taking, problem sensitivity, tolerance for ambiguity, and self-confidence. The second level involves more complex thinking and feeling processes than the first level; it includes the following cognitive constructs: application, analysis, synthesis, evaluation, methodological and research skills, transformations, and metaphor and analogy. Affective dimensions in the second level include awareness development, openness to complex feelings and conflicts, relaxation, growth, values development, psychological safety in creating, fantasy, and imagery. The third level in Treffinger's model of creative learning allows the creative thinker to be involved in real challenges. Cognitive measures at this level include the following: independent inquiry, self-direction, resource management, product

development, and what Treffinger quoted as “the practicing professional.” Affective dimensions in this level include internalization of values, commitment to productive living, and self actualization (Treffinger, Isaksen, & Firestein, 1992).

Creativity Defined as a Process

Creative problem solving, as a discipline, was originated by Alex F. Osborn (1963) and further developed by Parnes (1967) and other members of the Creative Education Foundation (Torrance & Safter, 1999, p. 19). According to the Osborn and Parnes model, creative problem solving occurs in the following consecutive steps: (a) sensing problems and challenges, (b) recognizing the real problem, (c) producing alternative solutions, (d) evaluating ideas, and (e) preparing to put ideas into use.

The first step in the creative thinking process involves sensing problems and challenges. It simply implies that the problem solver becomes aware of a perplexing problem and recognizes it as a challenge (Torrance & Safter, 1999, p. 20). The second step involves recognizing the real problem. This step often involves searching for facts, difficulties and gaps, or puzzling situations. The first two steps are also referred to as the fact finding stages in the Osborn and Parnes model (Osborn, 1963, p. 86). The third step involves producing alternatives. During this stage the search for ideas and possible solutions to a problem are launched. Parnes (1967) and Osborn (1963) established four well known rules for this stage: (a) criticism is ruled out, which means that criticism is suspended during this stage, (b) free-wheeling is welcomed, meaning that the crazier the ideas the better, (c) quantity is wanted, meaning that the greater number of ideas, the greater the likelihood of successful ideas, and (d) combination and improvement are sought, meaning that individuals are encouraged to suggest how ideas from other peers

can be turned into better ones. The third step is also referred to as the idea finding stage in the Osborn and Parnes model. The fourth step involves evaluating ideas. Evaluating ideas generally occurs based on several factors such as cost, time required, usefulness, practicality, social acceptance, and other considerations (Torrance & Safter, 1999, p. 21). Osborn referred to the fourth step as the solution finding stage (Osborn, 1963, p. 86). Finally, the last step in Osborn and Parnes creative problem solving process is preparing ideas into use (Torrance, & Safter, 1999, p. 22). As Osborn (1963) mentioned, “A fair idea to use is better than an idea kept on the polishing wheel” (as cited in Parnes, 1967, p. 34).

Edward de Bono (1970; 1992) introduced the concept of lateral thinking in creative problem solving. His method has been distinguished by targeting on dominant ideas and searching for many ways of looking at the problem prior to finding alternative solutions (Torrance & Safter, 1999, p. 25). This concept was demonstrated in the CoRT (Cognitive Research Trust) program he developed where he described creative problem solving as a stepwise process. The first step involves targeting the dominant problem; the next step involves narrowing down the elaborated thinking to something useful such as conclusion, summary, main points, and choice. The third step involves making a decision. The fourth step is called the “total input” that goes into the thinking. The fifth step includes finding alternatives. Finally, the sixth step includes the implementation of the decision.

Smith (1967) also described creativity as a process. According to Smith (1967), creativity is usually enriched where several of the learning conditions are present. Examples of these conditions include the presence of an environment where a) divergent

thinking takes place, b) new ideas are developed, c) ideas are explored, d) self-criticism is constructively developed, e) the outcomes of the inquiries are unpredictable, f) open ended situations are utilized, g) ideas are explored and most importantly, and h) the creative process is as important as the product (p. 171).

Subsequent research was based on Smith‘s (1967) theory that the process in creativity is equally as important as the product (as cited in Clague, 1981). This study investigated how creativity was nurtured both as a process and as a group of constructs in an experiential learning environment.

Summary of the Review of Literature

Educators in the United States continue to seek good educational practices that can prepare students to function successfully in current industrial environments and meet society’s needs. Boyer (1990) emphasized the need to clarify campus missions and make the work of academia more related to the realities of contemporary life.

Given that agricultural education has been both hands-on and conceptual in purpose, design, and instruction (Knobloch, 2003), agricultural educators have called for models of teaching and learning that promote active student learning (Padron & Waxman, 1999). Experiential learning has been one of the most commonly used educational practices that supports active student learning (Cheek, Arrington, Carter, & Randell, 1994; Hughes & Barrick, 1993; Randell, Arrington, & Cheek, 1993).

One of the main aspects of experiential learning has been identified by Knobloch (2003) as problem solving. This educational practice has been of great interest to many

researchers and has triggered interest in exploring further associated learning environments such as team problem solving and creative problem solving.

Creativity has been identified as a key element in reaching high educational goals (Torrance, 1993). Therefore, agricultural educators continue to seek models of teaching and learning that encourage students to be more creative while solving complex problems in the world of agriculture. Examples of learning models of creative behavior include Treffinger et al., Smith, Osborn and Parnes, de Bono, Dacey, Jackson and Messick, and Torrance. This study focuses on analyzing the students' creative behavior based on these theoretical models.

Creative models which use a list of dimensions to analyze creativity were categorized as construct-based models for the purpose of this study. These include Torrance, Treffinger, Dacey, and Jackson and Messick models of creative behavior.

Creativity models which describe creativity as a stepwise process were categorized as process based models. In this study, the process-based models that were utilized were Osborn and Parnes Creative Problem Solving models. Since the Creative Problem Solving Model was initiated by Osborn (Osborn, 1963, p. 86) and further elaborated by Parnes (Parnes, 1967, p. 38) and both models were based on the same fundamental principles, the two models were considered as a single theoretical model and were referred to as the Osborn and Parnes process model *(OPPM)* in this study.

Table 3 provides a summary of all creativity models used in this study with their associated constructs or process steps.

Table 3

Summary of creativity models used in this study with their associated constructs or process steps

Torrance	Treffinger	Dacey	Jackson and Messick	Osborne and Parnes
Problem awareness	Sensitivity to problems/ Tolerance of ambiguity	Sensitivity to problems	-	Problem recognition
Ability to produce and consider many alternatives	Fluency / good research management and skills	Divergent thinking	-	Search for Alternatives
Ability to elaborate	Elaboration	Divergent thinking	-	Search for Alternatives
Flexibility	Flexibility	-	-	-
Originality	Originality/Risk taking	Use of self control when faced with any emotional disturbance while being original	Tolerance of incongruity	-
Ability to highlight the essence	-	-	-	-
Openness	Openness to experience	Open-mindedness	Open-mindedness	-
Being aware of emotions	-	-	-	-
Ability to put ideas into context	Cognition/memory/ analysis/ application	Convergent thinking	Analysis and intuition	Finding solutions
Combination and Synthesis	Synthesis/evaluation/product development	-	-	Finding solutions
Ability to visualize richly and colorfully	Commitment to productive living	Ability to view complex problems positively	-	-

Table 3 (continued)

Summary of creativity models used in this study with their associated constructs or process steps (continued)

Ability to enjoy work and use fantasy	-	-	-	-
Kinesthetic responsiveness	Willingness to respond	-	Reflection and spontaneity	-
Ability to look at things in different visual perspectives	Metaphor and analogy	Deep visualization	-	-
Internal visualization	Internalization of values	Questioning of status quo	-	-
Ability to break through the boundaries	Transformations	-	-	-
Ability to use humor	-	Playfulness	-	-
-	Curiosity/perseverance in seeking the truth	Perseverance	-	-
-	-	High degree Intelligence and imagination	-	-
-	Confidence/Independence in inquiry	Independence of other judgments/self guidance	-	-

CHAPTER III

METHODOLOGY

Research Procedures

This study used an agricultural and life sciences course as the setting for data collection. The course used semester-long design projects to teach students the engineering design process. Engineering design requires students to use various creative problem solving skills to obtain design solutions. The course allowed collecting various data and obtaining findings about how creativity was nurtured among the students while they were conducting their project designs. The researcher was used as the human instrument in the study (Lincoln & Guba, 1985, p. 156). The study sample was 14 participants who consisted of mostly incoming freshmen, with the rest being sophomores, juniors, and transfer students. Students were both males and females with a majority being White and a minority being either Hispanic or African American. Participants were coded based on the group they were assigned by topic interest area. Participants were coded using the group name which they belonged and a random number (C, E, F, and H). Further details about the course content and participants are fully described in Chapter IV.

Qualitative approaches were used while observing students and analyzing their work in four distinct settings, which allowed gathering information from four different sources. This process has been referred to by Lincoln and Guba (1985) as data triangulation. The first approach involved observing the students' interactions among

themselves and with their class facilitators during a prolonged period of 6 weeks. The second approach involved collecting data during focus group interviews with the students and transcribing their statements. The third approach consisted of gathering documented answers to specific questions that were used as follow up to the focus group interview activity. The fourth approach involved assessing students' portfolios presented to their professor as written reports of their final projects at the end of the course period.

Data analysis of all four sources (field notes, focus group interview, questionnaire and portfolios) was based on Miles and Huberman's (1994) flow analysis model. The data analyses consisted of three concurrent flows of activity: data reduction, data display, and conclusion drawing and verification (Miles & Huberman, 1994, p. 10).

Data reduction and display were performed by evaluating the existence of various creativity constructs based on the Torrance's, Treffinger's, Dacey's, Jackson and Messick's, and Osborn and Parnes' creativity models. Strauss (1987) recommended researchers use sociological constructs based on the researcher's scholarly knowledge and knowledge of the field under investigation. This concept was utilized while the researcher used creativity literature as the sociological construct and coding scheme to reach beyond local meanings to broader social scientific ones (Berg, 2001).

Conclusion drawing and verification were performed by conducting a peer debriefing session with a creativity expert and an interview with the course instructor to verify study context and findings. The interview conducted with the course instructor allowed verification of course content and students' performance on their projects from a creativity perspective. The peer debriefing session conducted with the creativity expert allowed confirmation of the students' creative performances in their portfolios. The

course instructor was coded X1 while the creativity expert was referred to as Z1 in this study.

Table 4 includes a list of all creativity dimensions that will be referred to in this study with their associated coding scheme.

In order to establish trustworthiness (Lincoln & Guba, 1985, p. 290) in the data collection, processing, and interpretation, four measures were established: (a) credibility, (b) transferability, (c) dependability, and (d) confirmability.

Credibility of the study was enhanced by data triangulation, prolonged engagement, persistent observation, referential adequacy, and peer debriefing (Lincoln & Guba, 1985, p. 328).

Data triangulation was implemented (Lincoln & Guba, 1985, p. 283) while using the four different sources to gather data: focus group interviews, the researcher's documented observations of the students' actions and statements, student portfolios, and documented answers from a student survey.

Observing the students during an extended period of time allowed for prolonged engagement in the study.

Persistent observations were assured throughout the research period while the students were involved in their in-class activities.

Referential adequacy (Lincoln & Guba, 1985, p. 283) was assured by recording and transcribing the focus group interviews. Finally, peer debriefing sessions were conducted to gather information about teaching practices, course context, and evaluation of creativity among student participants in the study.

Table 4

Coding scheme for various creativity constructs according to process and construct-based creativity models

Torrance	Treffinger	Dacey	Jackson and Messick	Osborne and Parnes	Coding Scheme
Problem awareness	Sensitivity to problems/ Tolerance of ambiguity	Sensitivity to problems	-	Problem recognition	Problem awareness
Ability to produce and consider many alternatives	Fluency / good research management and skills	Divergent thinking	-	Search for Alternatives	Divergent thinking
Ability to elaborate	Elaboration	Divergent thinking	-	Search for Alternatives	Divergent thinking
Flexibility	Flexibility	-	-	-	Flexibility
Originality	Originality/Risk taking	Use of self control when faced with any emotional disturbance while being original	Tolerance of incongruity	-	Originality
Ability to highlight the essence	-	-	-	-	Ability to highlight the essence
Openness	Openness to experience	Open-mindedness	Open-mindedness	-	Openness
Being aware of emotions	-	-	-	-	Being aware of emotions
Ability to put ideas into context	Cognition/memory/ analysis/ application	Convergent thinking	Analysis and intuition	Finding solutions	Convergent thinking
Combination and Synthesis	Synthesis/evaluation/product development	-	-	Finding solutions	Convergent thinking

Table 4 (continued)

Coding scheme for various creativity constructs according to process and construct-based creativity models

Ability to visualize richly and colorfully	Commitment to productive living	Ability to view complex problems positively	-	-	Positive thinking
Ability to visualize richly and colorfully	Commitment to productive living	Ability to view complex problems positively	-	-	Positive thinking
Ability to enjoy work and use fantasy	-	-	-	-	Fantasy
Kinesthetic responsiveness	Wiliness to respond	-	Reflection and spontaneity	-	Reflection
Ability to look at things in different visual perspectives	Metaphor and analogy	Deep visualization	-	-	High visualization skills
Internal visualization	Internalization of values	Questioning of status quo	-	-	Internal visualization
Ability to break through the boundaries	Transformations	-	-	-	Ability to break through the boundaries
Ability to use humor	-	Playfulness	-	-	Ability to use humor
-	Curiosity/perseverance in seeking the truth	Perseverance	-	-	Perseverance
-	-	High degree Intelligence and imagination	-	-	Intelligence
-	Confidence/Independence in inquiry	Independence of other judgments/self guidance	-	-	Confidence

A peer debriefing (Lincoln & Guba, 1985, p. 283) and interview session was conducted with the professor (X1) who was teaching the course. The session allowed for verifying information about the course context, teaching philosophy, and teaching practices. Another peer debriefing session was conducted with a creativity expert (Z1) who assisted in evaluating the students' portfolios from a creativity standpoint.

Transferability (Lincoln & Guba, 1985, p. 124) was established by providing descriptive details about assumptions made to complete the research, research context, data analysis procedures, and the evaluation tools that supported the research findings.

Dependability (Lincoln & Guba, 1985, p. 219) was established by the researcher through descriptions of her interpretations of the data by providing raw data, coding and auditing feedback, and describing data analyses and findings while allowing others interested in the study to draw conclusions.

Confirmability (Lincoln & Guba, 1985, p. 319) was established by conducting an audit trail for labeling traits and coding the participants. The researcher used the audit trail to systemize, relate, cross-reference, and prioritize data.

At the beginning of the course, students were informed that a study was going to be conducted using focus group interviews, observations in class activities, and follow up surveys. The students were given an informed consent and reminded that the focus group interviews would be recorded and kept confidential (Appendix A).

The following sections explain how data were collected, analyzed, and reduced from the researcher's field notes, focus interviews, questionnaires, and portfolios.

Part 1: Observations during In-class Activities

Data Collection

The data collection process for this stage was based on the researcher's written observations while attending 6 class sessions where the students were actively involved in their team projects. Each session lasted for 50 minutes. The first activity involved developing an appropriate problem definition to their design project. In the second activity, the students were required to write as many key words as they could to help them look for research articles, books, manuals or journals relevant to their research areas. The third activity involved finding five different research topics to research and two distinct resources where they could acquire their information. In the fourth activity, the students were instructed to find 25 different alternatives to their design projects. The fifth activity required the students to form an alternative matrix to rank their choices and make some final decisions about what the best alternatives might be for their final designs. Finally, during the sixth session, the students were instructed to use the computer lab to start designing their project presentations in Power Point.

The investigator wrote notes throughout these sessions about her observations of the students based on several factors. These included: (a) the students' interactions with their team members, senior leader and instructor, (b) their confidence in generating ideas, (c) risk taking in voicing opinions, (d) frequency of asking assistance from the senior leader and instructor, (e) the way they shared information among themselves, and (f) their discussions and arguments to finalize decisions.

Data Analysis

The researcher was constantly seeking a list of specific traits that were emerging during these observation sessions. As an example, some sessions required the students to generate a significant number of ideas. This was a great opportunity for the researcher to observe how the teams were elaborating on their ideas and how they were sharing ideas among themselves to maximize the number of alternatives they could obtain for their designs. Results of the analysis will be provided in Chapter IV.

Part 2: Focus Group Interviews

Data Collection

A focus group interview can be defined as an interview style designed for small groups. “Focus group interviews also provide a means for collecting qualitative data in some settings and situations where a one-shot collection is necessary” (Berg, 2001, p. 111).

A total of 14 students participated in the focus group interviews and the survey that was collected at the end of the interview session (duration of 1.5 hours). Prior to the interview, the 14 students were divided into 2 different groups (7 students in each group) and were assigned an individual interviewer per group. Interviewers included the researcher and another doctoral student in the Department of Agricultural Leadership, Education, and Communications at Texas A&M University.

The 14 students were sampled from a total population of 54 students that were enrolled in the Biological and Agricultural Engineering introductory course during the Fall of 2004. The course was divided into two sections that met twice a week and all 14

students were selected from the same section which was comprised mainly of volunteers who chose to participate in the study.

Krueger (1994) suggests that for complex problems focus group size should be kept to no more than about seven participants. Also, Berg (2001) recommended the use of a moderator's guide for focus interviews, and this tool was especially valuable to this study because the focus group interviews were conducted by 2 interviewers. The moderator guide (Appendix B) was used for consistency in the interview method. A summary outline of the moderator's guide that was used included the following items: (a) introduction, (b) statement of the basic guidelines for the interview, (c) short question-and-answer discussions, (d) special exercise (survey), and (e) guidance for dealing with sensitive issues.

Both interviewers implemented the same moderator guide and the interviews were immediately transcribed by the researcher after they have been audio-recorded by both interviewers. The researcher assured that all data were analyzed using the same human instrument (which was the researcher herself) to assure consistency in data analyses and interpretations.

Introduction

During this process, the researcher introduced herself to the subjects, allowed them to introduce themselves, and then explained what the project was seeking and how focus groups operate in general. The investigator also assured confidentiality, notified respondents that the interviews were going to be recorded, and asked the respondents if they understood the project and their role in this specific research.

Statement of the Basic Guidelines for the Interview

The moderator reminded the respondents that everyone may have different opinions or answers to the questions even if they belonged to the same team and that she wanted to hear all opinions. The subjects were reminded that the moderator would be asking different questions to the full group that could be answered by anyone, and not in a particular order.

Short Question and Answer Discussion

In most focus groups, a short series of discussions are "sparked" with a series of questions asked by the moderator (Krueger, 1994). A script of questions was used to initiate discussions (Appendix C).

Special Exercise

A special activity was introduced at the end of the focus group interview. Fourteen students completed a questionnaire during this segment of data collection (note that this data collection procedure is detailed in part three of this chapter).

Guidance for Dealing with Sensitive Issues

Given the fact that some students were less involved than others in their teams during the course period, the last question in the interview addressed this issue. The interviewer gave the option for all respondents to write any question they preferred on paper in case they did not feel comfortable saying it in front of the group.

Data Analysis

Data analysis for the focus group interviews was conducted by implementing the first two steps of Miles and Huberman's flow model (Miles & Huberman, 1994, p. 10) as described in the following three steps:

- All respondents' unique answers or statements were recorded on index cards (data reduction).
- Content in cards was coded to ensure confidentiality and to assist with the audit trail (data reduction).
- All unique answers were identified as independent units, and then were clustered into categories at the second stage of this analysis. For example, a statement from a respondent as such: "I enjoy listening to others because different team members have different opinion" was categorized under a category called: "Openness" (data reduction and data display).

Part 3: Student Questionnaire

Data Collection

A questionnaire (Appendix D) was distributed to the students who participated in the focus group interviews (E6, E4, E2, C2, C1, H1, H2, E3, C3, F2, F1, H3, F3, F4) at the end of the activity. This served as further triangulation of the focus group data.

Data Analysis

As an initial step, all students' responses were entered into a spreadsheet based on which answers they chose. These responses included descriptive and key statements that allowed the researcher to extract which creativity constructs emerged. Responses to all

questionnaire questions were assigned a specific code (example 2A in Appendix E). Percentages of responses describing emergent creativity dimensions were calculated and were also included in Appendix E. The following section describes how all 24 questions were analyzed.

In the first two questions of the questionnaire, the students were asked to describe how they proceeded with thinking about the given problem and especially whether they were confident enough to think about the issue independently without using other team members or senior leader's inputs. No creative thinking is likely to occur unless there is a commitment to deal with it (Torrance, & Safter, 1999). Also, Dacey (1985) indicated that creative individuals are more independent of the judgment of others. If the students think about the problem first prior to consulting with others, this would be a good indicator that they are independent thinkers. This trait has also been described as self-directedness (Treffinger et al., 1992). In general, the main purpose of the two questions was to evaluate whether the students could think independently in approaching real world problems both in a classroom environment and in their professional life.

Questions three, four, five, six, and seven evaluated the students' ability to organize thoughts using various creative thinking tools such as brainstorming and check listing (Osborn, 1963) in order to generate alternatives. It is known that the more alternatives a person of group of people produce and consider, the greater the likelihood of success in problems solving (Parnes, 1967). In question three, the students were asked to describe the source of their design alternatives; whether it was from other peers, electronic or paper resources, or based on discussions with the senior leader or the professor. Question four involved asking them if their method of searching for

alternatives changed after taking this course. The main purpose of question three was to evaluate how the students searched for alternatives using available and easily accessed resources such as senior leader or professor's inputs or based on thorough research in electronic and paper resources and which would allow for more reflective thinking. Ability of students to face ambiguities and extend their search for alternatives through electronic and paper resources could be a good indicator of creativity. Their search for immediate answers from their senior leaders or professor was considered as an indicator for search for immediate answers and was interpreted as non-creative thinking. The purpose of question four was to determine whether the students acquired the quality of being able to face ambiguities while finding alternatives was improved by taking this course.

Questions five, six, and seven investigated which creative thinking tools were implemented to organize thoughts and alternatives. These included techniques such as diagrams, brain writing, and brainstorming. These creative thinking techniques are often associated with the student's temptations to elaborate in a specific subject, and which has been quoted by Torrance and Safter (1999) as elaboration. Questions five and six investigated whether the students were familiar with any of these techniques or acquired them while enrolled in the engineering design course, and whether they used them individually or in groups.

Questions eight and nine investigated how the students evaluated their alternatives and finalized their solutions. According to Dacey (1985), creative thinkers are able to think both convergently, which means that they are capable of solving problems that have

only one correct answer, and divergently, which means that they are capable of solving problems that have many possible answers.

Question 10 investigated whether the students rushed into quick answers or took time to think about the problem and find alternatives and possible solutions by seeking both paper and online resources rather than rushing into using what is available in online resources. Students were asked how often they used online resources in the course. Students who seek knowledge beyond what is available are characterized by Torrance also as "beyonders" given the fact that they have the ability to extend boundaries while searching for facts and overlook the obvious (Torrance & Safter, 1999, p. 214).

Questions 11, 12, 13, and 14 investigated how confident the students were in generating ideas while compiling their design alternatives and choosing their final design after taking this course. Treffinger (1992) considered confidence as one of the major affective traits of creative individuals. The intent of the questions was to determine whether confidence was acquired while solving their design problems through various in-class activities as well as their interactions with their peers and senior leaders.

Questions 15 through 20 investigated students' openness to listening and exchanging information with their peers, senior leaders, and professor. Psychological openness is considered to be one of main traits of creative people (Rogers, 1979). The questions also investigated whether openness was gained during the course period.

Questions 21 through 24 investigated whether the students acquired oral and written communication skills during the course. The ability to communicate effectively is one of the main indicators of reflection and spontaneity, which Jackson and Messick (1965) considered a main trait among creative individuals.

Part 4: Students' Portfolios

Data Collection

Student portfolios were collected and labeled by team participation and individual respondent numbers. For example, participants F1, F2, F3, and F4 were responsible for completion of the project labeled F1234.

Data Analysis

Analysis of portfolios was based on indications of use of both construct and process-based creativity dimensions while describing final designs in the project reports. A creativity assessment was also included based on a peer debriefing session and interview conducted with a creativity expert (Z1).

In the next chapter, results of the field observation, focus group interviews, questionnaire, and student portfolios will be described.

CHAPTER IV

RESULTS

Introduction

All data were interpreted based on both construct-based creativity models (Torrance & Safter, 1999; Treffinger, 1992; Dacey, 1985; Jaskson & Messick, 1965) and process-based models (Parnes, 1975; Osborn, 1963) for creative behavior.

Results of the study were clustered into four sections: description of field notes produced by observing the students during various classroom activities, focus group interviews results, questionnaire responses, and portfolio assessments.

Course Context

The course that was used for the study has been a required course for students in the Biological and Agricultural Engineering Department at Texas A&M University. Students enrolled in this course meet twice a week, one hour for lecture and a second hour for recitation.

The freshman design course used semester-long design projects to teach the engineering design process. Students worked on these projects in teams of three or four. The course usually includes 40 to 50 students. Therefore, the students are divided in two different sections of the course. While most of the students are incoming freshmen, the course also includes 30 to 40 percent sophomores, juniors and transfer students. The overall student population with all academic classifications (freshmen, sophomore, junior

and transfers) generally comprises both males and females with the majority being White (usually more than 80 percent of the population) and the minority being either Hispanic or African American.

The Department of Biological and Agricultural Engineering at Texas A&M University offers design-focused courses for senior engineering students also. The senior design courses are equivalent in context to the freshman design course used in this study, and were quoted to be to the curriculum's capstone design experience (Kenimer & Lacey, 2003). Seniors work in teams on a design project suggested by industry clients. Many of these same projects are used in the freshman-level course. Seniors that are enrolled in the upper level design course also assume the role of "senior leaders" and serve as facilitators for the students enrolled in the freshmen level design course. Besides being enrolled in the senior design course, senior leaders are required to attend a weekly session in the freshmen design course to answer questions that the freshmen may have about their design projects or the design process. Senior leaders also play the role of mediators in case team members experience any conflicts (Kenimer & Lacey, 2003).

Course Objectives

The primary educational objectives for the freshman design course, as described by the course professor (X1), were to provide the students with a working knowledge of the engineering design process, get them acquainted with design problems typical to real world problems, give them the opportunity to gain experience with learning, and maximizing communication between them and the professor. Additional outcomes included getting the students excited about the discipline to maximize student retention,

providing them with a learning community experience early in their undergraduate education, initiating a sense of camaraderie among students within the same major, and finally, introducing them to math and science concepts they cover during the first two years of college.

Human Instrument

The researcher was a doctoral student in the Department of Agricultural Leadership, Education and Communications and had taken the same freshman design course used in the study 7 years before during her Bachelors Degree which was in Biological and Agricultural Engineering. During her Masters program (also conducted in the Department of Biological and Agricultural Engineering), the researcher also served as a teaching assistant for the course. For this qualitative study, the researcher as the human instrument collected, analyzed, and interpreted all data.

The researcher's prior knowledge and experience with the course content (and the problem solving activities the students had to perform) enhanced the data collection process. The researcher's familiarity with the student creative thinking activities allowed her to prepare a preliminary list of possible creative thinking dimensions that the students might exhibit during each course activity. Hence, the researcher's prior experience played a key role in the research design and collection procedures. Additionally, being familiar with the professor and course expectations helped the researcher identify the artifacts for data triangulation (ex: student portfolios, interactions among themselves, interactions with the professor/senior leader, in-class activities).

Project Contents

All projects provided to the students in this course were retrieved from design projects that are similar to those offered at the senior level. The professor selects only the projects that are conceptual and does not offer any design problems that are quantitative or require advanced knowledge in math and science. All selected projects are solicited from professionals in the industry and on-going projects outside the College and Agriculture and Life Sciences research group. Students are given several topics to choose from at the beginning of the semester. Project teams are formed based on which class section the students are in and also their project topic preferences.

Teaching Philosophy

The teaching philosophy used in this particular classroom environment can be described in the following quote written by the course professor (X1):

> I adore teaching. I take great personal satisfaction in seeing a student grow interested in a subject and take control of their own learning. I believe teaching extends beyond simple transmission of knowledge from instructor to student. My teaching should spark student curiosity and foster a desire to genuinely comprehend the material. To achieve this, I provide challenging, relevant material in an interactive, open classroom environment. I employ several specific methods to achieve my desired objectives including setting teaching goals that span all of my courses, defining roles and responsibilities for me as instructor and for my students, and continuously improving my courses and pedagogy and sharing my strategies with others.

I am to provide current and pertinent information to students with a basis in fundamental principles. Rather than viewing teaching as providing students with new information, I strive to help them expand and deepen the knowledge they already have.

I believe students should be required to reach beyond simple recitation and repetition of course topics. Problems using higher-order thinking skills such as synthesis, critical evaluations, and design, require students to develop a more thorough understanding of course material. While students are not always comfortable or happy with such assignments, I believe these projects help students retain information beyond the end of the semester and to effectively deal with problems they will likely face when entering the work force.

I believe I must help students become effective self-learners. With only 127-128 credit hours in our departmental curricula, we cannot fully prepare students for every pathway they could potentially take following graduation. It is essential that our graduates be able to identify their knowledge gaps, locate and evaluate appropriate sources of information, and have sufficient grounding in fundamentals to understand and use what they learn on their own.

I try to maintain a light-hearted yet businesslike classroom atmosphere. I enjoy joking around with students, but I balance this fun attitude by stretching students with challenging material and problems. I move aggressively through course topics, yet I feel it is important to provide adequate background and reference information so students will genuinely understand the concepts. I take time to

solicit questions from students and I strive to provide respectful, accurate responses (X1).

Description of Study Sample

The total population in the design class was composed of 54 students with different academic classifications, ethnicity, and gender backgrounds as indicated in Tables 5, 6, and 7. Volunteers from the class who participated in the study were representative of the class population. The study sample was composed of 14 students which formed 4 different project teams that were enrolled in the College of Agriculture and Life Sciences course in the fall of 2004.

Table 5
Gender distribution in the design and study samples

	Gender	
	η of females	η of males
Students in the design class	4	50
Students in the study sample	1	13

Table 6
Classification of student participants in the design and study samples

	Classification			
Students	η of freshmen	η of sophomores	η of juniors	Others
Design class	36	11	7	0
Study sample	9	3	2	0

Table7
Ethnicity distribution in the design and study samples

	Ethnicity			
Students	η of Hispanic	η of White	η of African American	Others
Design class	5	48	1	0
Study sample	2	12	0	0

Participants were constantly engaged in problem solving activities which allowed them to utilize various creative thinking skills.

Part 1: Field Observation Results

The overall intent from conducting observation sessions in the course was to get a feel for how the students in general interacted among themselves, how they approached the given design problems and how they proceeded with solving those problems as groups.

Most results reported in this part were in the form of field notes collected by the researcher while observing the students in a six week period during the fall semester of the academic year. During this data collection process, five main criteria were particularly observed: students' awareness of the problem presented to them by the instructor, their interaction with the senior leader and the instructor, the way they generated ideas, the way they worked collaboratively with others, and their confidence in risk taking while producing final decisions about individual class activities.

Session 1

During this session, the students were asked to provide a problem statement to their design project in a real life situation.

Overall, most group members were highly aware and eager to find out from the instructor what was expected from them. At the beginning of the new semester, attention was given to the senior leaders and their opinions. At that point, no particular creativity trait was identified since the students were getting familiar with their teammates and the classroom environment, getting acquainted with the role of a senior leader as a facilitator, and to this project/ team-based environment.

Session 2

During this session, the students were instructed to find different topics to research, and most senior leaders provided students with key words they could use to find relevant literature for their topics. The instructor made rounds and discussed ideas with the seven teams. The instructor mainly played a role of listener to the students' suggestions. The senior leaders were slightly more involved in this session and initiated ideas about which types of relevant key words might be appropriate to include in the search for literature. The students were sharing thoughts and verifying whether they were researching the appropriate topics that would be relevant to their designs. Only a few students in this session did not participate in group discussions. Overall, the students were more open to listen and share ideas with their teammates as well as with the senior leader than during the previous session.

Session 3

The objective of this session was to give the students the opportunity to finalize their research topics by producing five main subjects to research as well as defining two different resources to acquire their information. For the first time, I noticed that the senior leaders were involved only in delegating the roles in most cases and were mainly in charge of recording the ideas their teams suggested. Hence, I saw more interactions between team members, and four out of the seven teams had individuals who were deeply discussing research topics. They were commenting: “I do not think this will give us the flexibility to do...” and “what if we use the other alternative….”

Having said this, I noticed that the students were getting more involved and comfortable discussing topics and asking for clarifications among themselves without involving either the instructor or the senior leader directly in most cases.

Session 4

This session was one of the most interesting sessions the researcher attended. The students were instructed to use brainstorming techniques and come up with 25 different ideas related to their design project. Some groups seemed very quiet and busy thinking individually at the beginning, but a few minutes later, all the groups were involved and shared ideas. I noticed that there was some sense of humor used on some occasions. Generally speaking, most groups found their ideas quickly until they got to between 16 and 20 ideas, and then I noticed slow reactions for generating ideas. In general, the students seemed to be more confident and open to expressing their ideas than in the first session. The students were discussing their thoughts while providing strong arguments

about their design ideas with the professor and their senior leaders rather than asking questions about the validity of their choices.

Session 5

During this session, the students were tasked to complete an alternative matrix where they had to include all their alternatives, rank them, then decide which alternatives they should include in their final design project. I did notice that the students were synthesizing and sharing valuable discussions and decisions at this level with their senior leaders and course professor by justifying their rating for the best alternatives. Specific examples of arguments different teams communicated with the professor and senior leaders to justify their selection of best design alternatives were also reported in the student portfolios and will be listed in details in part 4) of this chapter.

Session 6

During this session, the senior leaders' involvement was minimal. Most senior leaders left the teamwork in the middle of the session since the students were mainly working in the computer lab preparing their project presentations. They were definitely communicating among themselves constantly while deciding how to present their material. The researcher did not get the chance to observe the students' interactions as most material topics were already defined and the team members only discussed their presentations.

Summary of All Six Field Observations

It is clear that all previously listed in-class activities created a dynamic research atmosphere that allowed the investigator to observe the students' acts and statements while sharing information with their peers, instructor, or the student leader, who was

referred to as senior leader. Senior leaders played the role of facilitators in this course as they had more experience academically and were working on more complex design projects in their senior year of college.

After observing the students during these six experiential-based learning sessions, the researcher identified five distinct constructs that emerged while the students were conducting their inclass activities:

(a) Divergent thinking

This construct was utilized while students were generating their alternative matrices and during the brainstorming session.

(b) Openness

The observer noticed that the students were improving this trait throughout the sessions as they were discussing more issues among themselves.

(c) Confidence

The observer noticed that the students were becoming more self directed from session to session and required less involvement from their senior leaders. This trait was observed while students were generating their ideas during the brainstorming session as well as discussing their “preferred” design alternative to be included in the final design.

(d) Humor

This trait was observed while the students were discussing their 25 design alternatives. The researcher noticed the use of some sense of humor while the students were exchanging ideas with their teammates.

(e) Convergent Thinking

This trait was observed during session 5 while the students were ranking their alternatives using decision matrices and delimiting their final solutions.

Part 2: Focus Group Interview Results

A list of questions that was provided to the students in the focus group interviews is available in Appendix B.

As a result of implementing Miles and Huberman's (1994) flow model data analysis, all student comments were transferred into index cards and then were categorized into five distinct emergent themes: convergent thinking, divergent thinking, openness, humor, and confidence (note these constructs were the same as those observed in part 1).

Divergent Thinking

The ability to generate alternatives and elaboration (Torrance & Safter, 1999; Parnes, 1967; Osborn, 1963), also described by Treffinger (1992) as the fluency to generate ideas (Treffinger, 1992), and by the ability to think divergently by Dacey (1985) were observed while the students were given an in class activity which required them to generate 25 alternative solutions to their assigned problems.

These traits were expressed while they were describing their design components and adding new ideas to their final design projects. One of the respondents commented: "For our design, we used Auto Cad and found pictures on the Internet, kind of mixed and matched and developed what we wanted it to be" (E4). This statement was also considered as a good indicator for ability to combine and synthesize and was noted as

present in two categories: elaboration, synthesis and combination. The same respondent indicated that his team used several resources to reduce the alternatives to a single design.

Another respondent was more explicit in stating a creative problem solving technique used in elaboration which was brainstorming (Osborn, 1983): “We brainstormed bad and good ideas” (E4). In some situations, branching was also utilized: “After 18 ideas, we got stuck so we tried forming new ideas off the ones we previously had” (C2). Another participant stated: “We had to think outside the box” (F1). Respondent (F2) indicated that his project was divided into major components; therefore, working in group helped his team generate more ideas. Respondent H1 indicated that working in groups help generate more ideas as long as the team members were accepting to each other’s ideas. This concept has been referred to by Torrance as psychological openness (Torrance, & Safter, 1999, p. 117).

Openness

One of the most commonly accepted characteristics of the creative person is psychological openness (Rogers, 1979, Torrance & Safter, 1999). Dacey (1985) characterized open minded individuals as those who are open to experience and less defensive about accepting new information. Jackson and Messick (1965) characterized open individuals by the ones who are flexible.

This trait was described by students in regard to how they interacted with each other and shared ideas among themselves. One of the respondents quoted: “We had ideas; we got along really easily, with several ideas without having much conflict” (F4). Another respondent commented: “What helped our project is the fact that we were from diverse backgrounds to know different aspects of the project” (E6). The same respondent

was pleased to have the opportunity to receive comments and critiques from other classmates during his class presentation and claimed: “I liked the questions from peers during the presentations” and felt this had a great impact on improving his team’s final design project. Also, the same respondent admitted he is normally quiet and is hesitant about sharing ideas and that this experiential based learning environment helped him improve his openness and share ideas (E6). Another respondent (E3) added to the previous comment that group work usually helps students that are quiet get more involved and exchange more ideas with the group. Respondent F1 indicated that if the students had to do the projects individually, the quality of the outcome would have been lower. Respondent H1 indicated that their group members were hesitant to exchange ideas at the beginning of the semester and that their openness to each other had improved throughout the semester. The same comment was supported by respondent F2 who indicated that his group “took a couple of weeks to get comfortable to each other.” Respondent F1 also admitted that if he had to do the project individually, the quality of the outcome would have been lower. Finally, respondent C1 commented that none of his team members had problems working in the team.

Convergent Thinking

Parnes (1975) has mentioned that the essence of the concept of creativity is the notion of the “aha”–meaning the relevant association of thoughts, facts, and ideas into a new figure, which provides a synergistic effect (Torrance & Safter, 1999). Synthesis was identified by Treffinger (1992) as one of the main cognitive traits of creative behavior.

Different attributes of synthesis were identified using different word indicators such as picked, constraint, alternative matrix, rank, best and solution. One respondent

quoted: “We used the matrix to know which idea was best” (E4). Another respondent commented: “After brainstorming we picked the best brainstorms” (E3). Respondent E2 indicated that using the matrix helped his team justify which ideas were best for their design. In some cases, the same concept was expressed by several respondents. For example, one respondent stated: “Everybody had a certain idea and we worked together to form the best possible solution” (F2). Respondent F3 indicated his group selected the best idea based on the constraints they specified. Another respondent indicated that one of the main advantages of the matrix is that it helped his team to rank the ideas.

The ability to associate thoughts, facts, and ideas and develop new concepts or configurations has been referred to as the ability to combine and synthesize and was also defined by many creativity scholars as a major creativity trait (Parnes, 1975, Torrance & Safter, 1999). The use of combination and synthesis was also indicated by one of the team members while stating: “ For our design, we used Auto Cad and found pictures on the internet, kind of mixed and matched and developed what we wanted it to be” (E4).

Confidence

Confidence was characterized by Treffinger (1992) as one of the main affective traits of creative individuals. Dacey (1985) described confident individuals as the ones who are likely “to stand in their ground in the face of criticism.” Self-direction was also characterized by Treffinger (1992) as one of the major cognitive traits in creative behavior and was described by Dacey (1985) by the characteristic of being independent of judgment of others. The most predominantly used indicators to identify confidence in the focus group interview analysis were the following expressions: “…felt very confident,” “never had to ask questions,” and “…was confident.” One of the respondents

said: “whether the idea worked or not I was confident in voicing my opinion” (E2). Another respondent quoted: “I was confident because the teacher indicated that even the craziest ideas can turn out to be good ones” (F2). This concept “of using crazy ideas” has been referred to by Torrance as the ability to use fantasy as a trait of creativity (Torrance, 1999). Respondent C1 indicated that his team never had to ask the professor many questions. Presence of confidence was also extracted from the following statement: “My team felt very confident with the help of the senior leader” (E3).

Humor

Only a single statement was extracted from the focus interview about the ability to use humor: Respondent E6 quoted: “We got a number of ideas that were just crazy…and which turned out to be good ones”. Dacey (1985) also indicated that creative individuals tend to enjoy being playful and childlike and have the ability to “toy” with the environment. Therefore, producing “crazy” ideas as respondent E6 quoted is rather a positive step toward improving creativity.

Table 8 provides a detailed summary of focus group interview results based on several creativity constructs distributed among students.

Table 8

Creativity traits among students

Creativity construct	Respondents acquiring the trait
Divergent thinking	E4/C2/F1/F2/H1
Convergent thinking	E4/E3/E2/F2/F3
Confidence	E2/F2/C1/E3
Openness	F4/E6/E3/F1/H1/F2/F1/C1
Humor	E6

Part 3: Questionnaire Results

Results of the student questionnaire (Appendix D) were used to identify any creativity traits that the students utilized or improved during this study. Several sets of questions were prepared in such a way that would allow students to express different feelings while being exposed to an experiential learning environment.

Some questions assessed their feelings about working in a group, others concerned strategies they used to generate and evaluate alternatives for their final design projects. All questions with their associated feedback from the students are provided in Appendix E.

Results of the student answers can be summarized as follows:

- In response to question one and two, most students indicated that they prefer thinking about the problem statement independently prior to discussing it with other members. Therefore, independent thinking was identified as the emergent theme categorized as confidence.
- In response to question three, four, five, six, seven, eight and nine, most students claimed that they organized their thoughts using creative thinking tools such as SCAMPER, brainstorming, and check listing in order to generate ideas and exchange information with their teammates, then assessed their ideas against their design objectives before drawing conclusions about the alternatives. The students also used both convergent (ex: matrix for searching for final solutions) and divergent thinking tools (ex: SCAMPER) through the course. Therefore, both divergent and convergent thinking were identified as emergent constructs.

- In response to question 10, most students indicated that they used several online educational tools to learn about their topics. This was interpreted as seeking commercially available designs that were similar to their projects in order to minimize cost and improve what is already in the market vs. working on reproducing designs that already existed. The students focused on improving existing designs which then allowed them to extend boundaries and improve various systems to obtain workable designs, which were unique and original. This analysis was confirmed following a peer debriefing session with the professor teaching the course. Students who indicated the use of existing sketches and sought ways to improve and modify them were classified as having the ability to extend boundaries.
- In response to questions 11 through 14, most students indicated that they were confident selecting a single alternative (convergent thinking) for their design problems. Also, while most students indicated that they were confident in selecting several alternatives for their designs (divergent thinking), the majority also indicated that in the professional life they would feel “very confident in generating alternatives. “Therefore, confidence was identified as one of the emergent themes among students.
- In response to questions 15 through 20, most students indicated that they felt comfortable working with teammates and that they felt comfortable discussing subjects with their team leaders and professor. Most students also emphasized that they preferred working in a group, which was a strong indicator of openness.

- In response to questions 21 through 24, most students identified themselves as having average oral communication skills prior to taking the course. They also indicated that they acquired good communication skills after taking the course. Most students also indicated that they had good written communication skills both prior and after taking the course. Good communication skills were associated with student spontaneity in communicating results and were categorized under the reflection theme.

Questionnaire results indicated that the most predominant creativity traits that emerged were: divergent thinking, convergent thinking, confidence, openness, ability to extend boundaries, and reflection (Treffinger, 1992; Torrance & Safter, 1999; Treffinger, 1992; Dacey, 1985; Jackson & Messick, 1965).

Appendix E includes calculated percentages of all emergent creativity constructs that emerged in the questionnaire.

Part 4: Portfolios' Results

The following section contains a full description of the students' final designs as they were presented in their final reports upon completion of their projects at the end of the course period. Results of the analysis of the project reports indicated that all students used the four steps of Osborn's (1963) and Parnes' (1967) creative problem solving process.

Each project report included an introductory paragraph with a thorough description about the design problems. Results of the analysis of this section of the reports demonstrated that all students truly sensed and recognized the problems posed

(phases one and two of the Osborn (1963) and Parnes (1967) creative problem process (*OPCPSP*). This concept corresponds to the coding scheme referred to as problem awareness in this study. All reports also included full sections describing various criteria and methods the students used to produce their design alternatives. Each team demonstrated fluency and ability to "break though the box" while compiling various alternatives (phase 3 of the *OPCPSP*). This concept corresponds to the coding scheme referred to as divergent thinking in this study. Final design solutions were based on design alternatives the students classified and rated in decision matrices. All students reports included justifications on how final solutions were selected based on rated alternatives in the decision matrices. Selecting final solutions constitutes phase 4 of the *OPCPSP*. This concept corresponds to the coding scheme referred to as convergent thinking in this study. Finally, all students' designs were characterized by the creativity expert (Z1) as being unique. Hence, originality was identified as being one of the major emergent constructs in the portfolios. A summary of each project with *OPCPSP* phases identified are included in the next sections.

Land Remediation and Equipment Wash Rack Project (Project F1234)

The team defined (phases one and two of the *OPCPSP*) this project as comprising two separate tasks: land remediation of 100 gallons of spilt oil on land that was available for purchase in Giddings, Texas, and the design of wash rack to clean equipment utilized for soil remediation. The main objective of this project was to provide a soil remediation solution that was affordable, provided fast results, allowed proper disposal of contaminated soil and proper leveling and filling of new soil, and met EPA requirements.

The wash rack was designed to be safe, adaptable to different machinery, and easy to use and to allow quick equipment cleaning.

The team considered six different alternatives (phase three of the *OPCPSP*) while seeking a solution for their soil remediation issue: remove the soil, burn the oil, remediate with solvents, soil farming, phyto remediation, and removal by bacteria. After using the decision matrix, the students concluded that removal of the soil was the best solution available.

For the wash rack, different alternatives were considered (phase three of the *OPCPSP*) based on multiple filters to remove oil and particles, width of the adjustable rack, hydrocarbon filters, automated wash rack, and concrete drain channels for storm water. Results of the wash rack alternative matrix indicated that all alternatives were of equal importance which led to the generation of further matrices to narrow down the final solution. The obtained matrix mainly included comparisons of several pumps and water nozzles that could be used for the final design (phase four of the *OPCPSP*).

The final design for soil remediation included removing the contaminated soil and placing it in a hazardous material landfill. The final design for the wash rack consisted of three major components: a base, a filter, a pump system, and the two walls of the rack (phase five of the *OPCPSP*) one of which was adjustable (Portfolio F1234 of Appendix F).

Pampa Dairy Project (Project H123)

A dairy near Tampa, Texas, had an outdated waste water system. One of the major problems of the dairy was that the pipe carrying the flush water from the milking parlor to the treatment pond was at a lower elevation than the bottom of the pond. The

site of the dairy was comprised of an old concrete runway which included many storm water drains along the side of the runway which was linked to an inlet pipe that transferred the flush water from the dairy causing backup problems when the pond level was above the end of the pipe.

The team in this project defined their problem (phases one and two of the *OPCPSP*) by having to design a system to replace the old drainage pipes without having to remove them in order to minimize labor and cost. The improved system was designed above ground while complying with all government regulations. It was reliable, cost effective, and accounted for all storm water drains. The designed system also required no operator, had low maintenance, and included weather resistant materials. The improved system was isolated from any sort of contamination by feces, unsafe water in water troughs or storage tanks, and from sanitizers into water lines.

The team considered several alternatives (phase three of the *OPCPSP*) and used a decision matrix to delimit the final drainage (phase four of the *OPCPSP*) design to the following components: pump, new pipe system, lift station, air pressure as a driving force, water for irrigation, and a storage tank. A final design included a list of pipes, a lift station, and a storage tank. An overall schematic of the drainage system (phase five of the *OPCPSP*) that was presented by the team is demonstrated in Portfolio H123 of in Appendix F.

Real Time Monitoring and Automatic Shutdown System Equipment for Diabetic Equipment Operators Project (Project C123)

The team in this project defined the problem (phases one and two of the *OPCPSP*) by having to design a system that monitored the consciousness level of an equipment operator, and if needed, shut down the machinery being used and send for medical assistance. This team modified the system to monitor blood sugar level since there are several important side effects that could affect a tractor driver, even if never he becomes unconscious.

The team evaluated five design alternatives (phase three of the *OPCPSP*) using the decision matrix and delimited their final design to the following components (phase four of the *OPCPSP*): a glucowatch which monitors the blood sugar level of the person wearing it, a receiver mounted inside the tractor which could automatically shut down the tractor engine if necessary, and the OnStar monitoring system which would send for help if the person wearing the watch becomes incapacitated (phase five of the *OPCPSP* is demonstrated in Portfolio C123 of Appendix F).

Equipment Wash-Down Rack and the Remediation of Soil (Project E2346)

The team in this project defined the problem (phases one and two of the *OPCPSP*) by having to also design a wash rack as well as the remediation of 100 gallons of spilt oil in a land that was available for purchasing in Giddings, Texas.

The main objective was also to provide a soil remediation solution that was cost effective, allowed replacement of the all contaminated soil and meet all EPA regulations. The wash rack was designed to accommodate all sizes of small and large machinery, and keep the waste water contained meeting EPA regulations. For soil remediation, a

simplified plan of excavation and replacement of contaminated soil was proposed by the team. For the wash rack, the team proposed the use of a large tin building with reinforced concrete and two simple pressure washers to clean the machinery. The water will be used to clean the machinery as well. A car wash reclaim tank will be used to treat the waste water and recycle it for continuous use.

The team considered several alternatives for soil remediation (phases three of the *OPCPSP*). One main idea was to physically excavate the soil and haul in new soil. The team also considered the use of microorganisms to break down the oil or burning the oil using fire. The team also proposed several other ideas and which were derived from those two ideas. The final alternative was chosen (phase four of the *OPCPSP*) based on cost effectiveness, amount of time to complete the solution, ease of implementation and its compliance to EPA regulations. This included digging up the soil using a full dozer or an excavator (phase five of the *OPCPSP* is demonstrated in Portfolio E2346 of Appendix F), or purchasing dirt, top soil, and turf to replace all soil removed. The replaced soil would be selected based on the dominant soil that exists in the surrounding environment.

For the wash rack, the team considered the use of multiple cleaning stations for cleaning specific components of the machinery or steam cleaning the entire piece of equipment (phase three of the *OPCPSP*). For treating wastewater, the team considered pumping it from a holding tank and hauling it off, using evaporators, and a recycling reclaim tank.

The final decision (phase four of the *OPCPSP*) was based on ease of maintenance, installation, and accommodation to any type of waste being used. This included the use of a single station for steam cleaning and one or two reclaim tanks. The

team designed a wash house which allowed several water jets to wash the dirt, oil, and grime off of the cement into the drain. Three water pumps were used to transfer water to washers and the sprayers to clean the floor (phase five of the *OPCPSP* is demonstrated in Portfolio E2346 of Appendix F).

Summary of the Creative Performance in All Students' Portfolios

Overall, all four groups of students demonstrated an ability to tolerate incongruity by assuming a complex design issue with an unknown solution. This has been referred to by creativity scholars as problem awareness (Torrance & Safter, 1999; Jackson, & Messick, 1965).

All four groups of students defined the problems thoroughly, took time to accumulate enough information from different resources, allowed for incubation and deep thinking while exploring different alternatives to solve their design issues which demonstrated their fluency, ability to "break through the box" and produce many ideas. Being able to consider several alternatives and obtain a final working design demonstrated that these students were able to think both convergently and divergently (Dacey, 1985).

Originality (Torrance & Safter, 1999) of their ideas was demonstrated through their unique designs demonstrated through several manual or automated sketches they produced as indicated in the Portfolios in Appendix F.

The following section includes a creative assessment of the students' portfolios by a creativity expert through a personal interview (Z1):

> From a creative assessment perspective, I would judge all four groups of students to be quite creative.

Confronting ambiguities and puzzling phenomena, i.e., confronting problems that don't have answers is the first step in the creative process. Being able to "tolerate ambiguities" long enough to adequately define problems, collect information, and allow for incubation to occur seems to be a primary characteristics of highly creative individuals, and the work of these students shows strong evidence of both confronting ambiguities and allowing for incubation. Unfortunately, many individuals rush to quick, easy answers which often turn out to be wrong and sometimes even dangerous. This does not seem to be the case with these projects.

Another characteristic of highly creative individuals is the ability to "break out of the box," so to speak. That is, there seems to be a desire to see things differently, to seek to be original in work. In my opinion, the ability to generate great many ideas (sometimes we commonly refer to it as "fluency") is strongly related to success with regard to a propensity for originality. Producing many ideas allows us to work through the common place ones and move on to the more unique ones. If we stop too soon, we are left with just the common place solutions to problems. I will say that some creative individuals are able to "warm up" quickly and move to unique ideas sooner than others (creativity usually involves a "warm up" process, just as does sports, music, and most activities). All of these students seem to be able to generate many ideas for testing and are quite "fluent" (fluency is also an aspect of elaboration or the embellishment of a solution, which they display).

Part 5: Synthesized Findings from All Data Sources

Data triangulation has been a useful tool to verify findings in this study. The following section describes how accumulating data from all four sources (student questionnaire, field observations, focus interviews and portfolios) allowed for data verification and enhanced credibility in the study.

Findings from this study indicated that nine distinct creativity traits emerged among students during this experiential and team-based learning environment: (a) Convergent thinking, (b) Divergent thinking, (c) Openness, (d) Humor, (e) Confidence, (f) Reflection, (g) Ability to extend boundaries, (h) Problem awareness, and (i) Originality.

Respondent F3 expressed the use of divergent thinking during the focus group interview session and also demonstrated the use of convergent thinking in question eight and nine of the questionnaire (Appendix B) while specifying that he used design constraints and project goals to select the final design.

Respondent F2 expressed the use of convergent thinking, divergent thinking while being confident, and open minded during the project, and also demonstrated all these traits in his responses to questions two, eleven, and six. However, even though the respondent indicated he feels very confident generating various alternatives (question 11) and using different thinking tools such as brainstorming to elaborate on ideas, he also indicated that he preferred to listen to other peers' opinions prior to thinking about the problem individually.

Respondent F1 expressed the use of divergent thinking and openness during the focus group interview session, and demonstrated the same traits while responding to

questions six, fifteen, and sixteen. Respondent F1 indicated in question six that he uses different planning tools to justify his answers to the team leader and teammates which indicated the use of divergent thinking. It was also included from respondent F1 answer to question 15 that openness was acquired during the course period, and that he did not feel very comfortable sharing opinions with his teammates at the beginning of the semester.

Respondent C2 expressed the use of divergent thinking during the focus group interview session, and demonstrated this trait while answering question six and stating that he uses diagrams as a way to organize his thoughts during the divergent thinking process.

Respondent E4 expressed the use of both convergent and divergent thinking by his answers to questions three, six, and eight and indicating that he uses thinking tools to organize his thoughts. He also demonstrated openmindness by indicating that he finalizes solutions based on other peers' opinions (question eight).

Respondent H1 expressed the use of divergent thinking and openness during the course of the project and demonstrated the same trait while indicating the use of planning thinking tools such as brainstorming (question six) and being comfortable working a team environment (question 15 and 16).

Respondent E3 expressed the use of convergent thinking while being self directed, confident and open-minded during the focus interview group session and demonstrated the same traits while responding to questions eight, one, 15, and 16. Respondent E3 indicated the use of similar work that was done (question eight) to assess his final solution. This was interpreted by the researcher as a way to search for existing

solutions to minimize cost and maximize obtaining a successful design. This concept was confirmed by the researcher following a peer debriefing session with the professor, X1. Respondent E3's answer to question 1 indicated that he prefers thinking independently about the issue prior to discussing it with other team members. Responses to questions 15 and 16 indicated that the respondent E3 enjoyed working in a team during the project.

Respondent C1 demonstrated the traits of being confident and self directed during the focus interview session, and also indicated the same traits while responding to questions one, 11, and 12. The respondent C1 indicated that he prefers thinking about the problem first prior to discussing it with the rest of the team members. The respondent also indicated that he feels very confident in generating ideas as alternatives after taking this course (question 11 and 12), and which also indicates his ability to think divergently.

Respondents F4 and E6 indicated the characteristic of having an opened mind during the focus interview session and that was further demonstrated while answering questions 15, 16, 17, and 18 and indicating that they feel very comfortable working in a team environment and asking questions to the senior leader and course professor.

Respondent E6 also expressed the use of humor during the course of his team project. Even though this characteristic was not demonstrated in the student questionnaire as none of the questions was intended to retrieve the existence of this trait in particular, the researcher did record the use of fantasy and "crazy idea" during session 4 field observations while the students were asked to generate alternatives for their designs.

Study findings indicate that creativity constructs that emerged in the focus group interview and the field observations were exhibited in the questionnaire responses with the exception of humor. New constructs that were exhibited in the student questionnaire

include the ability to extend boundaries and reflection. Additional new constructs emerged in the team portfolios and include originality, and problem awareness. Table 9 includes a list of all identified phases of the Osborn and Parnes Creative Process model in the four data sources. Table 10 includes a list of all identified creativity traits that emerged in the four data sources according to various creativity models and their corresponding coding scheme. Table 11 includes the compiled data, coding scheme, and audit trail from respondent codes.

Table 9

Phases of the Osborn and Parnes creative process model

Compiled data	Osborn and Parnes Creative Process Phases
Po	Phase 1&2: Problem awareness and recognition
Po-F-Q-I	Phase 3: Idea generation
Po-F-Q-I	Phase 4: Idea finding
Po	Phase 5: Idea implementation

Table 10

Distribution of traits according to data sources

Compiled Data	Coding Scheme	Torrance Constructs	Treffinger Constructs	Dacey Constructs	Jackson and Messick Constructs
Po-Pd	Problem awareness	Problem awareness	Sensitivity to problems/ Tolerance of ambiguity	Sensitivity to problems	-
Po-F-Q-Pd-I	Divergent thinking	Ability to produce and consider many alternatives	Fluency / good research management and skills	Divergent thinking	-
Po-F-Q-Pd-I	Convergent thinking	Ability to put ideas into context	Cognition/memory/ analysis/ application	Convergent thinking	Analysis and intuition
F-Q-Pd-I	Openness	Openness	Openness to experience	Open-mindedness	Open-mindedness
F-Q-Pd-I	Confidence	-	Confidence/Independence in inquiry	Independence of other judgments/self guidance	-
F-Pd-I	Humor	Ability to use humor	-	Playfulness	-
Q-Pd	Reflection	Kinesthetic Responsiveness	Wiliness to respond	-	Reflection and spontaneity
Q-Pd	Ability to break through the boundaries	Ability to break through the boundaries	Transformations	-	-

Note. Po: Portfolios, Pe: Peer debriefing/Instructor Interview, Q: Questionnaire, F: Field observations, and I: Focus group interview results.

Table 11

Coding scheme and audit trail from respondent codes according to data sources

Data sources	Coding scheme								
	Problem awareness	Divergent thinking	Convergent thinking	Openness	Confidence	Humor	Ability to extend boundaries	Originality	Reflection
Field observations		F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6			
Focus group interviews		E4/C2/F1/ F2/H1	E4/E3/E2/ F2/F3	E4/E6/E3/F1/ H1/F2/F1/C1	E2/F2/C1/ E3	E6			
Questionnaire		F2/C1/F1/ C2/E4/H1	F3/F2/E4/ E3	F1/E3/E4/F4/ H1/E6	F2/E3/C1				
Portfolios	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6						
Peer debriefing/ Instructor interview	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/E3/ E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6	F3/F2/F1/ C2/E4/H1/ E3/E2/C1/ F4/E6

CHAPTER V

SUMMARY OF STUDY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of Study

Agricultural educators continue to seek models of teaching and learning that encourage students to be more creative (Baker & Rudd, 2001; Parr & Edwards, 2004).

This study used a convenience sample of students from a purposively selected course to analyze how creativity was enhanced as a result of exposing students to an experiential learning environment. Data were analyzed based on Miles and Huberman's (1994) flow model.

Conclusions

In response to the following study questions:

> How well do construct-based creativity models for determining creative behavior apply to a college level experiential learning environment?

Based on Field Observation Findings

Five distinct constructs emerged during the field observations: divergent and convergent thinking, humor, confidence, and openness. The researcher concluded from the field observation findings that confidence and openness among students were nurtured as a result of their constant engagement in several creative problem solving sessions. It was also concluded that without the use of the creativity construct instrument such as Torrance's Tests of Creative Thinking, five distinct creativity

constructs out of 18 constructs identified in the creativity literature were observed. The field observation findings confirmed that this particular learning experiential and team-based learning environment allowed fostering convergent and divergent thinking, humor, openness, and confidence among college students.

Based on Focus Group Interview Findings

The focus group interview findings confirmed the emergence of the creativity constructs observed during the in-class activities and was used as further evidence of the field observations to strengthen credibility of the data obtained. Findings from the focus group interview analysis indicated that the same five distinct constructs that emerged in the field observations emerged among students. These include divergent and convergent thinking, humor, confidence, and openness. Hence, five distinct creativity constructs out the 18 constructs identified in the creativity literature were observed during the focus group interview session.

Based on Questionnaire Findings

The questionnaire was the culminating exercise for the focus group interview and provided triangulation for the data gathered.

A summary of the results of the students' answers to the questionnaire can be presented as follows:

- Student feedback from question one and two triangulated that most students were confident.
- Student feedback from questions three though nine triangulated that divergent thinking was used during the experiential learning environment.

- Student feedback from questions eight and nine triangulated that convergent thinking was used during the experiential learning environment.
- Student feedback from question ten provided a new creativity trait among students which was the ability to extend boundaries. This particular construct was not observed during the field observations or during the focus group interview session. The students indicated the use of simple commercial designs and extended the boundaries by improving those simple systems or various system components to obtain workable designs relevant to their research topics. This analysis was confirmed following a peer debriefing session with the professor teaching the course. Students who indicated the use of existing sketches and sought ways to improve and modify them to apply them to their particular research topics were classified as having the ability to extend boundaries.
- Student feedback from questions 11 through 14 allowed the researcher to triangulate that confidence was acquired throughout the course by using several thinking strategies. This concept was initially noted by the researcher during the field observations.
- Student feedback from questions 15 through 20 allowed the researcher to triangulate that openness was nurtured among students during this experiential learning environment.
- Student feedback from questions 21 through 24 allowed the researcher to identify an additional creativity construct that had not emerged previously during the field observations or focus group interviews. This new construct was coded as reflection during this study and referred to as the ability to communicate study

steps and findings either though good oral, written, or drawing skills. Student answers to questions 21 through 24 also indicated that reflection skills were acquired among students as a result of being exposed to this particular learning environment that required them to constantly communicate thoughts and results among themselves as well as with the course professor.

In summary, results of the student questionnaire further supported the observance and descriptions of divergent and convergent thinking, confidence, and openness obtained in the field observation and focus group interview analyses. Two new constructs (ability to extend boundaries and reflection) were also evident from the student answers to the questionnaire.

Based on Portfolios Findings

Results of the analysis of student portfolios demonstrated that all students truly sensed and recognized the problems posed. This was a good indicator of problem awareness. Also, all team designs were unique and original. Problem awareness and originality were not observed in any of the three data collection sources previously listed (field observations, focus group interview, and student questionnaire).

All four team portfolios included sections describing various criteria and methods the students used to produce their design alternatives. Each team demonstrated fluency and ability to “break though the box” while compiling various alternatives to solve the design problems. Seeking of alternatives for design problems allowed the researcher to determine that divergent thinking was used.

Final design solutions were based on decisions the students included in matrices (where they rated all their possible solutions). All student reports included justifications

on how final solutions were selected based on rated alternatives in the decision matrices. Providing justifications on how final design solutions were selected allowed the researcher to conclude that convergent thinking was used.

Finally, all student portfolios included unique designs which indicated that originality was one of the major constructs in the student portfolios. This construct did not emerge during field observation, in the focus group interview, or in the questionnaire answers. Student portfolios included unique sketches and design components where the students either hand drew or used more sophisticated drawing packages such as AutoCAD to represent their design components and/or overall design processes. Each group presented unique sketches and designs that were identified by a creativity expert (Z1) as being original.

In response to the research question:

> How well do process-based creativity models for determining creative behavior apply to a college level experiential learning environment?

Based on Field Observation Findings

Problem awareness (phase one and two of the Osborn and Parnes Model *OPM*) among students was indicated in the field observations during sessions one and two. During the first session, the students were asked to provide a problem statement for their design project as well as a list of constraints. Overall, most group members were highly aware and eager to find out from the instructor what was expected from them. Also, students demonstrated problem awareness while looking for research topics relevant to their designs in session two by communicating thoughts among themselves and verifying

whether they were researching the appropriate topics that would be relevant to their designs.

Idea generation (phase three of the *OPM*) was completed during the brainstorming in-class activity where the students were asked to generate 25 ideas related to their topics among which they were asked to choose possible solutions to their final designs.

Idea finding (phase four of the *OPM*) was completed during the in-class activity where the students were required to use the decision matrix method to rate their solutions and choose a final alternative to their designs.

Idea implementation (phase five of the *OPM*) did not emerge during the field observation since this step of *OPM* is generally expressed as a product. This step will further be discussed in the portfolio section were idea implementation was expressed through engineering drawings.

Based on Focus Group Interview Findings

Problem awareness (phase one and two of the *OPM*) did not emerge in the focus group interview through student expressions. However, both idea generation (phase three of the *OPM*) and idea finding (phase four of the *OPM*) emerged during the focus group interview. Findings from the focus group interview about phase three and four triangulated the results form the field observations. Idea generation was demonstrated in the focus group interview findings while the students were describing the methods they implemented to generate their alternatives. Idea finding was present in the focus group interview based upon the student descriptive statements on how they used the decision matrices to rank their solutions and delimited their final designs.

Idea implementation (phase five of the *OPM*) was not explicitly expressed during the focus group interview session since the students did not provide any descriptive comments about how they implemented their ideas in their final designs. Idea implementation will be further discussed in the portfolio section were idea implementation was demonstrated through engineering drawings.

Based on Questionnaire Findings

Student answers to the questionnaire indicated that all students used both convergent and divergent thinking tools during the creative problem solving process. This allowed the researcher to conclude that idea generation (phase three of the *OPM*) and idea finding (phase four of the *OPM*) were used during the experiential learning environment. This finding triangulated the results about student implementation of phase three and four of *OPM* in the field observation and focus group interview findings. Problem awareness (phase one and two of the *OPM*) and idea implementation (phase five the *OPM*) were not identified in the questionnaire.

Based on Student Portfolio Findings

Findings from portfolio assessments indicated that the students completed all five steps of the Osborn and Parnes creative problem solving process: Problem awareness, problem identification, idea generation, idea finding, and idea implementation.

All four team portfolios included full descriptions about the design problems and how students considered them as major design issues that needed to be addressed. This allowed the researcher to conclude that phase one (problem awareness) and phase two (problem identification) of the *OPM* were implemented.

Each portfolio included a detailed section about the various alternatives the students used for their designs while supporting their choice with technical evidence about the validity of their alternatives. This stage was interpreted by the researcher as the completion of phase three of the *OPM*.

Each portfolio included a description on how final design decisions were generated through decision matrices and how non selected alternatives were rejected from the final design based on technical, feasibility and cost factors. The researcher concluded that phase four of the *OPM* was completed by the process of eliminating less appropriate ideas and selecting the most effective ones.

Finally, each portfolio included the best evidence of idea implementation through detailed manual or automated engineering drawings that represented the final designs in the student projects. All four engineering drawings were rated by the course professor and a creativity expert as being unique and technically doable.

Portfolio results triangulated findings about phase one and two of the *OPM* from the field observation, phase three and four of the *OPM* from the field observation, focus group interview and questionnaire. The researcher concluded that idea implementation (phase five of the *OPM*) was only expressed through manual and automated drawings in the portfolios and could not be identified in any other data source used in the study.

Summary of Conclusions

Overall conclusions of the study indicate that this college level course allowed the use of nine out of eighteen dimensions of construct-based creativity models. Three out of the nine creativity dimensions were developed among students during the creative problem solving process and include: confidence, reflection, and openness.

It can be concluded that this college level course allowed the students to explore all creative steps of a process-based creativity model.

It can be concluded from the study findings that process-based creativity models fully reflected the creative thinking atmosphere exhibited in this course. Therefore, process based models would be a good additional testing component in creativity assessment tools for evaluating creativity.

Recommendations

Recommendations for Future Research

Even though this study provided insight on how creativity was enhanced in a Biological and Agricultural Engineering course, it also raised the following questions for additional research regarding how creativity could be further explored and nurtured.

Process-based creativity models with portfolio assessment of projects were proven to be a good indicator of creative behavior in this course. Further study should explore the use of process-based models for project-based learning in other disciplines to assess whether these findings transfer to other college level courses. Educators who provide such courses and are interested in evaluating creativity among their students may wish to consider the use of creativity assessment that measures creativity among students as a process in addition to using construct-based assessment tools. Future research may focus on developing process-based creativity tests that can be used to assess students at the college level.

A further study could explore the emergence of the Torrance, Treffinger, Dacey, Jackson and Messick creativity constructs within a Biological and Agricultural

Engineering senior level course. The researcher can use a sample of senior leaders enrolled in the Biological and Agricultural Engineering course equivalent to the one used for this study, and apply the same research methodology to analyze creative behavior among senior students.

Creativity in this study was evaluated based on the students' performances and course outcomes among their teams which were associated with several factors such as team diversity and academic backgrounds. A further study could explore the emergence of the Torrance, Treffinger, Dacey, Jackson and Messick, and Osborn and Parnes creativity models in a course where the students are required to perform their projects and in-class activities individually rather than in a team.

A further study could explore the emergence of the Torrance, Treffinger, Dacey, Jackson and Messick creativity constructs as well as Osborn and Parnes creative thinking process in a non-problem based learning environment such as lecture-based courses where creative thinking activities are occasionally provided to the students after their lectures have been completed during the course period.

A further study could evaluate the K-12 core curriculum and investigate which components of the curriculum help enhance creativity both as a process and construct in elementary, middle school, and high school learning environments.

Recommendations for Practice

After proposing a model of the creative thinking process in a form of a cognitive map to be used by faculty to promote creativity among students, Baker and Rudd (2001) also encouraged further discussion on the creative potential in higher education, and recommended that agricultural faculty in higher education use their study as a foundation

to develop a more creative learning environment. This study was conducted in response to Baker and Rudd's comments on the need to conduct research to explore different avenues where creativity can be utilized at the college level.

Findings of this study may add to the cognitive map Baker and Rudd developed and be used as a reference to develop instructional material for faculty training sessions for in-class activities to enhance creativity. Results of this research may be used by educators to produce an assessment rubric to measure creativity based on process-based models using portfolios. The coding scheme for creativity constructs that were synthesized during the study may be used to evaluate college classrooms for both creativity constructs and processes.

The emergence of the Torrance, Treffinger, Dacey, Jackson and Messick constructs of creative behavior were driven by the specified creative thinking activities the students were involved in during the course. Therefore, the use of additional creative thinking activities may enhance further dimensions of creative behavior in this type of college course. Further study should examine the use of additional creative activities that allow enhancing other dimensions of construct-based models. The book entitled "*Making the Creative Leap Beyond"* by Torrance and Safter (1999), includes a wealth of information about how various activities can be used to enhance various creativity dimensions among learners. A good example is the exercise suggested by Torrance and Safter on how to enhance flexibility by using a single sketch to generate multiple figures. This exercise, for instance, could be used in the course studied by providing the students a list of design sketches they could manipulate in various ways to generate unique designs.

While the course used in this study showed that creativity can be enhanced in an introductory course in Biological and Agricultural Engineering, other disciplines in higher education can use this study findings to build teaching and learning environments that foster creativity among students through experiential learning.

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APPENDIX A

CONSENT FORM

Consent form:

I give my consent for the following:

a. As a student in AGEN 150, *Introduction to Engineering Design*, I agree to participate in the study involving the Examination of the effect of a project-based technique on the students' creative thinking within an agricultural and life science course. I also agree to conduct the interview (either face to face or over the phone, and which will be audio recorded) at the end of the semester to answer any type of questions related to this research. I also agree to provide copies of my assignments for assessment as desired, and fill out a brief questionnaire about my background.
b. I understand that these steps are part of a research study " Examination of the effect of project –based technique of the students' creative thinking within an agricultural and life science course " that is being conducted by Chehrazade Aboukinane as part of her PhD program under the guidance of Dr. Kim Dooley.
c. I understand that my participation in this study is voluntary; I can withdraw at any time with all information related to me destroyed.
d. I understand that my grade for AGEN 150 will not be affected by my participation in this study (the grade for AGEN 150 is based on in-class assignments, participation, written reports, poster and oral presentations as indicated in the course syllabus).
e. The data collected about me will include a questionnaire, interview responses, in-class behavioral activities, in-class assignments, my Grade Point Ratio, credit hours taken, major, age and gender.
f. There is no anticipated discomfort or stress accompanying this research; however, if any stress associated with any participation in this study happens, I am free to discontinue my participation in this study.
g. All information relating my name and identify to the results of this study will be kept confidential, and all results will be kept locked in the office of Ann Kenimer, TAMU 209 Scoates, and College Station until they are destroyed.

h. For problems related to this study or questions related to this conduct, I can contact Ann L. Kenimer, Associate Professor, Department of Biological and Agricultural Engineering, Texas A&M University, College Station, TX, 77840-2117. Phone: 979-845-3932. Email: a-kenimer@tamu.edu. Or Chehrazade Aboukinane, graduate research assistant , Department of Agricultural Education, Texas A&M University, College Station TX 77840-2116. Phone: 979-458-3039 FAX: 979-458-2698 email : chehra@neo.tamu.edu

i. The investigator will answer any further questions about the study, either immediately or during the course of the study.

j. I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in the study.

k. I have been given a copy of this consent form.

_____	_____	_____
Participant's Name	Participant Signature	Date

_____	_____
Study coordinator's signature	Date

I understand this research has been reviewed and approved by the Institutional Review Board-Human Subjects in Research, Texas A&M University. For research-related problems or questions subjects' rights, I can contact the Institutional Review Board through Dr. Michael W. Buckey, director of research compliance of the Office of Vice President for Research at (979) 458-4067 (mwbuckley@tamu.edu).

APPENDIX B

MODERATOR'S GUIDE

Moderator's guide:

1	**Introductions and introductory activities**
2	**Statement of basic guidelines for the interview**
	List of Questions used during the focus group interviews
	1. Describe the process of problem solving.
	2. How did you come up with your problem definition?
	3. Describe how you gathered your three research topics.
	4. Describe how you chose your 25 design ideas.
	5. Describe how the teacher's feedback on the in-class assignments affected your overall design.
	6. Describe how the professor's feedback on the in-class assignments affected your overall design.
	7. Describe how you produced your design sketches.
	8. Describe how you concluded your design solution based on the proposed alternatives.
	9. What are the factors that you think had the most impact on the improvement on the design?
	10. What kind of written skills were used through the semester?
	11. Describe your confidence in generating ideas for your design through this course.
	12. Describe how working in a team influenced your performance on the design project.
	13. Describe your skills in working with a team throughout the semester.
3	14. Considering the fact that some of your team members chose to hardly participate in most team discussion, what factors you think have caused their lack of participation?
4	**Guidance for dealing with sensitive issues**

APPENDIX C

SCRIPT OF QUESTIONS USED IN THE FOCUS GROUP INTERVIEWS

Script of questions:

List of Questions used during the focus group interviews
1. Describe the process of problem solving.
2. How did you come up with your problem definition?
3. Describe how you gathered your three research topics.
4. Describe how you chose your 25 design ideas.
5. Describe how the teacher's feedback on the in-class assignments affected your overall design.
6. Describe how the professor's feedback on the in-class assignments affected your overall design.
7. Describe how you produced your design sketches.
8. Describe how you concluded your design solution based on the proposed alternatives.
9. What are the factors that you think had the most impact on the improvement on the design?
10. What kind of written skills were used through the semester?
11. Describe your confidence in generating ideas for your design through this course.
12. Describe how working in a team influenced your performance on the design project.
13. Describe your skills in working with a team throughout the semester.
14. Considering the fact that some of your team members chose to hardly participate in most team discussion, what factors you think have caused their lack of participation?

APPENDIX D

QUESTIONNAIRE

Student questionnaire:

1. When you were given the team design problem at the beginning of the semester,
    - **a)** Did you prefer to think individually about the problem first, before exchanging information about your teammates?
    - **b)** Did you prefer listening to your teammates before thinking about the problem on your own?
    - **c)** Did you prefer to ask the team leader about his opinion first before thinking about the design problem?
    - **d)** Did you prefer to divide tasks among team members right away?
    - **e)** It depends: Explain……
2. If you were given a team design problem either in your professional life or in an upper college level class would you:
    - **a)** Think about the problem individually first, before listening to your team members?
    - **b)** Did you prefer listening to your teammates before thinking about the problem on your own?
    - **c)** Did you prefer to ask the team leader about his opinion first before thinking about the design problem?
    - **d)** Did you prefer to divide tasks among team members right away?
    - **e)** It depends: Explain……

3. How did you find your design alternatives?
    a) By listening to other peers
    b) By using electronic/paper resources
    c) By discussing with the group leader
    d) By asking the professor
4. Did you method change after you took the course?
5. How did you used to organize your thoughts prior to taking this course?
    a) By using diagrams
    b) By using different planning tools to justify the logic of your choices, then sharing your findings with your teammates and project leader
    c) By using other methods: Explain……..
6. How do you organize your thoughts now after your took this course?
    a) By using diagrams
    b) By using different planning tools to justify the logic of your choices, then sharing your findings with your teammates and project leader
    c) By using other methods: Explain……..
7. Are you familiar with any creative thinking technique that can help you organize your thoughts? Examples include brain writing, brainstorming, check listing and SCAMPER? Specify……
8. How do you assess your solutions?
    a) By comparing it to the goals?
    b) By checking similar work that has been done

c) Based on other teammates or team leader strong views, whether they support the idea or not

d) Other factors-Explain…….

9. Did you method change after you took this course?

10. How often would you use online educational tools to learn material in any of your classes?

a) Very often b) Often c) Never

11. Describe the level of your confidence in generating ideas to solve a design problem prior to taking this course:

a) Very confident b) Confident c) Not confident

12. Describe the level of your confidence in generating ideas to solve a design problem in the future:

a) Very confident b) Confident c) Not confident

13. When you were given several alternatives to solve your design problem, how confident were you when asked to pick a single alternative at the beginning of the semester?

a) Very confident b) Confident c) Not confident

14. If we give you several alternatives to solve a design problem in the future, how confident would you be if asked to pick a single alternative?

a) Very confident b) Confident c) Not confident

15. How comfortable were you working with other classmates at the beginning of the semester?

a) Very comfortable b) Comfortable c) Not comfortable

16. How comfortable are you now working with other classmates?

a) Very comfortable b) Comfortable c) Not comfortable

17. Describe the level of your confidence in generating ideas to solve a design problem prior to taking this course:

a) Very comfortable b) Comfortable c) Not comfortable

18. How comfortable were you asking questions to your senior leader or professor at the beginning of the semester?

a) Very comfortable b) Comfortable c) Not comfortable

19. Do you feel more productive when ___?

a) Working in a team b) Working individually

20. Did you feel the same way before you took this course? (Refer to question 11)

21. How good were you in communicating your results while you were given presentations before taking the course?

a) Very good b) Good c) Ok d) Not good

22. How good are you in communicating your results while you are given presentations now that you completed this course?

a) Very good b) Good c) Ok d) Not good

23. How good were you in communicating your results when writing a report before taking the course?

a) Very good b) Good c) Ok d) Not good

24. How good are you in communicating your results when writing a report after completing the course?

a) Very good b) Good c) Ok d) Not good

APPENDIX E

RAW DATA FROM QUESTIONNAIRE

Students answers from the questionnaire:

Question	Suggested Answers	Respondents
1. when you were given team design problem (either to define a problem or reference resources etc…) at the beginning of the semester:	a) Did you like to think about the problem individually first, before listening to your team members?	F1/E2/E3/E4/E6/F3/H2/H3/C1/C2/C3
	b) Did you prefer listening to your team members before thinking about the problem on your own?	F2/H1
	c) Did you prefer to ask the team leader about this opinion first before thinking?	
	d) Did you prefer to divide tasks among team members right away?	
	e) Other	F4
2. If you were given a team design problem either in your professional life or in an upper level class would you:	a) Think about the problem individually first, before listening to your team members?	E2/C2/H3/H2/H1/E6/E4/E3
	b) Prefer listening to your team members before thinking about the problem on your own?	C3/F3/F2/
	c) Prefer to ask the team leader about this opinion first before thinking?	
	d) Prefer to divide tasks among team members right away?	F4
	e) Other	C1/F1/
3. How did you find your design alternatives?	a) By listening to other peers?	C3/C2/C1/H3/H2/H1/F4/F3/F2/F1/E6/E4/E3
	b) Using electronic /paper resources?	
	c) Discussing with the group leader?	E2
	d) Asking the professor?	
4. Did your method change after you took this course?	a) Yes	E2/C3/H2/H1/F3/F2/F1/E4
	b) No	C2/C1/H3/F4/E6/E3
5. How did you used to organize your thoughts prior to taking this course?	a) By using diagrams?	E2/E3
	b) By using different planning tools to justify the logic of your choices then sharing your findings with your teammates and project leader?	C3/H3/H1/F4/F3/F2/E6/E4
	c)Other	C2/C1/H2/F1/

Students answers from the questionnaire (Continued):

Question	Suggested Answers	Respondents
6. How do you organize your thoughts?	a) By using diagrams?	C2/E2
	b) By using different planning tools to justify the logic of your choices then sharing your findings with your teammates and project leader?	E3/E6/F4/H3/C1/E4/F1/F2/F3/H1/C3
	c)Other	H2
7. Are you familiar with any creative thinking technique that can help you organize your thoughts (ex, brainstorming, check listing, SCAMPER)?	a) Yes	C2/H2/E3/E6/F4/H3/C1/E4/F1/F2/F3/H1/C3
	b) No	E2
8. How do you assess your solutions?	a) By comparing it to be goals?	C2/F4/H3/C1/F1/F2/F3/H1/C3/E2
	b) By checking similar work that has been done?	E3/E6
	c) Based on other team members/team leader strong views, whether they support the idea or not?	E4/H2
	d) Other factors	
9. Did your method change after you took this course?	a) Yes	F1/H1/C2/E6/E4/C3
	b) No	E2/E3/F3/F2/C1/H3/F4/H2
10. How often would you use online educational tools (example: specific websites) to better learn the material in any of your classes?	a) Very often	C3/E6/C2/F4/F2/E3/E2
	b) Often	F3/C1/H3/H2/F1/H1/E4
	c) Never	
11.Describe the level of your confidence in generating ideas to solve a design problem prior to taking this course	a) Very confident	F4/F2
	b) Confident	C2/H2/E3/E6/H3/C1/F1/F3/C3/E2/
	c) Not confident	E4/H1
12.Describe the level of your confidence in generating ideas to solve a design problem after taking this course	a) Very confident	E2/E3/C1/F2/F4/H2/H3/C2/C3
	b) Confident	F1/E6/H1/E4/F3
	c) Not confident	
13. When you were given several alternatives to solve your design problem, how confident were you in when asked to pick a single alternative at the beginning of this course?	a) Very confident	F4
	b) Confident	E3/C1/F2/H2/H3/C3/F3
	c) Not confident	E2/C2/H1/F1/E6/E4

Students answers from the questionnaire (Continued):

Question	Suggested Answers	Respondents
14. If we give you several alternatives to solve a design problem in the future, how confident would you be if asked to pick a single alternative?	a) Very confident	F4/E3/F2/H2/C3/F3/
	b) Confident	C1/H3/E6/F1/H1/C2/E2/E4
	c) Not confident	
15. How comfortable were you working with other classmates at the beginning of this semester?	a) Very comfortable	F2/F4/H3
	b) Comfortable	F3/C3/E3/C1/E2/C2/H1/E6
	c) Not comfortable	H2/E4/F1
16. How comfortable are you now working with other classmates?	a) Very comfortable	C2/E3/E6/F4/H3/C1/E4/F1/F2/F3/C3
	b) Comfortable	H2/H1/E2
	c) Not comfortable	
17. How comfortable are you asking questions to your senior leader or professor as the end of the semester is coming close?	a) Very comfortable	C2/E3/F4/H3/C1/F2/F3/E2
	b) Comfortable	H1/H2/E6/F1/E4
	c) Not comfortable	C3
18. How comfortable were you asking questions to your senior leader or professor at the beginning of the semester?	a) Very comfortable	F4/C3
	b) Comfortable	C2/H2/E3/E6/H3/C1/E4/F2/F3/H1/E2
	c) Not comfortable	E4/F1/H2
19. Do you feel that you are more productive when….?	a) Working in a team	C2/H2/E3/E6/F4/H3/C1/E4/F1/F2/F3/H1/C3
	b) Working individually	E2
20. Did you feel the same way before you took this course? (in reference to question 11)	a) Yes	H2/E6/F4/H3/C1/F2/F3/C3/E2/
	b) No	H1/E3/E4/F1/C2
21. How good were you in communicating your results while you were giving presentations (before taking this course)?	a) Very good	E3
	b) Good	E2/F4/C3
	c) Ok	C2/H2/E6/H3/C1/F1/F2/F3
	d) Not good	H1/E4
22. How good are you in communicating your results while giving a presentation (now after you have this course)?	a) Very good	E3/C3/E2
	b) Good	H2/H3/F2/F1/F4
	c) Ok	C1/F3/E6/C2
	d) Not good	E4/H1
23. How good were you in communicating your results when writing a report before taking this course?	a) Very good	F4
	b) Good	E3/E2/H2/F2/F3/H1
	c) Ok	C3/H3/F1/C1/E6/C2
	d) Not good	E4
24 How good are you in communicating your results when writing a report after you have taken this course?	a) Very good	F2/F4
	b) Good	C2/H2/E3/H3/F1/F3/H1/C3/E2
	c) Ok	C1/E6
	d) Not good	E4

Questionnaire findings:

Question	Suggested Answers	n of Yes feedback	Codes for Positive feedback
1. when you were given a team design problem (either to define a problem or reference resources etc…) at the beginning of the semester:	a) Did you like to think about the problem individually first, before listening to your team members?	11	1A
	b) Did you prefer listening to your team members before thinking about the problem on your own?	2	1B
	c) Did you prefer to ask the team leader about this opinion first before thinking?	0	1C
	d) Did you prefer to divide tasks among team members right away?	0	1D
	e) Other	1	1E
2. If you were given a team design problem either in your professional life or in an upper level class would you:	a) Think about the problem individually first, before listening to your team members?	7	2A
	b) Prefer listening to your team members before thinking about the problem on your own?	4	2B
	c) Prefer to ask the team leader about this opinion first before thinking?	0	2C
	d) Prefer to divide tasks among team members right away?	1	2D
	e) Other	2	2E
3. How did you find your design alternatives?	a) By listening to other peers?	13	3A
	b) Using electronic /paper resources?	0	3B
	c) Discussing with the group leader?	1	3C
	d) Asking the professor?	0	3D
4. Did your method change after you took this course?	a) Yes	8	4A
	b) No	6	4B
5. How did you used to organize your thoughts prior to taking this course?	a) By using diagrams?	2	5A
	b) By using different planning tools to justify the logic of your choices then sharing your findings with your teammates and project leader?	8	5B
	c)Other	4	5C

Questionnaire findings (Continued):

Question	Suggested Answers	n of Yes feedback	Codes for Positive feedback
6. How do you organize your thoughts?	a) By using diagrams?	2	6A
	b) By using different planning tools to justify the logic of your choices then sharing your findings with your teammates and project leader?	11	6B
	c)Other	1	6C
7. Are you familiar with any creative thinking technique that can help you organize your thoughts (ex, brainstorming, check listing, SCAMPER)?	a) Yes	13	7A
	b) No	1	7B
8. How do you assess your solutions?	a) By comparing it to be goals?	10	8A
	b) By checking similar work that has been done?	2	8B
	c) Based on other team members/team leader strong views, whether they support the idea or not?	2	8C
	d) Other factors	0	8D
9. Did your method change after you took this course?	a) Yes	5	9A
	b) No	9	9B
10. How often would you use online educational tools (example: specific websites) to better learn the material in any of your classes?	a) Very often	7	10A
	b) Often	7	10B
	c) Never	0	10C
11.Describe the level of your confidence in generating ideas to solve a design problem prior to taking this course	a) Very confident	2	11A
	b) Confident	11	11B
	c) Not confident	1	11C
12.Describe the level of your confidence in generating ideas to solve a design problem after taking this course	a) Very confident	9	12A
	b) Confident	5	12B
	c) Not confident	0	12C
13. When you were given several alternatives to solve your design problem, how confident were you in when asked to pick a single alternative at the beginning of this course?	a) Very confident	1	13A
	b) Confident	7	13B
	c) Not confident	6	13C

Questionnaire findings (Continued)

Question	Suggested Answers	n of Yes feedback	Codes for Positive feedback
14. If we give you several alternatives to solve a design problem in the future, how confident would you be if asked to pick a single alternative?	a) Very confident	6	14A
	b) Confident	8	14B
	c) Not confident	0	14C
15. How comfortable were you working with other classmates at the beginning of this semester?	a) Very comfortable	3	15A
	b) Comfortable	8	15B
	c) Not comfortable	3	15C
16. How comfortable are you now working with other classmates?	a) Very comfortable	11	16A
	b) Comfortable	3	16B
	c) Not comfortable	0	16C
17. How comfortable are you asking questions to your senior leader or professor as the end of the semester is coming close?	a) Very comfortable	8	17A
	b) Comfortable	5	17B
	c) Not comfortable	1	17C
18. How comfortable were you asking questions to your senior leader or professor at the beginning of the semester?	a) Very comfortable	2	18A
	b) Comfortable	9	18B
	c) Not comfortable	3	18C
19. Do you feel that you are more productive when….?	a) Working in a team	13	19A
	b) Working individually	1	19B
20. Did you feel the same way before you took this course? (in reference to question 11)	a) Yes	9	20A
	b) No	5	20B
21. How good were you in communicating your results while you were giving presentations (before taking this course)?	a) Very good	1	21A
	b) Good	3	21B
	c) Ok	8	21C
	d) Not good	2	21D
22. How good are you in communicating your results while giving a presentation (now after you have this course)?	a) Very good	3	22A
	b) Good	5	22B
	c) Ok	4	22C
	d) Not good	2	22D
23. How good were you in communicating your results when writing a report before taking this course?	a) Very good	1	23A
	b) Good	6	23B
	c) Ok	6	23C
	d) Not good	1	23D
24 How good are you in communicating your results when writing a report after you have taken this course?	a) Very good	2	24A
	b) Good	9	24B
	c) Ok	2	24C
	d) Not good	1	24D

Distribution of creativity traits according to the students 'coded feedback

Codes for Positive feedbacks	Creativity traits identified	% of positive feedback in each sample question
1A	Self directedness/Independent thinking	79
1B	Self directedness/Independent thinking	14
1C	Self directedness/Independent thinking	0
1D	Self directedness/Independent thinking	0
1E	Self directedness/Independent thinking	7
2A	Self directedness/Independent thinking	50
2B	Self directedness/Independent thinking	29
2C	Self directedness/Independent thinking	0
2D	Self directedness/Independent thinking	7
2E	Self directedness/Independent thinking	14
3A	Elaboration/Ability to use alternatives/use of creative thinking tools	93
3B	Elaboration/Ability to use alternatives/use of creative thinking tools	0
3C	Elaboration/Ability to use alternatives/use of creative thinking tools	7
3D	Elaboration/Ability to use alternatives/use of creative thinking tools	0
4A	Elaboration/Ability to use alternatives/use of creative thinking tools	57
4B	Elaboration/Ability to use alternatives/use of creative thinking tools	43
5A	Elaboration/Ability to use alternatives/use of creative thinking tools	14
5B	Elaboration/Ability to use alternatives/use of creative thinking tools	57
5C	Elaboration/Ability to use alternatives/use of creative thinking tools	29
6A	Elaboration/Ability to use alternatives/use of creative thinking tools	14
6B	Elaboration/Ability to use alternatives/use of creative thinking tools	79
6C	Elaboration/Ability to use alternatives/use of creative thinking tools	7
7A	Elaboration/Ability to use alternatives/use of creative thinking tools	93
7B	Elaboration/Ability to use alternatives/use of creative thinking tools	7
8A	Elaboration/Ability to use alternatives/use of creative thinking tools	71
8B	Elaboration/Ability to use alternatives/use of creative thinking tools	14
8C	Elaboration/Ability to use alternatives/use of creative thinking tools	14
8D	Elaboration/Ability to use alternatives/use of creative thinking tools	0
9A	Elaboration/Ability to use alternatives/use of creative thinking tools	36
9B	Elaboration/Ability to use alternatives/use of creative thinking tools	64
10A	Extend boundaries	50
10B	Extend boundaries	50
10C	Extend boundaries	0
11A	Confidence	14
11B	Confidence	79
11C	Confidence	7

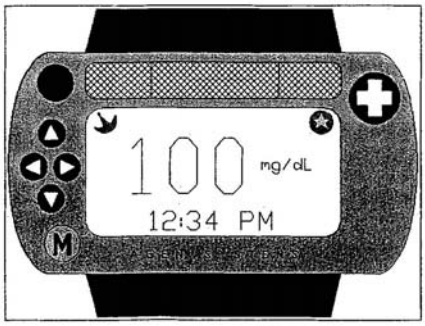
Distribution of creativity traits according to the students 'coded feedback, (Continued):

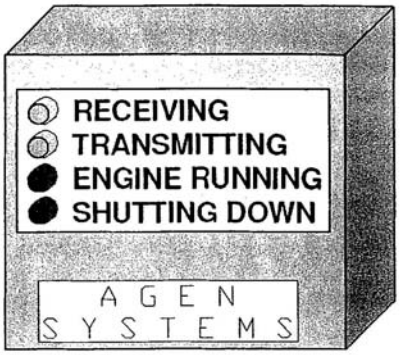
Codes for Positive feedbacks	Creativity traits identified	% of positive feedback in each sample question
12A	Confidence	64
12B	Confidence	36
12C	Confidence	0
13A	Confidence	7
13B	Confidence	50
13C	Confidence	43
14A	Confidence	43
14B	Confidence	57
14C	Confidence	0
15A	Openness	21
15B	Openness	57
15C	Openness	21
16A	Openness	79
16B	Openness	21
16C	Openness	0
17A	Openness	57
17B	Openness	36
17C	Openness	7
18A	Openness	14
18B	Openness	64
18C	Openness	21
19A	Openness	93
19B	Openness	7
20A	Reflection and spontaneity	64
20B	Reflection and spontaneity	36
21A	Reflection and spontaneity	7
21B	Reflection and spontaneity	21
21C	Reflection and spontaneity	57
21D	Reflection and spontaneity	14
22A	Reflection and spontaneity	21
22B	Reflection and spontaneity	36
22C	Reflection and spontaneity	29
22D	Reflection and spontaneity	14
23A	Reflection and spontaneity	7
23B	Reflection and spontaneity	43
23C	Reflection and spontaneity	43
23D	Reflection and spontaneity	7
24A	Reflection and spontaneity	14
24B	Reflection and spontaneity	64
24C/24D	Reflection and spontaneity	14/7

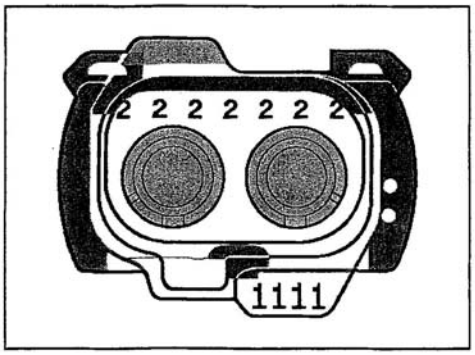
APPENDIX F

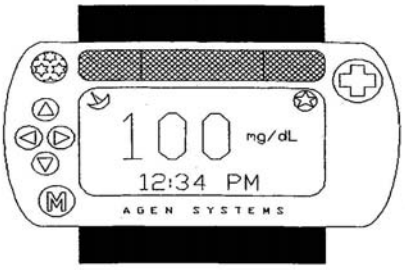
STUDENTS' DESIGN SKETCHES FROM THE PORTFOLIOS

Portfolio C123:







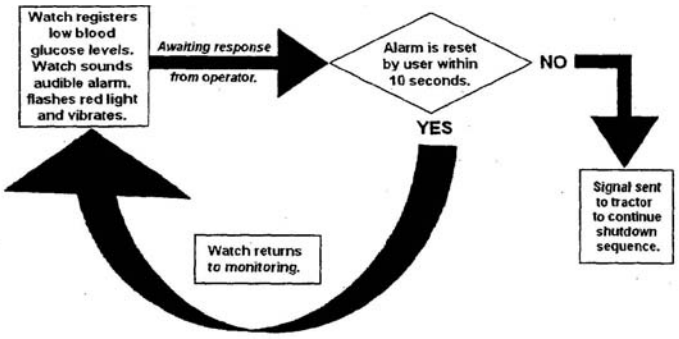


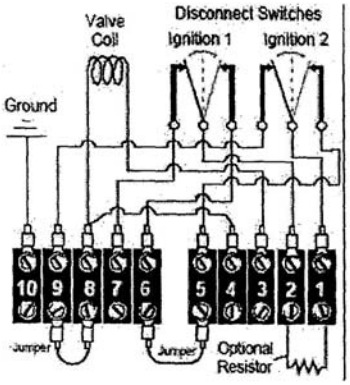
Modified Glucowatch Face Legend:

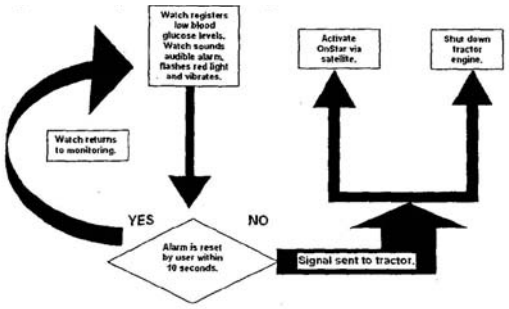
- Emergency Activation Button
- Red Warning Light
- Menu Button
- Satellite Range
- OnStar Monitor
- Menu Arrow

Microphone
Speakers

Portfolio C123 (Continued):







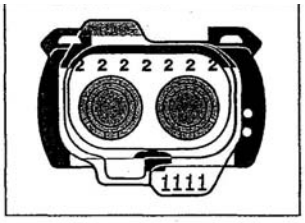
Portfolio C123 (Continued):

GLUCOWATCH® G2™

AUTOMATIC GLUCOSE BIOGRAPHER

and

AUTOSENSORS



How does the GlucoWatch G2 Biographer work?

An extremely low electric current pulls glucose through the skin. The glucose is collected in 2 gel discs that are part of the AutoSensor. Then, an electrode in the AutoSensor measures the glucose.

- Each glucose reading is stored in memory and the readings can be viewed with the touch of a button
- The Biographer compares each 10-minute reading with High and Low Alert levels that you and your health care team select
- The Biographer sounds an alarm if glucose readings are:
  - Below the Low Alert level
  - Above the High Alert level
  - Declining towards the Low Alert level

What is the GlucoWatch G2 Biographer used for?

The Biographer detects trends and tracks patterns in your glucose levels. The Biographer can be used during your normal daily routine (while awake or asleep) at home or at work. The frequent readings provided by the Biographer may help you manage your diabetes better.

The Biographer is meant for use by adults (aged 18 and older) and children/adolescents (aged 7 to 17) with diabetes. This is because, so far, the Biographer has been studied only in these populations.

Can I use GlucoWatch G2 Biographer readings in the same way I use finger-stick test results?

No. The Biographer is designed to help detect trends and patterns in your glucose levels. Most Biographer readings are similar to finger-stick test results taken around the same time. But some Biographer readings will differ from finger-stick tests. This difference can be important for proper treatment.

Managing diabetes means that you must make treatment decisions every day. Unfortunately, these decisions can sometimes cause problems. For example, too much insulin can result in low glucose levels and not enough insulin can result in high glucose levels.

When it is time to make an important decision, the Biographer should not be used as a substitute for a finger-stick test. The Biographer must be used with finger-stick blood testing. You can then make the best treatment decisions and reduce the chance of problems.

How can I use GlucoWatch G2 Biographer readings to help manage my diabetes better?

The Biographer makes frequent glucose monitoring easier. With the Biographer, you can see the trends and patterns in your glucose levels. For example, you can see your glucose levels rising after meals. This can help you and your health care team identify ways to improve your diabetes management.

The Biographer can also alert you when your glucose levels are too high or too low. These situations may be hard to identify with finger-stick testing alone.

PATIENT INFORMATION

CAUTION: U.S. federal law restricts the GlucoWatch® G2™ Biographer and AutoSensors to sale by or on the order of a physician.

WARNING: This device is not designed to replace your regular blood glucose meter. The GlucoWatch G2 Biographer must be used with your blood glucose meter. Together, they can give you more information about glucose levels. You and your health care team may be able to use this information to manage your diabetes better.

IMPORTANT: Before you use the GlucoWatch G2 Biographer, you must do 2 things:

- Read the *User's Guide* provided in the Starter Kit
- Complete an Introductory Training Program located in the *User's Guide*

This product information sheet does not replace a complete reading of the *User's Guide*. Parents and guardians should read the *User's Guide* and supervise use of the Biographer by their children/adolescents (aged 7 to 17). You should understand the benefits and limitations of the Biographer. You should think about any risks involved with unsupervised use of the device by your child (eg, while at school) and make appropriate preparations for such use. If you have questions or need another copy of the *User's Guide*, please call our Customer Service Department. The toll-free phone number is 1-866-GLWATCH (1-866-459-2824).

What is the GlucoWatch G2 Biographer?

The Biographer is a glucose monitoring device that is worn like a watch. Glucose readings are taken noninvasively through your skin. The Biographer provides automatic glucose readings every 10 minutes for up to 13 hours at a time.

The G2™ Biographer consists of 2 main parts:

- The **Biographer:** the watch-like device that measures glucose

- The **AutoSensor:** a plastic part that snaps into the Biographer and sticks to your skin. Each AutoSensor provides up to 13 hours of readings. The AutoSensor must be replaced every time you wear the Biographer

Portfolio C123 (Continued):

- Bumping or jarring the Biographer may also cause skipped readings or a shut-off
- The Biographer alarm may be difficult to hear if there is a lot of background noise. The alarm may also be difficult to hear at night if:
  - You are a heavy sleeper
  - You have difficulty with your hearing
  - The Biographer is under a pillow or blanket

The alarm will stay on and beep faster and faster until you press a button to shut it off.

- Never immerse your Biographer in water. Your Biographer is splash resistant, not waterproof. This means you can wear it in the rain or while washing your hands. You should not wear the Biographer while showering, bathing, or swimming
- The Biographer has been studied in adults (aged 18 and older) and children/adolescents (aged 7 to 17). Studies have included over 1,400 uses of the Biographer by hundreds of people with diabetes. No change was seen in accuracy or skin irritation during the studies. No studies have yet been done for longer than 6 weeks
- The Biographer readings may be affected by some hospital tests that use high electromagnetic equipment. This includes x-rays and MRI tests
- The medicines tolazamide or dopamine may affect the Biographer readings. Tolazamide is a pill sometimes used for Type 2 diabetes. Dopamine is given by injection for heart failure or shock. Ask a member of your health care team if you are uncertain if you are taking either of these medications

Target glucose values for people with diabetes

Your own target glucose values should be determined with your health care team. If your glucose readings are frequently too low or too high, consult your health care team.

Your regular blood glucose meter gives test results that are either:

- **Whole blood** glucose values, or
- **Plasma** glucose values

All meters use whole blood to begin the test. The difference comes with how the result is calculated. Check the instructions for your meter to find out what kind of values it gives.

The Biographer readings are based on the finger-stick test result you use to calibrate the Biographer. This means that if your meter gives whole blood glucose values, the Biographer readings will also be whole blood values. If your meter gives plasma glucose values, the Biographer readings will be plasma values.

Target glucose levels for people with diabetes depend on what type of result your meter and the Biographer provide. **TABLE I** below shows the general targets suggested by the American Diabetes Association.[1]

TABLE I	If your regular meter provides **whole blood** glucose values:	If your regular meter provides **plasma** glucose values:
Before meals:	80–120 mg/dL	90–130 mg/dL
At bedtime:	100–140 mg/dL	110–150 mg/dL

Ensuring the accuracy of your GlucoWatch G2 Biographer readings

- The *User's Guide* includes directions for how to test your Biographer to make sure it is working correctly. Two types of tests can be done: the System Check and the Quality Control (QC) Test
  - The System Check tests to make sure your Biographer is operating properly. Run a System Check before using your Biographer for the first time and then once before using the first AutoSensor from a new box. Also run a System Check if the Biographer is dropped or damaged in any way
  - The QC Test checks the AutoSensors. Conduct a QC Test if you suspect that the AutoSensors have been exposed to extreme temperatures. Also run a QC Test if you have trouble calibrating the Biographer or if you question a series of Biographer readings

The *User's Guide* explains how to do these tests.

- The accuracy of the Biographer depends on the accuracy of the blood glucose test used for calibration. Be sure to check your blood glucose meter and test strips according to the instructions. Your doctor may also want to check your meter against a standard lab test from time to time
- If you question the finger-stick reading that you plan to use for calibration, repeat the finger-stick test
- If you question a Biographer reading, use your regular blood glucose meter to do a finger-stick test. Keep in mind that Biographer readings correspond to blood glucose values from about 15 minutes earlier

HEALTH CARE PROFESSIONAL INFORMATION

This section is meant for health care professionals. If you are a patient with diabetes, please read the Patient Information first. If you have questions about the Health Care Professional Information, ask a member of your health care team.

Health Care Professionals: Please read the Patient Information for the Warnings, Precautions, and Limitations. Patients must be able to use a standard blood glucose meter accurately before using the GlucoWatch® G2™ Biographer. Each patient must complete an Introductory Training Program (located in the *User's Guide*) before using the device. In addition, some patients may need further training on how to use the Biographer. The training needs of each patient should be assessed by the health care professional before prescribing this device. Parents and guardians should be advised to read the *User's Guide* and supervise use of the Biographer by children/adolescents (aged 7 to 17). They should understand the benefits and limitations of the Biographer. Parents and guardians should be counseled to think about any risks involved with unsupervised use of the device by their child or adolescent (eg, while at school) and make appropriate preparations for such use.

The GlucoWatch G2 Automatic Glucose Biographer qualifies for waived status under the Clinical Laboratory Improvement Amendments of 1988 (CLIA).

INTENDED USE

The GlucoWatch G2 Biographer is a glucose monitoring device intended for detecting trends and tracking patterns in glucose levels in adults (aged 18 and older) and children/adolescents (aged 7 to 17) with diabetes. This device is intended for use by patients at home and in health care facilities. The device is for prescription use only.

The GlucoWatch G2 Biographer is intended for use as an adjunctive device to supplement, not replace, information obtained from standard home glucose monitoring devices.

The GlucoWatch G2 Biographer is indicated for use in the detection and assessment of episodes of hyperglycemia and hypoglycemia, facilitating both acute and long-term therapy adjustments, which may minimize these excursions. Interpretation of Biographer results should be based on the trends and patterns seen with several sequential readings over time.

OTHER IMPORTANT INFORMATION

- The device is for prescription use only
- The device provides supplemental information that is not a replacement for blood glucose results obtained from standard home glucose monitoring devices
- Changes in insulin therapy should not be made based solely on the Biographer results. Interpretation of Biographer results should be based on the trends and patterns seen with several sequential readings over time
- The Biographer works differently than standard blood glucose meters (see Testing Principle Section). As a result, individual Biographer readings can differ substantially from blood glucose measurements taken at approximately the same time. These individual differences can be somewhat unpredictable and should be taken into account when interpreting results (see Performance Characteristics Section)
- Performance of the device can vary from use to use (ie, Day 1 versus Day 2) as well as within an individual 13-hour monitoring period
- Mild to moderate skin irritation occurs in many patients
- Skipped readings and unexpected shut-offs may occur due to excessive perspiration, jarring, or dislodging of the device from the skin
- Performance of this device has been studied only in patients aged 7 and older

Patients should be advised of when and how often to use the Biographer. Decisions about how to use the Biographer in a patient's diabetes management program should take into account the patient's ability to operate the device correctly and to understand device limitations. The patient must also be willing to accept the mild to moderate skin irritation that can result from use of the Biographer.

The Biographer is appropriate for daytime and/or nighttime use on a routine, periodic, or situational basis.

- Routine use (ie, daily) should be considered for patients making frequent therapy adjustments based on glucose monitoring results and for patients subject to frequent problems with hypoglycemia and/or hyperglycemia
- Periodic use (ie, weekly) should be considered for patients with more stable glucose levels or simpler therapy regimens
- Situational use (ie, during a change in therapy) can be helpful in addressing specific treatment or educational issues with certain patients

The Biographer is designed to help your patients identify trends and patterns in their glucose levels. Biographer readings, although accurate most of the time, may occasionally differ significantly from finger-stick test results and therefore must be used with finger-stick blood testing. Using Biographer results solely could result in improper and potentially harmful treatment decisions.

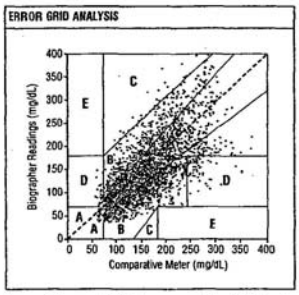
Portfolio C123 (Continued):

The paired point results are summarized in **TABLE IV**.

TABLE IV	
Paired glucose measurements	2665
Mean absolute difference	24.5%
Deming regression slope (95% confidence interval)	0.92 (0.89, 0.96)
Deming regression intercept (95% confidence interval)	4.5 mg/dL (−0.9, 9.7)

Substantial variability was observed in the difference between individual Biographer readings and the paired comparative BG measurements. This can be seen in the correlation plot below.

Correlation plot of GlucoWatch G2 Biographer readings versus BG measurements
(N=2665 Paired Points)



Some of the variability in agreement is related to the differences in sample source, timing of readings, and accuracy of the comparative devices. However, analyses have indicated that performance of the Biographer can vary from use to use (ie, Day 1 versus Day 2) and within an individual 13-hour monitoring period.

The amount of variability was analyzed by looking at the percentage of Biographer readings falling within 20% and within 30% of the comparative BG measurement (or within 20 mg/dL in the low BG range). Results are shown in **TABLE V**.

TABLE V			
BG range (mg/dL)	# of paired points	% within 20%*	% within 30%*
Overall	**2665**	**52%**	**69%**
41–80	238	55%	55%
81–120	680	54%	71%
121–240	1489	52%	70%
>240	258	47%	64%

*For the low glucose range (41–80 mg/dL) the value shown is the percent within 20 mg/dL.

The Clarke Error Grid was used to assess the clinical relevance of the differences between the Biographer readings and the comparative BG measurements.[2] The Error Grid divides a correlation plot into 5 zones (see **TABLE VI**).

Results in zones A and B are considered clinically acceptable while results in zones C, D, and E are potentially dangerous and therefore clinically significant errors. The Error Grid zones are labeled on the correlation plot.

TABLE VI		
Zone	**Description**	
A	Clinically accurate, would lead to correct treatment decisions	≤20% difference versus comparative BG measurement*
B	Would lead to benign decisions or no treatment	
C	Would lead to overcorrection of normal glucose levels	>20% difference versus comparative BG measurement
D	Would lead to failure to detect and treat high or low glucose levels	
E	Would lead to erroneous treatment decisions	

*Also includes all points where both measurements are in the hypoglycemic range (≤70 mg/dL).

The percent of Biographer readings within the clinically acceptable zones (A and B) was 95%. No points were in the erroneous treatment zone (E).

To assess the clinical relevance of Biographer performance at high and low glucose levels, the Error Grid results were stratified by BG range. **TABLE VII** shows the overall distribution of points by Error Grid zone along with stratified results by 4 BG ranges.

TABLE VII							
BG range (mg/dL)	# of paired points	A+B	A	B	C	D	E
Overall	**2665**	**95%**	**51%**	**43%**	**1%**	**4%**	**0%**
41–80	238	76%	47%	30%	0%	24%	0%
81–120	680	99%	54%	45%	1%	Not applicable	
121–240	1489	98%	52%	47%	2%		0%
>240	258	77%	47%	30%	0.8%	22%	0%

95% of the Biographer readings were in the clinically acceptable zones (A and B). 4% of Biographer readings fell into zone D. Most of the zone D results occurred in the low range when the Hemocue BG was below 70 mg/dL and the Biographer reading was greater than 70 mg/dL. This type of low-range zone D error has also been seen with standard home BG meters.[3]

Precision of GlucoWatch G2 Biographer readings

Precision was estimated by comparing readings from 2 Biographers worn simultaneously at different skin sites. **TABLE VIII** shows the median within individual results.

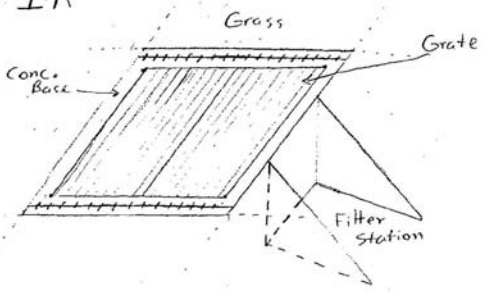
TABLE VIII				
Average Biographer reading (mg/dL)	# of individuals	# of paired points	Median standard deviation	Median (range) % coefficient of variation
Overall	**55**	**2541**	**15 mg/dL**	**11% (5%, 35%)**
41–80	35	218	9 mg/dL	14% (3%, 31%)
81–120	50	706	12 mg/dL	12% (0%, 37%)
121–240	54	1393	14 mg/dL	9% (4%, 26%)
>240	29	224	23 mg/dL	8% (1%, 34%)

The variability between paired Biographer readings increases as a function of glucose range. All covariances for each individual were <37%, both overall and within each glucose range. Note that this experimental method includes additional sources of variability compared to the standard precision study in which repeated measurements are made from a single sample of capillary blood.

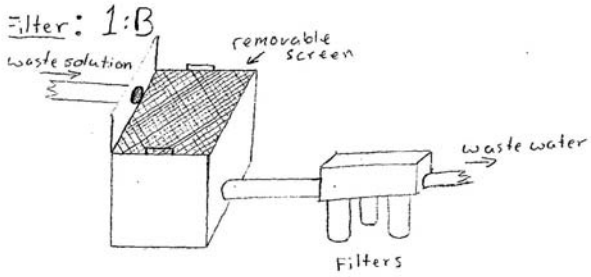
Portfolio F1234:

Automated Equipment
wash-down Rack

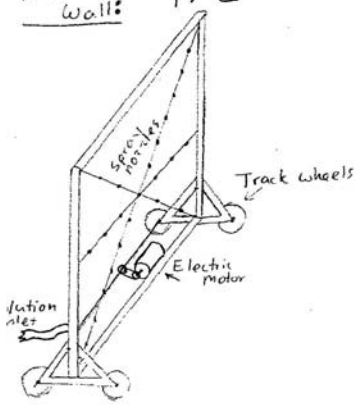
Base: 1:A



Filter: 1:B

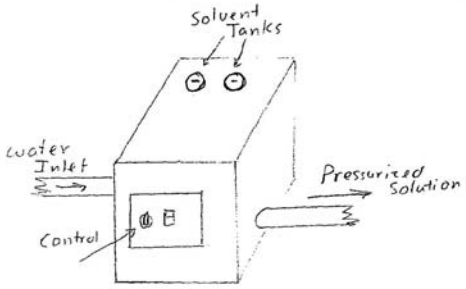


Automated Wall: 1:C

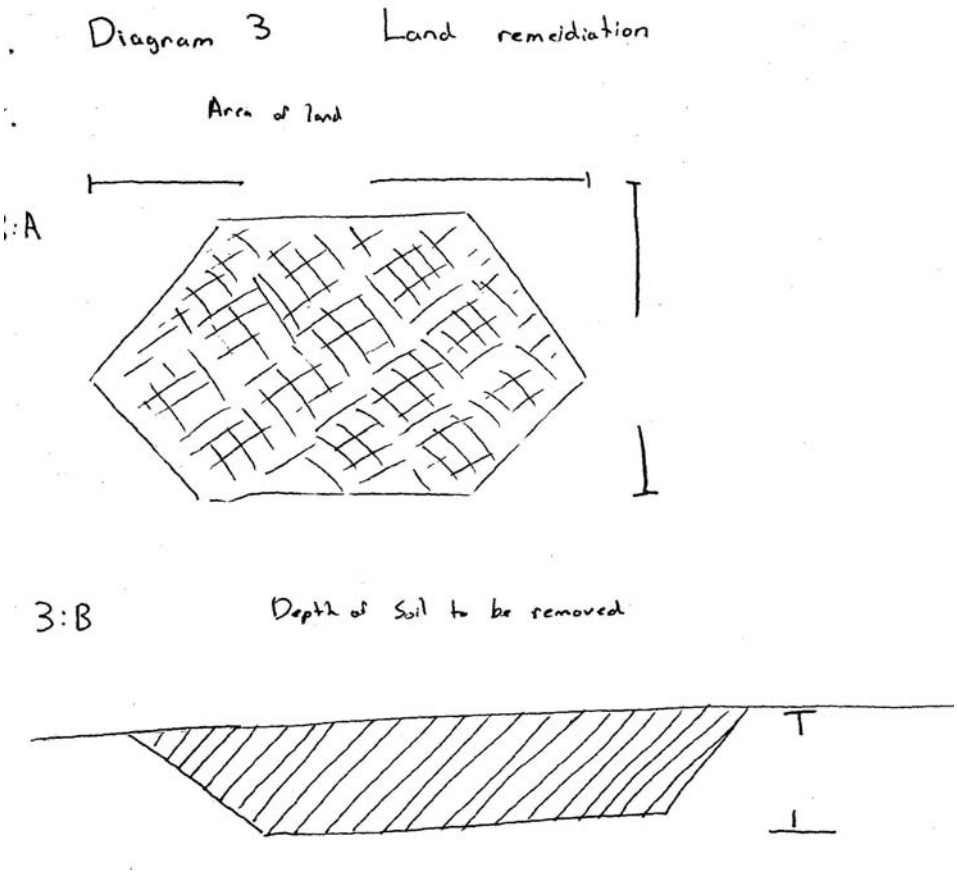


1:D

Pressure Pump / Solvent Mixer:



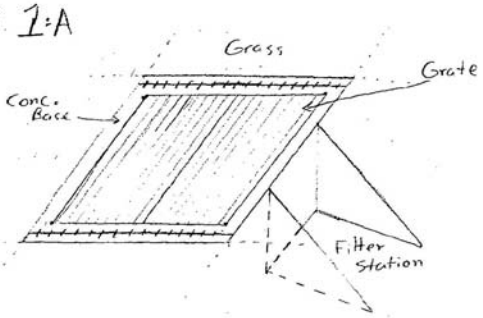
Portfolio F1234 (Continued):



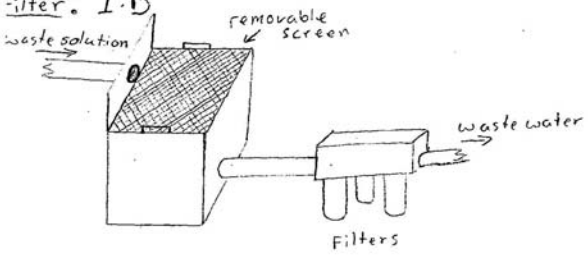
Portfolio F1234 (Continued):

Automated Equipment
wash-down Rack

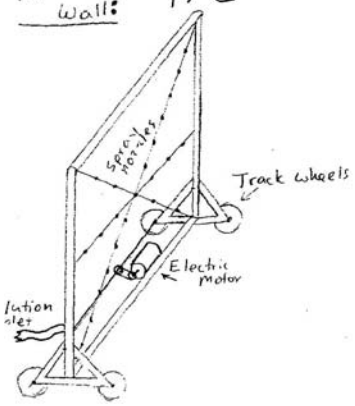
Base: 1:A



Filter: 1:B

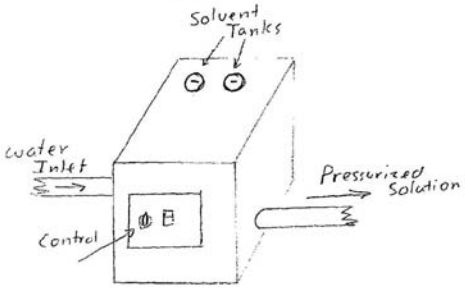


Automated wall: 1: C



1: D

Pressure Pump / Solvent Mixer:



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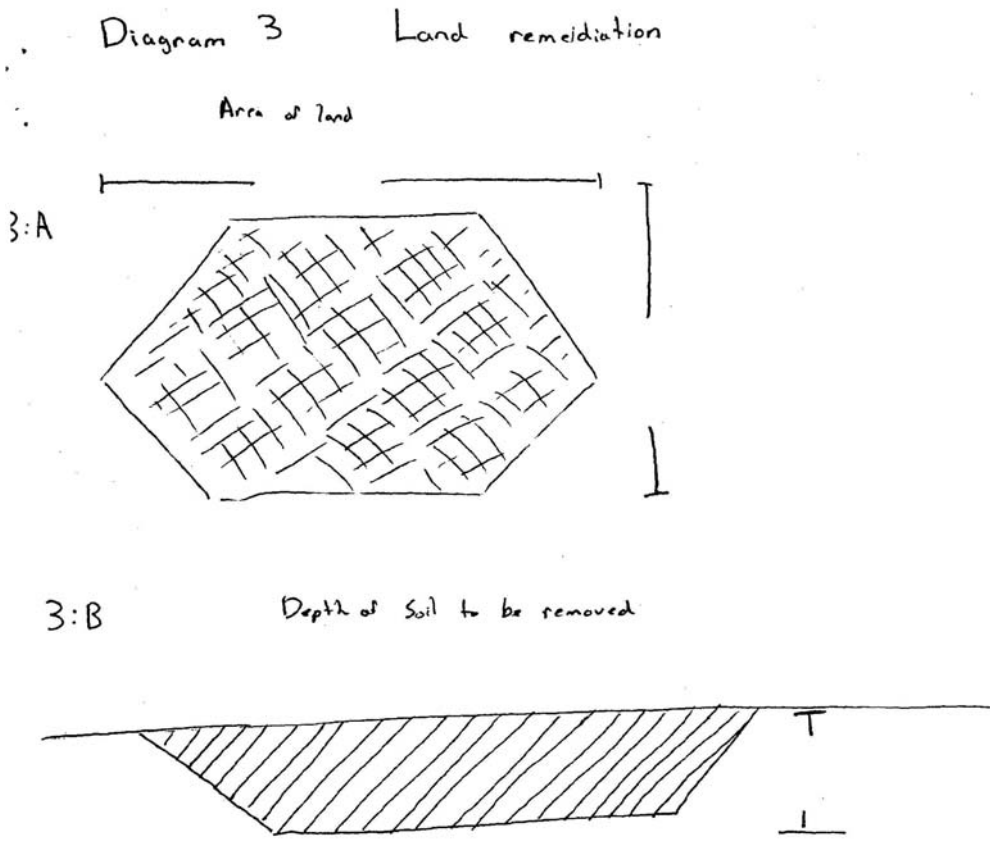

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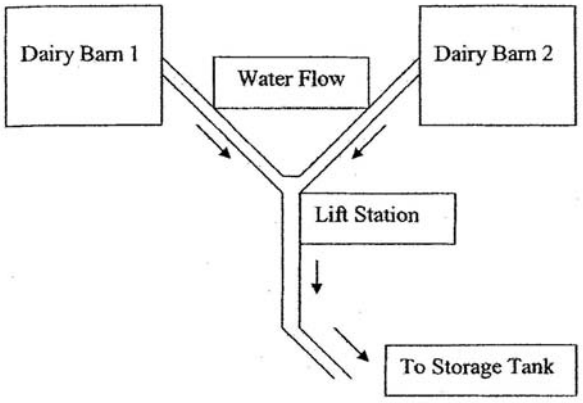

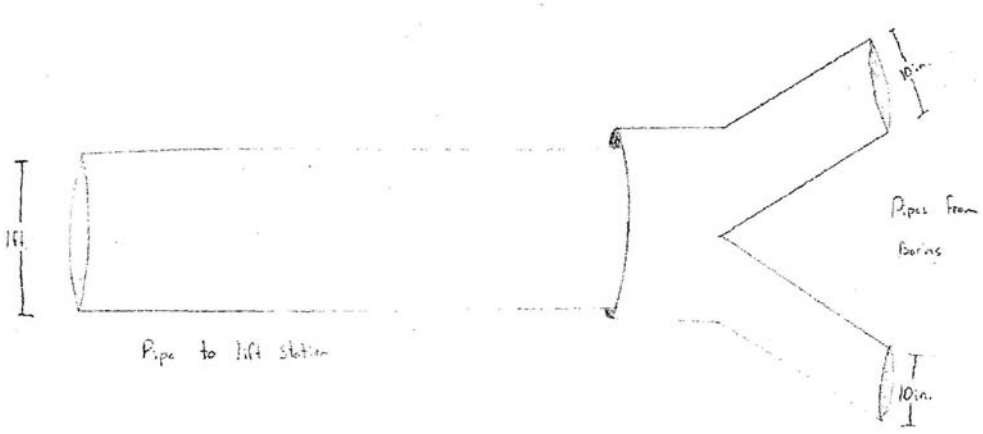

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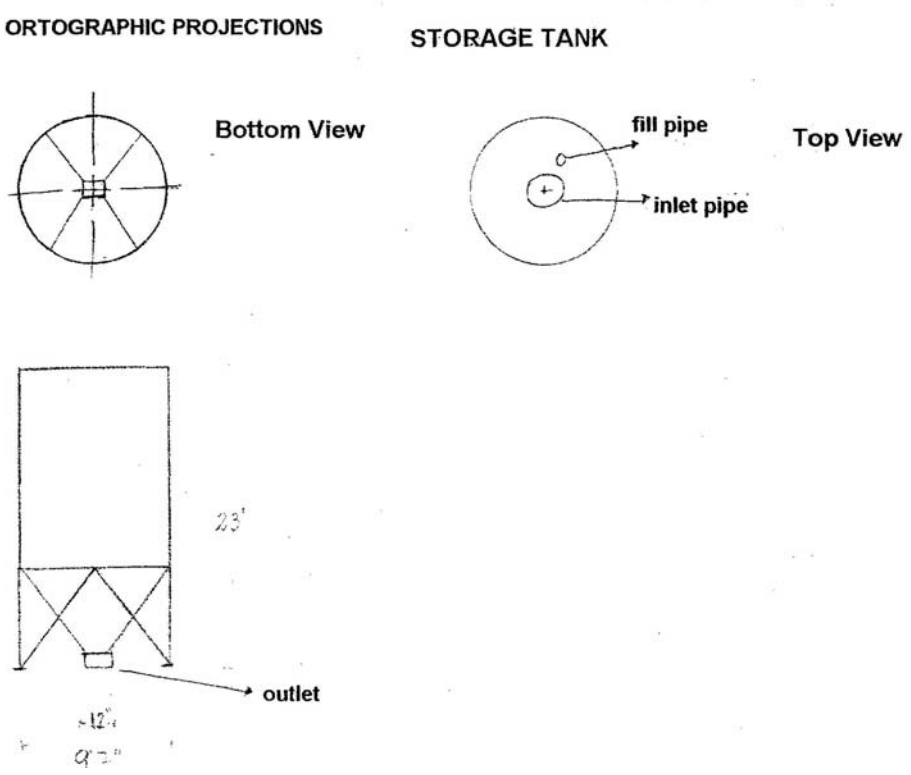

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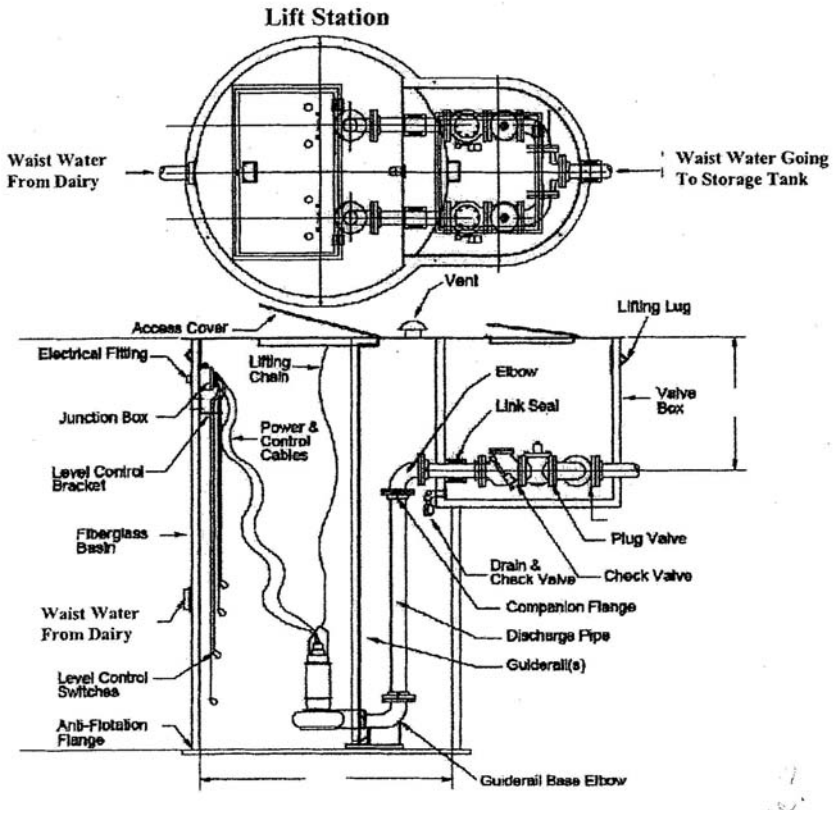
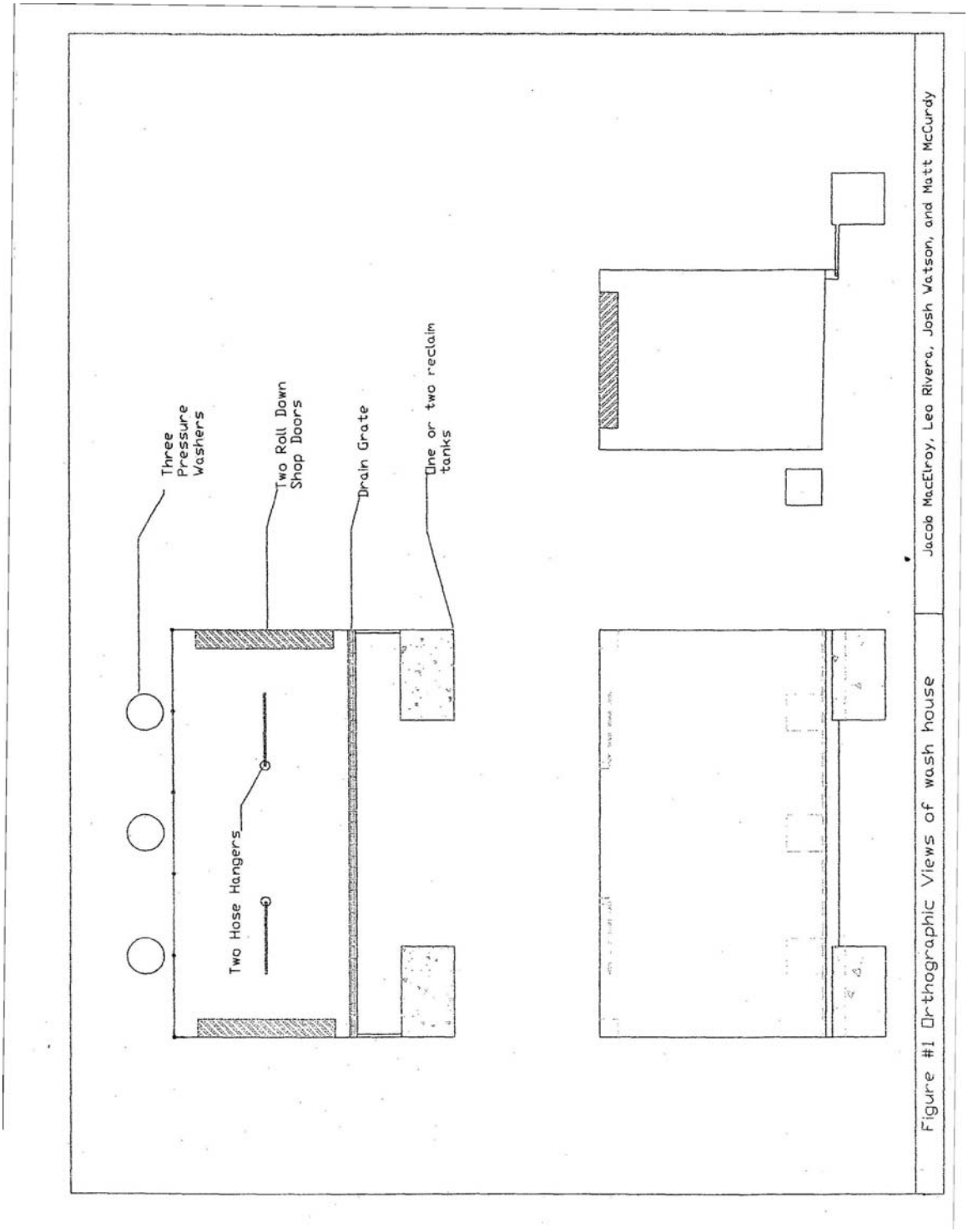


Portfolio E2346:



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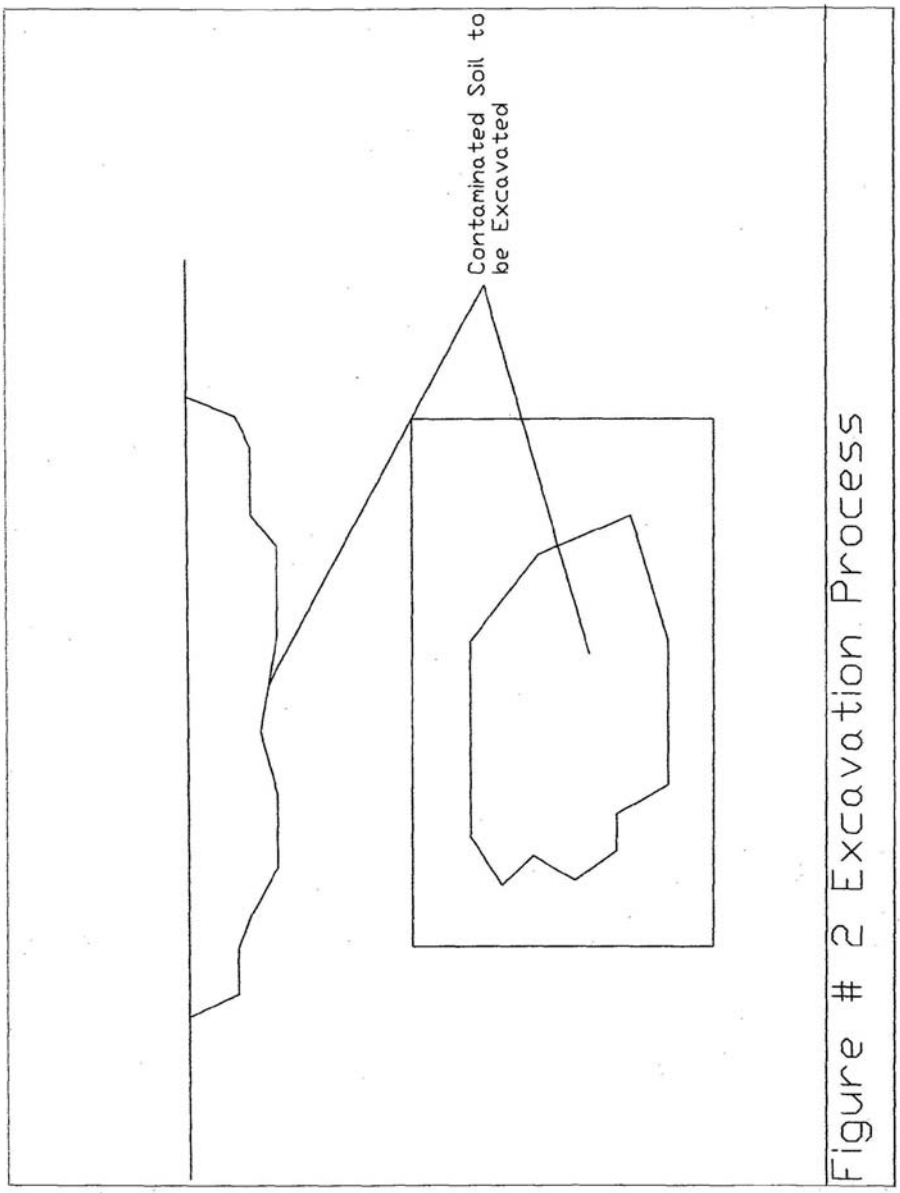

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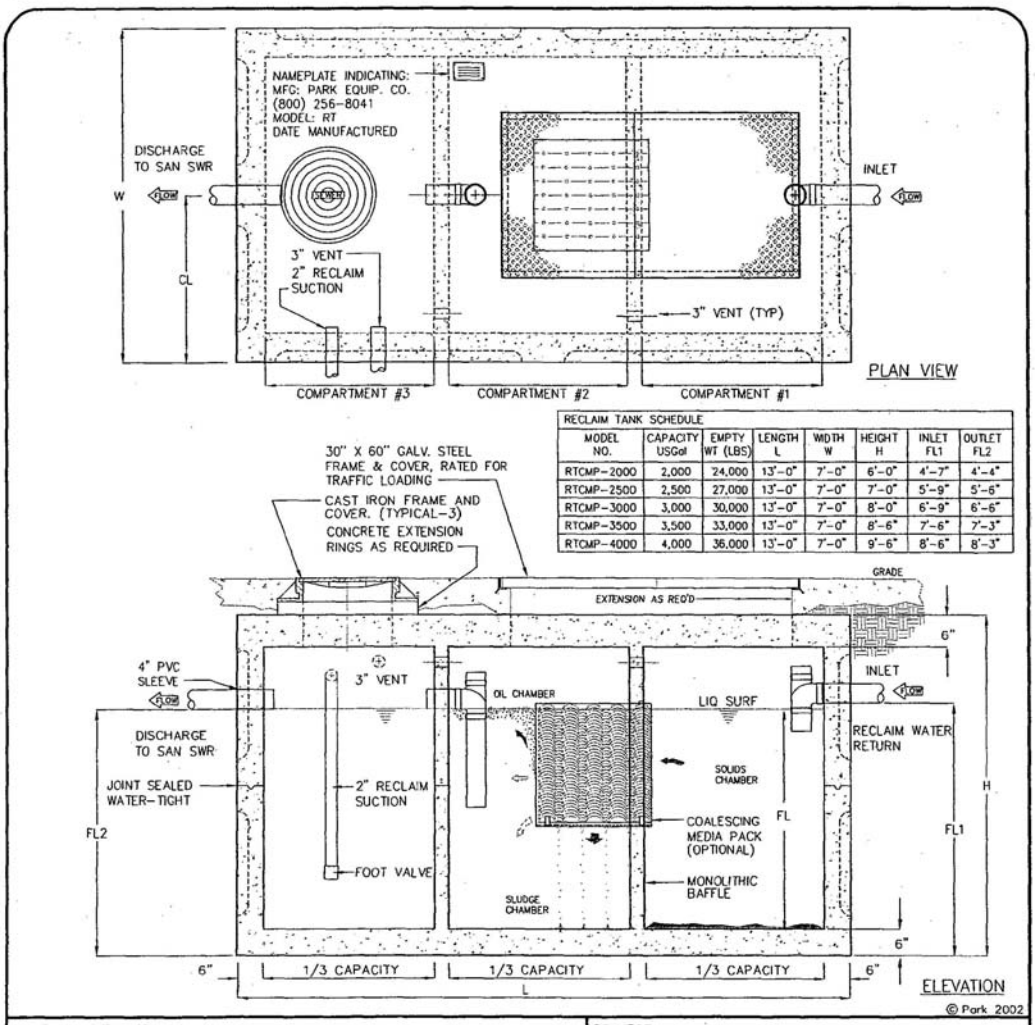

RECLAIM TANK SCHEDULE							
MODEL NO.	CAPACITY USGal	EMPTY WT (LBS)	LENGTH L	WIDTH W	HEIGHT H	INLET FL1	OUTLET FL2
RTCMP-2000	2,000	24,000	13'-0"	7'-0"	6'-0"	4'-7"	4'-4"
RTCMP-2500	2,500	27,000	13'-0"	7'-0"	7'-0"	5'-9"	5'-6"
RTCMP-3000	3,000	30,000	13'-0"	7'-0"	8'-0"	6'-9"	6'-6"
RTCMP-3500	3,500	33,000	13'-0"	7'-0"	8'-6"	7'-6"	7'-3"
RTCMP-4000	4,000	36,000	13'-0"	7'-0"	9'-6"	8'-6"	8'-3"

Specifications

CONCRETE : Class 1 concrete with design strength of 4500 PSI at 28 days. Unit is of monolithic construction of floor and first stage of wall with sectional riser to required depth.

REINFORCEMENT: Grade 60 reinforced with steel rebar conforming to ASTM A615 on required centers or equal.

C.I. CASTINGS: Manhole frames, covers or grates are manufactured of grey cast iron conforming to ASTM A48-76 Class 35. Manhole shall have 24 inch inside diameter.

Engineering Data

Interceptor is structurally and hydraulically engineered conforming to Uniform Plumbing Code. Nominal capacity as indicated.

Field excavation and preparation shall be completed prior to delivery of interceptor. Use dimensional data as shown.

PROJECT :
CUSTOMER :
GC :
ENGINEER :
ORDER # : DATE :

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MODEL RT w/ 3 COMPARTMENTS

SCALE	NONE	DWG. NO.	REV.
DATE	6/94	RTCMP-1	A

VITA

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