THE EFFECTS OF DURATION OF EXPOSURE TO THE REAPS MODEL IN DEVELOPING STUDENTS' GENERAL CREATIVITY AND CREATIVE PROBLEM SOLVING IN SCIENCE

by

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DEDICATION

To my father, my mother, my father-in law, my mother-in law, my wife, and my daughters for their love, support, and prayers…

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

ABSTRACT

The Real Engagement in Active Problem Solving (REAPS) model was developed in 2004 by C. June Maker and colleagues as an intervention for gifted students to develop creative problem solving ability through the use of real-world problems. The primary purpose of this study was to examine the effects of the REAPS model on developing students' general creativity and creative problem solving in science with two durations as independent variables. The long duration of the REAPS model implementation lasted five academic quarters or approximately 10 months; the short duration lasted two quarters or approximately four months. The dependent variables were students' general creativity and creative problem solving in science. The second purpose of the study was to explore which aspects of creative problem solving (i.e., generating ideas, generating different types of ideas, generating original ideas, adding details to ideas, generating ideas with social impact, finding problems, generating and elaborating on solutions, and classifying elements) were most affected by the long duration of the intervention. The REAPS model in conjunction with Amabile's (1983; 1996) model of creative performance provided the theoretical framework for this study.

The study was conducted using data from the Project of Differentiation for Diverse Learners in Regular Classrooms (i.e., the Australian Project) in which one public elementary school in the eastern region of Australia cooperated with the DISCOVER research team at the University of Arizona. All students in the school from first to sixth grade participated in the study. The total sample was 360 students, of which 115 were exposed to a long duration and 245 to a short duration of the REAPS model. The principal investigators used a quasi-experimental research design in which all students in the school received the treatment for different durations.

Students in both groups completed pre- and posttests using the Test of Creative Thinking-Drawing Production (TCT-DP) and the Test of Creative Problem Solving in Science (TCPS-S).

A one-way analysis of covariance (ANCOVA) was conducted to control for differences between the two groups on pretest results. Statistically significant differences were not found between posttest scores on the TCT-DP for the two durations of REAPS model implementation. However, statistically significant differences were found between posttest scores on the TCPS-S. These findings are consistent with Amabile's (1983; 1996) model of creative performance, particularly her explanation that domain-specific creativity requires knowledge such as specific content and technical skills that must be learned prior to being applied creatively. The findings are also consistent with literature in which researchers have found that longer interventions typically result in expected positive growth in domain-specific creativity, while both longer and shorter interventions have been found effective in improving domain-general creativity.

Change scores were also calculated between pre- and posttest scores on the 8 aspects of creativity (Maker, Jo, Alfaiz, & Alhusaini, 2015a), and a binary logistic regression was conducted to assess which were the most affected by the long duration of the intervention. The regression model was statistically significant, with aspects of generating ideas, adding details to ideas, and finding problems being the most affected by the long duration of the intervention. Based on these findings, the researcher believes that the REAPS model is a useful intervention to develop students' creativity. Future researchers should implement the model for longer durations if they are interested in developing students' domain-specific creative problem solving ability.

Keywords: REAPS, DISCOVER, PBL, TASC, Developing General Creativity, Developing Creative Problem Solving in Science

CHAPTER I: INTRODUCTION

Problem Solving

Considering the myriad challenges facing society today, the ability to engage in creative problem solving is one of the most important survival tools humans have at their disposal. Many educators and psychologists believe that the skills involved in creative problem solving are teachable. Political leaders have become vocal about the necessity of developing students' abilities in creative problem solving by engaging them in solving real-world problems. For instance, King Abdullah ben Abdul-Aziz of Saudi Arabia pronounced *Building a Creative Society* as the most important national goal for the near future. Toward that end, he established the King Abdul-Aziz and His Companions Foundation for Giftedness and Creativity (Al-Saud, 2011), which provided several summer programs for gifted students to (a) develop their latent potentials to the maximum level, (b) improve their critical and creative thinking skills, and (c) apply scientific principles to solve real-world problems (Muammar, 2011).

Education is one of the most important factors in economic competitiveness; a successful education system promotes the success of its nation, especially evidenced throughout the twentieth century. One of the most notable limitations that educators and political leaders have recognized in today's schools has been that the knowledge taught in classrooms has not transferred well to the knowledge needed for professional success (Boud & Feletti, 1991). While some scholars in the field of education have felt that "school is not 'the world' but a place that presents its students with an 'image' of the world" (Westbury, 2002, p. 110), I argue that to provide students with an abstraction of the world that will ultimately be useful to them, educators must redesign their curricula around real-world problems. In this vein, Dewey (1937) recommended that school should not be simply preparation for life, but should be more like life itself (as cited in Burke, 2010, p. 36).

In many classic texts and research studies in the field of education, researchers have emphasized the benefits of redesigning school curricula around real-world problems drawn from students' local environments. Dewey (1923) critiqued the traditional curricula in which teachers ignored the context of the student's life: "The child is taken out of his familiar physical environment, hardly more than a square mile or so in area, into the wide world—yes, and even to the bounds of the solar system. His little span of personal memory and tradition is overlaid with the long centuries of the history of all peoples" (p. 342). Here Dewey introduced the idea of reflective thinking and problem solving, a foundation that subsequent educators used in redesigning school curricula. He believed that reflective thinking revealed the distinction between knowing and doing (Dewey, 1933). Educators who developed hands-on and problem solving educational models such as Problem-Based Learning (PBL) based those innovations on Dewey's thought (Boud & Feletti, 1991).

Experts in the field of giftedness and creativity have suggested that problem solving is an underlying component of cognitive ability. Gardner (1983) stated that human intellectual competence was "… a set of skills of problem solving enabling the individual to resolve genuine problems or difficulties…and must also entail the potential for finding or creating problems—thereby laying the groundwork for the acquisition of new knowledge" (p. 60). Problem solving has been a valuable experience for students, supporting their learning of content and promoting the development of life skills (Holroyd, 1989). Through redesigning school curricula around open-ended, real-world problems, educational systems could be improved to develop competent thinkers and problem solvers (Nickerson, 1981).

Definition of Problem Solving

From the beginning of the twentieth century to the present, researchers have made many advances in the study of creative problem solving ability, including developing theoretical frameworks, definitions, assessments, and approaches to teaching it, and they have also worked toward the development of a conceptual definition of creative problem solving. Polya (1962) defined problem solving as a process "… to search consciously for some action appropriate to attain a clearly conceived, but not immediately attainable aim" (p. 698). Jackson (1975) formed the conceptualization, "Problem = Objective + Obstacle" (Adams & Wallace, 1991, p. 107). Adeyemi (2008) elaborated on Jackson's conceptual equation by stating, "Problem solving involves taking a series of actions in the process of an investigation that seeks to bridge the gap between a problem state and the anticipated goal" (p. 698).

Reviewing the literature about problem solving across different fields, including education, sociology, psychology, business, and industry reveals that the concept of problem solving has been used in slightly different ways in each field. For instance, psychologists and educators equate problem solving with a desire to achieve a certain goal, with the accomplishment of this goal understood as a requirement for finding missing information through the use of complex logic (Robertson, 2001). Bahar (2013) reviewed various definitions of problem solving and concluded that similarities exist across the definitions articulated in different fields, despite the varying concepts of problem solving found within each definition. For instance, a consistent theme Bahar identified across definitions was that "… problem solving is an act toward making an unknown situation known" (p. 14).

Due to the diversity in extant definitions of problem solving, Schoenfeld (1992) recommended that any researchers conducting work involving this construct should provide a clear operational definition of the term “problem solving”. Following Schoenfeld’s advice, my operational definition of problem solving in the current study is a self-directed, cognitive process used by the problem solver (i.e., student) toward making the unknown solution known, whether the problem and the method are known or unknown to the problem solver (see Table 1.1).

Types of Problem Solving

Hennessey and Amabile (2010) defined creative problem solving ability as a process that results in a product, idea, or problem solution that is valuable to a person or society. Creative problem solving ability has often been conceptualized with reference to the problem solver (Barron, 1988; Guilford, 1950; Taylor, 1988; Torrance, 1962; Weisberg, 1986), motivating some researchers to focus on testing or identifying aspects of creativity as cognitive ability, personality traits, or behavioral characteristics that are believed to influence the individual’s ability to engage in the complex tasks of problem solving. Other researchers have studied environments that might be conducive to the development of problem solving ability (Elam & Mead, 1987; Mouchiroud & Lubart, 2002; Torrance, 1990; Sailer, 2011; Williams, 2001), questioning whether creative problem solving could be enhanced and reinforced by external factors. Studying creative problem solving as a solution (e.g., final product) has also played a part in this field, whether as an outcome variable for measuring creative problem solving ability (Amabile, 1982; Amabile, 1996; Hennessey & Amabile, 2010) or an innovation that might vary from one culture to another or across genders (Alhusaini & Maker, 2010; Alhusaini & Maker, 2015; Goldenberg, Mazursky, & Solomon, 2001; Kaufman, 2006; Rob & Jan, 1992).

Approaching creative problem solving as a social interaction between the presenter (e.g., teacher) and the solver (e.g., student), Getzels and Csikszentmihalyi (1967; 1976) introduced the concept of problem types into the literature. The key finding from Getzels and

Csikszentmihalyi's research was that problem solving could be categorized into three types based on the social interaction between the presenter and solver of a problem. Problem types ranged from convergent thinking to divergent thinking (Guilford, 1950) based on the knowledge of each person about (a) the problem, (b) the method for solving the problem, and (c) the solution. Maker (1993) adapted the idea of problem types by expanding the continuum from three types to six, enabling a gradual progression from closed to open-ended problems (see Table 1.1). The expansion of problem types in Maker's work was especially significant in that it transferred Getzels and Csikszentmihalyi's ideas from the field of research with adults into the field of educational practices with students (Maker, 1993; Maker, Jo, & Muammar, 2008; Maker & Schiever, 2010).

Table 1.1

Problem continuum

Problem Type		**Problem**		**Method**		**Solution**	
		Presenter	**Solver**	**Presenter**	**Solver**	**Presenter**	**Solver**
Closed	**I**	Specified	Known	Known	Known	Known	Unknown
	II	Specified	Known	Known	Unknown	Known	Unknown
	III	Specified	Known	Range	Unknown	Known	Unknown
Open-Ended	**IV**	Specified	Known	Range	Unknown	Range	Unknown
	V	Specified	Known	Unknown	Unknown	Unknown	Unknown
	VI	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Note: Adapted from "Problem Continuum" by Maker, J., & Schiever, W. (2010). *Curriculum development and teaching strategies for gifted learners* (3rd ed.). Austin, TX: Pro-Ed.

Maker and Schiever's (2010) problem continuum contains problem solving types ranging from I to VI. In problem Type I, the problem is clearly stated and students solve a problem that has only one correct solution. In problem Type II, the problem is specified, but only the presenter knows the method for solving the problem, which has only one correct solution. In problem Type III, the problem is specified, but many methods for its solution are possible, and only the presenter knows the correct solution. In problem Type IV, the problem is specified, multiple solutions are possible, and only the presenter knows the range of possible solutions. In problem Type V, the problem is specified, and neither the presenter nor solver knows the method or the solution. In other words, the problem solver is responsible for generating possible methods and selecting the one to use, then generating and elaborating on solutions and selecting the best. In problem Type VI, the problem is unknown and neither the presenter nor the solver knows the method or the solution. Problem Types V and VI are the most open-ended and potentially real-world problems; solving these types of problems needs to be an integral part of curricula in today's schools.

Adapting the idea of problem types into science education, Johnstone (1993) developed another problem continuum that involved eight problem types based on the information available about three aspects of problem solving: data, method, and goal (see Table 1.2). In this context, Brabeck and Wood (1990) and Jonassen (1997) provided two general categories for problem types as follows: (a) well-structured, in which the solution is known, important data are given, one method is preferred (if there are different methods, they will all lead to the same correct answer), and the solutions are either correct or incorrect; and (b) ill-structured, in which many solutions exist (sometimes there is no preferred solution), important data are not available, many methods can be used, and many decisions and judgments about the solution are necessary. In Johnstone's continuum, Type 1 problems are algorithmic, basic exercises. Types 1 and 2 are normal problems that can be found in textbooks and traditional tests. Types 3 and 4 are more complex conceptual problems because the data are incomplete. Types 5 to 8 are open-ended problems and are considered real-world problems.

Table 1.2

Problem Types (Johnstone, 1993)

General Classification		Type	Data	Method	Goal
Well-structured	**Algorithmic Problems**	**1**	Given	Familiar	Given
		2	Given	Unfamiliar	Given
	Conceptual Problems	**3**	Incomplete	Familiar	Given
		4	Incomplete	Unfamiliar	Given
Ill-structured	**Open-ended Problems**	**5**	Given	Familiar	Open
		6	Given	Unfamiliar	Open
	Real-world Problems	**7**	Incomplete	Familiar	Open
		8	Incomplete	Unfamiliar	Open

Note: Adapted from "*Problem Types (Johnstone, 1993)*" by Surif, J., Ibrahim, N. H., & Dalim, S. F. (2014). Problem solving: Algorithms and conceptual and open-ended problems in chemistry. *Procedia-Social and Behavioral Sciences, 116*, 4955-4963.

Although Johnstone's (1993) problem types and Getzels' and Csikszentmihalyi's (1967; 1976) ideas are similar in many aspects, such as classifying problem types from closed to open-ended, differences between the two approaches can be found. Getzels and Csikszentmihalyi included only three problem types, which were later expanded by Maker and Schiever (2010) into six types, whereas Johnstone included eight problem types. Getzels and Csikszentmihalyi's problem types included the presenter's and solver's knowledge about the problem as an essential aspect, whereas Johnstone's problem types were based on the availability of data. While Johnstone's ideas are useful in explaining independent learning, Getzels and Csikszentmihalyi's ideas are more useful in explaining problem solving types as interactive processes. For this reason, I believe Getzels and Csikszentmihalyi's conceptualization of problem types is more appropriate for use in educational settings than Johnstone's because of the focus on the social interaction between the presenter (e.g., teacher) and solver (student). Maker and Schiever's problem continuum, comparable to Johnstone's eight problem types because of the varying status of the problem, has been used and discussed more in the literature about giftedness and creativity.

The Real Engagement in Active Problem Solving (REAPS) Model

The Real Engagement in Active Problem Solving (REAPS) model is a relatively new educational approach intended to meet the educational needs of gifted students. The REAPS model is based on the general education curriculum and includes the following three teaching models: (a) the Discovering Intellectual Strengths and Capabilities while Observing Varied Ethnic Responses (DISCOVER) model, (b) Thinking Actively in a Social Context (TASC), and (c) Problem-Based Learning (PBL). The three combined models contain pragmatic elements that complement each other, yet all models share a primary emphasis on the development of creative problem solving ability. The main focus of the REAPS model has been to assist students in finding and solving the most complex real-world problems (i.e., Types V and VI) to create solutions that are efficient, effective, ethical, elegant, and economical (Maker, 1993; Maker, Zimmerman, Alhusaini, & Pease, 2015b).

The story of the REAPS model began in 2004 when Maker, Zimmerman, and Schiever, in collaboration with doctoral students from Turkey, Saudi Arabia, Taiwan, Russia, and Egypt, used the three models together in a professional development project for teachers of gifted students in math and science in Seoul, Korea (Maker & Zimmerman, 2008). Later, Maker and Zimmerman worked with elementary and middle school teachers to implement the model in several classrooms of a public school in the Navajo Indian Nation, (Reinoso, 2011). The results of these projects, as well as the responses from teachers from the two countries who used the model, were very encouraging. Based on this success in two different contexts, the model was then applied in elementary classrooms with students of various levels of ability in the urban Southwestern United States over a span of 5 years, with Mr. Randal Pease as the teacher and doctoral students from Turkey, Saudi Arabia, and Chile as collaborators (Zimmerman, Maker, Gomez-Arizaga, & Pease, 2011).

The DISCOVER Model

The DISCOVER model has two major components: (a) a problem continuum (see Table 1), and (b) a theoretical grounding in the Prism of Learning Model (Prism) (Maker, Alhusaini, Pease, Zimmerman, & Alamiri, 2015c). When using the DISCOVER model, teachers (a) provide opportunities for students to develop their multiple abilities, (b) provide opportunities for students to solve a variety of problem types, (c) use active hands-on learning with the creative 'tools' possessed within each of the multiple abilities, (d) integrate the culture of the students and the local community into the curriculum, and (e) plan curricula around state standards and abstract themes (Maker, Muammar, & Jo, 2008; Maker, Muammar, Serino, Kuang, Mohamed, & Sak, 2006).

The Prism, based on Maker's research conducted in the United States and Anuruthwong's research conducted in Thailand, was synthesized in a collaborative work and presents the overall theoretical framework grounding the recent literature on the DISCOVER model (Anuruthwong, 2002; Maker & Anuruthwong, 2003). The primary elements of Prism are similar to Sternberg's (1985; 1997) theory of Successful Intelligence and Gardner's (1983; 1999) Multiple Intelligences theory. For example, as depicted in *Figure* 1.1, human abilities include both general capacities (i.e., Memory, Creativity, Logic, Intuition, and Metacognition) and specific human abilities (i.e., Linguistic, Mathematical, Auditory, Emotional, Social, Scientific, Mechanical-Technical, Visual/Spatial, Bodily/Somatic, and Spiritual/Ethical). All the general capacities are necessary for the successful functioning of all specific human abilities and are expressed through one or more of these specific abilities (Maker, et al., 2015c).

A prism (see *Figure* 1.1) is used as a metaphor to demonstrate how problem solving and the aspects of learning situations are related to the development and expression of gifts, talents, and creativity through different human abilities (Maker & Anuruthwong, 2002). Problem solving is the white light that enters the prism, stimulating or activating the desire to meet a challenge. The Prism has three sides. One side reflects the environment; while another side reveals the competencies or outcomes educators help learners acquire; and on the third side, the learning processes exist. In the middle, or the axis, are human abilities. Guides and teachers must provide the type of environment that will enable each person to be illuminated from within (Maker, et al., 2015c).

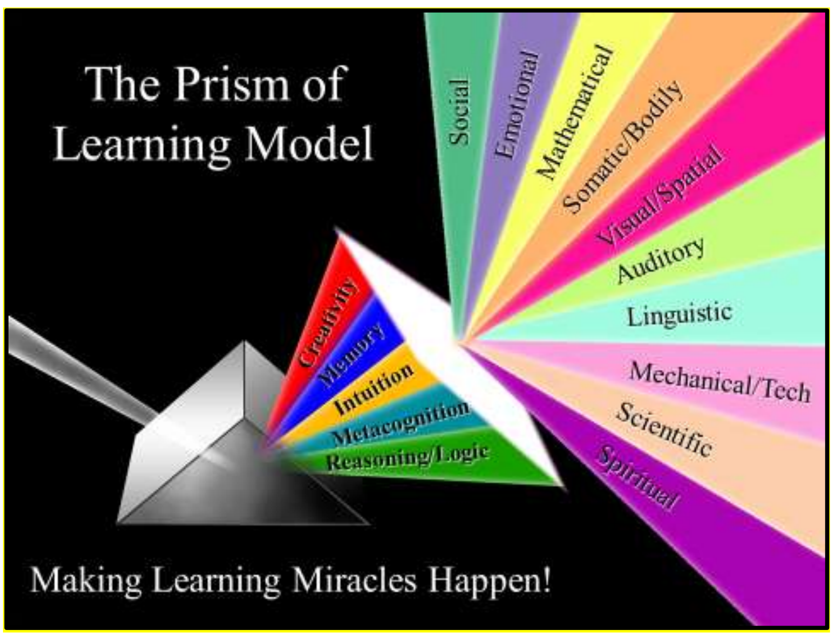


Figure 1.1: The Prism of Learning Model

Note: The figure was published in Maker, J., Alhusaini, A., Pease, R., Zimmerman, R., & Alamiri, F. (2015c). Developing creativity, talents, and interests across the lifespan: Centers for creativity and innovation. *Turkish Journal of Giftedness and Education, 5*(2), 83-109.

The TASC Model

Using the TASC model for the development of thinking and problem solving, students are led through a process of eight steps in which they (a) gather and organize information about the problem—both what they already know and what they want to find out, (b) clearly define the problem they will solve, (c) generate as many ideas as possible for solving the problem, (d) evaluate the ideas and select those that they consider the best by developing and applying clear criteria, (e) implement their selected solution or plan, (f) evaluate the quality of this implementation, (g) communicate their solution to others, and (h) reflect on what they learned (Wallace, 2001; Wallace & Bentley, 2002; Wallace, Cave, & Berry, 2009).

The TASC model is depicted as a wheel (*Figure* 1.2) to indicate that although the steps are generally followed sequentially, students often return to earlier steps when necessary. At step one, students gather and organize the available information about the task or problem situation. At the second step, they define the problem or clarify the task. Next, they generate many different ways to solve the problem or complete the task. After they have developed different ideas, the students develop criteria for evaluating them and deciding which ones to use. Then, students implement their solution or complete their task. Next, students evaluate their implementation of the solution and share their results with others. Finally, they use their metacognitive skills to review what they have done well, what they need to improve, and what they learned; they take time to think about how to solve a similar problem better in the future (Wallace, 2003; Wallace, Maker, & Cave, 2004).

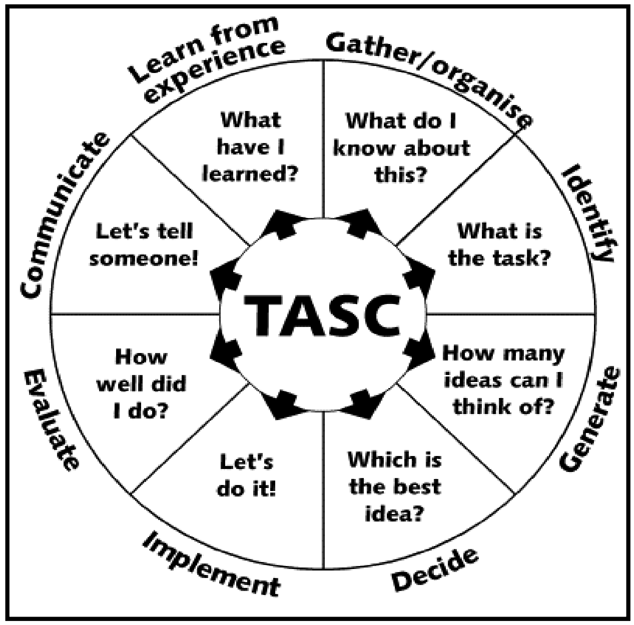


Figure 1.2: The TASC Model

Note: The figure was taken from Wallace B. (2003). *Using history to develop thinking skills at key stage 2*. London: David Fulton Publishers.

The PBL Model

Problem-Based Learning (PBL) is a student-centered model in which students learn in small groups. Teachers act as facilitators, guiding students and encouraging their learning through the use of open-ended problems (Barrows, 1996). Using PBL, teachers assist their students in choosing problems from their local, regional, or national contexts and, when students become more advanced, from international contexts. The PBL model requires using real, rather than contrived, problems which, because they are real, are complex and contain both multiple factors and multiple methods appropriate in searching for solutions. Using stakeholder groups has been an important component of the PBL model so that students can consider a problem from multiple perspectives, develop realistic solutions, and present these solutions to real audiences (Maker, et al., 2015b).

The following are key aspects of the PBL model: (a) Problems are ill-structured to allow students free inquiry, (b) problems are real-world problems, (c) problems are interdisciplinary, (d) students must work collaboratively, (e) students spend most of the time in self-directed learning, (f) students reflect on what they have learned, (g) students use self and peer assessments, (h) teachers assess students based on their progress toward the goals, and (i) the PBL model is used as the pedagogical base in the curriculum and not part of a didactic curriculum (Savery, 2006; Wee, Kek, & Kelley, 2003). Maker, Jara and Alamiri (2015d) emphasized the seven characteristics of PBL that were most clearly used in the REAPS model, which are presented in *Figure* 1.3.

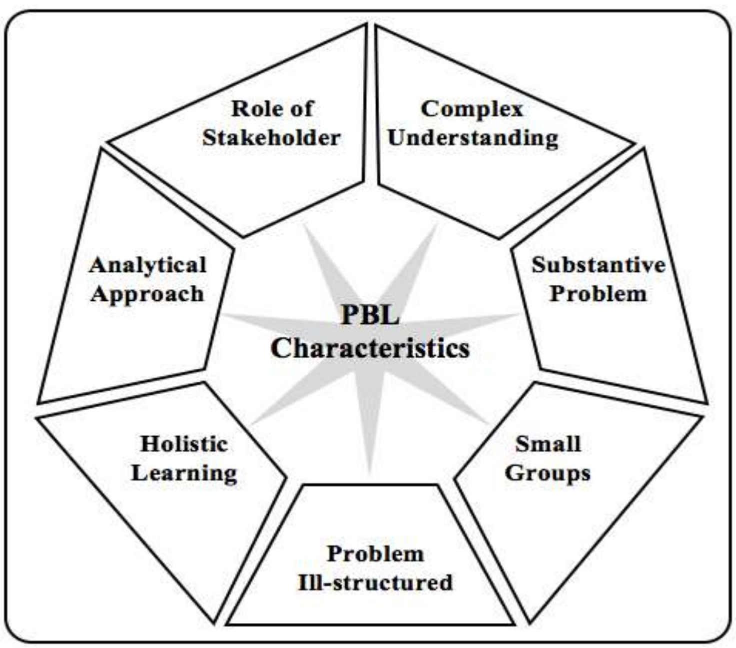


Figure 1.3: The characteristics of PBL emphasized in REAPS

Note: The figure was presented by Maker, J., Jara, M., & Alamiri, F. (2015d) Global partnerships to create evidence-based curricula and programs for gifted students in Saudi Arabia and Chile: *The 21st Biennial World Conference of the WCGTC*. Denmark: Odense.

Appropriateness and Validity of the REAPS Model

Maker and colleagues evaluated the appropriateness and validity of REAPS as a combination of three models (DISCOVER, TASC, PBL) using a list of questions proposed by Maker and Schiever (2005). When evaluating the *appropriateness* of the REAPS model, researchers asked questions about how easily the model could be combined with other models to provide a comprehensive curriculum, or be adapted to all content areas, or a school's administrative structure, or to the curriculum framework for special schools for the gifted. When evaluating the *validity* of the REAPS model, researchers asked questions about whether the model was developed using appropriate methods, what research was available to demonstrate its effectiveness, what evidence was available to support the theoretical validity of the model, and whether the approach was defensible as a qualitatively different program for gifted students. Researchers have found that the REAPS model as a combination of DISCOVER, TASC, and PBL is a valid and appropriate model that may particularly benefit gifted, and possibly other students in general education classrooms (Maker, et al., 2015b).

Comprehensiveness of the REAPS Model

Using the principles for differentiating Content, Process, Product, and Learning Environment, which are components of the curriculum recommended for differentiating school curricula for gifted students (Maker & Schiever, 2010), Maker, et al. (2015b) evaluated the *comprehensiveness* of the combination of the three models in the REAPS model. Results of the evaluation are summarized in Table 1.3.

Table 1.3

Evaluation of the comprehensiveness of the REAPS model

Differentiation	**Principles**	**PBL**	**TASC**	**DISCOVER**
Content	Abstractness	√		√
	Complexity	√		√
	Variety	√	√	√
	Organization for Learning Value	√		√
	Study of People			
	Study of Methods	√	√	√
Process	Higher Level Thinking	√	√	√
	Open-Endedness	√	√	√
	Discovery	√	√	√
	Evidence of Reasoning	√	√	
	Freedom of Choice	√	√	√
	Group Interaction	√	√	
	Pacing	√	√	√
	Variety		√	√
Product	Result from Real Problems	√		
	Presentation to Real Audience	√	√	
	Transformation	√	√	√
	Variety	√	√	√
	Self-Selected Format	√	√	√
	Appropriate Evaluation		√	
Learning Environment	Learner Centered	√	√	√
	Encouragement of Independence	√	√	√
	Openness	√	√	√
	Acceptance		√	√
	Complexity	√		√
	Variety of Groupings		√	√
	Flexibility	√	√	√
	High Mobility	√	√	√

Note: Summarized from “Evaluation of Comprehensiveness of Teaching Models in REAPS” by Maker, J., Zimmerman, R., Alhusaini, A., & Pease, R. (2015b). Real Engagement in Active Problem Solving (REAPS): An evidence-based model that meets content, process, product, and learning environment principles recommended for gifted students. *APEX: The New Zealand Journal of Gifted Education, 19*(1).

Maker and her colleagues successfully integrated the three teaching models with general education curricula to introduce a comprehensive teaching model, REAPS, which has been researched in many published and unpublished studies. Alhusaini, Maker, and Alamiri (in press) introduced a visualization of the REAPS model (*Figure* 1.4) to assist educators in better understanding its components, including the general education curriculum, considered an essential piece when the model is adapted in different environments, content areas, and grade levels.

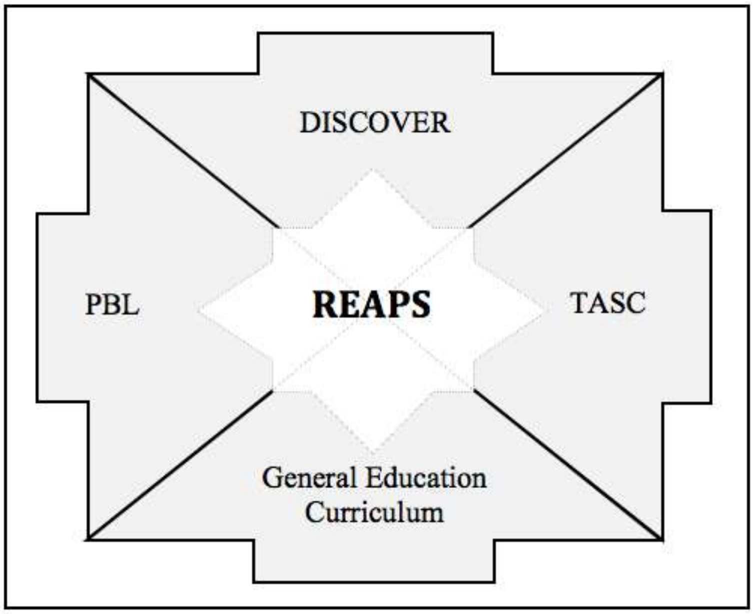


Figure 1.4: The REAPS model

Note: The figure was introduced by Alhusaini, A., Maker, J., & Alamiri, F. (in press). *Adapting the REAPS model to develop students' creativity in Saudi Arabia: An exploratory study*. Manuscript submitted for publication. Submitted to *Annals of Psychology Journal*, December, 2015.

Key Aspects of Implementation of the REAPS Model

Problem Solving and the REAPS Model

The problem solving aspect of the REAPS model has been explained and well supported by research. The DISCOVER model provides a meaningful, wide range of problem-solving types (i.e., I to VI) that can be used to guide students' thinking and development of content understanding throughout the school curricula. The integration of the TASC model is critical because it provides the structure, sequence, and organization for creating solutions. Incorporating the real-world model of PBL ensures that students are actively involved in the inquiry-based process and in realistic, complex problem solving, with the teacher facilitating and guiding their learning.

Small Group Work and the REAPS Model

Scholars in the field of giftedness and creativity, such as Sternberg in the Developing Expertise (1998) and the Cultural Context of Intelligence (2007) theories, and Gardner in the Multiple Intelligences theory (1983; 1999), have presented more inclusive conceptualizations of giftedness and creativity by providing a framework in which cognitive ability can be viewed as developed in multiple domains (i.e., domain-specific). With these theories, researchers have opened the door to an understanding of giftedness as both influenced by society and predicated on specific abilities (i.e., personal strengths). I believe this conceptualization provides a powerful rationale for adapting group work as a teaching method in the field of giftedness. Teachers who employ group work acknowledge both the specific strengths of each student and the importance of the polyphonic knowledge that results from collaboration. The founders of the REAPS model drew from modern theories in the field of giftedness as frameworks for identifying and teaching all students (Maker, 1993; Maker, Nielson, & Rogers, 1994), as well as a belief in the effectiveness of small group work in providing students the opportunity to learn from one another and attain higher levels of thinking.

The shift in using new teaching strategies such as small group work occurred years ago. This movement was influenced by the work of Johnson and Johnson (1989); and Johnson, Johnson, and Smith (1991), in which they synthesized 375 studies on the effects of group work on students' competitive and individualistic efforts, achievement, and productivity. Their research provided strong evidence that small group work affected students' higher-level reasoning, generation of new ideas, academic achievement, self-concept, and communication.

Cohen (1994) found that small group work was an effective tool for reaching intellectual goals, developing creative problem solving and higher levels of thinking, learning complex information, and acquiring basic skills. Small group work has also been shown to be effective in developing oral language proficiency (Cohen, 1994).

The historical assumption that gifted students prefer to work alone was found to be not accurate in all cases. In a recent study, Walker and Shore (2015) investigated sixty-nine high-performing students' learning preferences. They found that students' preferred to work with others depending on the learning situation. Although not much research on the use of group work with gifted students was found, incorporating the body of research with general education students on group work has been extremely useful to enhance the goals of the REAPS model. More research about grouping gifted students was within the framework of traditional cooperative learning strategies, such as giving small groups tasks to solve, but did not address the main problems found by Cohen (1994), such as status or inequitable participation in the group work (i.e., students in each group tend to develop a hierarchy based on their social ranking, in which a member of high rank will dominate the group), and the establishment of norms (i.e., a basic set of required behaviors or standards that govern students' behavior while working in their groups) and roles (i.e., each student in the group must have important work to do, and without his or her work the group cannot function). In the REAPS model, these problems were discussed thoroughly with the teachers interested in using the model, especially when designing stakeholder groups emphasizing that each student needed to have a specific and important role in his or her group.

Action Research and the REAPS Model

The terms, “Action Research,” “Research by Practitioners,” and “Teachers’ Research,” have similar meanings. To promote flexibility in adapting the REAPS model to new contexts, its creators encouraged teachers to use an action research perspective when designing and implementing the model (Alhusaini, et al., in press). Alamiri (2013) found that using participatory action research empowered Saudi teachers as it improved their professional knowledge and teaching practices when working with gifted students using the REAPS model.

History of action research. Action research methodology can be traced to the social psychologist Kurt Lewin, who used it for research he conducted on social issues in 1946 (Kemmis & McTaggart, 1988). Lewin introduced the concept of action research as a method of social inquiry distinguished from other methodologies by its emphasis on social change. The two key ideas in Lewin’s conceptualization of the action research method are group decision-making and the promise of improvement. Stenhouse (1975) later introduced what he called “Teachers’ Research” while working on the Humanities Curriculum Project in the United Kingdom (at the Center for Applied Research in Education at the University of East Anglia). Stenhouse also emphasized that to implement effective changes in school curricula, teachers have to work as active researchers (Cochran-Smith & Lytle, 1990).

Definition of action research. Action research is a method “conducted by one or more individuals or groups for the purpose of solving a problem or obtaining information in order to inform local practice” (Fraenkel & Wallen, 2010, p. 589). The founder of action research, Lewin (1948), defined it as “comparative research on the conditions and effects of various forms of social action, and research leading to social action” (p. 202). The critical nature of action research is “an implicit critique of the usefulness of basic research for social change” (Cochran-

Smith & Lytle, 1990, p. 3). One could say, therefore, that action research in the field of education has entailed a scientific (i.e., problem solving) procedure by which an instructor—by himself or working with a group of colleagues—identifies a problem in his class or school, hypothesizes a solution, implements the solution, observes the outcome, modifies or changes the solution based on reflection, and perhaps repeats this sequence of steps as needed. Fraenkel and Wallen classified action research as a discrete research category, which they called "Research by Practitioners". They argued that action research was not inherently associated with either quantitative or qualitative methodologies, although action researchers used both of these methods to collect their data. A theoretical model of action research is presented in *Figure* 1.5.

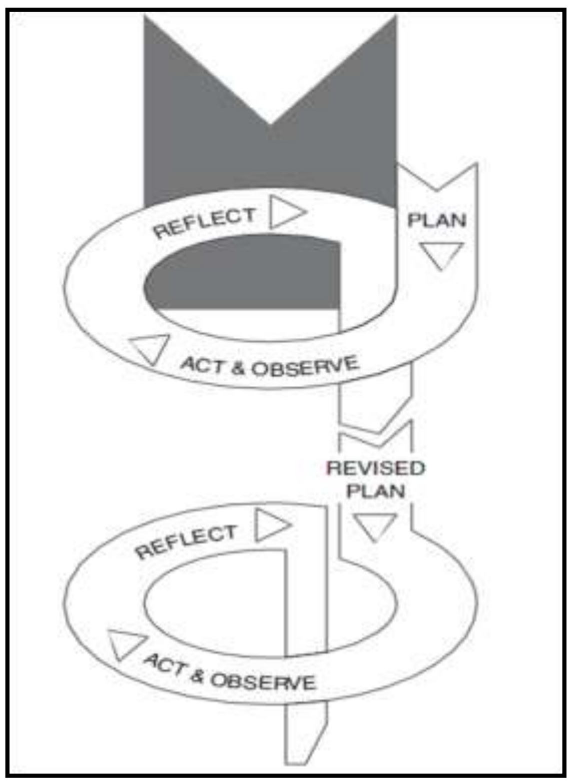


Figure 1.5: The action research spiral

Note: The figure was introduced by Kemmis, S., & McTaggart, R. (2005). Participatory action research: Communicative action and the public sphere. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE handbook of qualitative research* (3rd ed., pp. 559–603). Thousand Oaks, CA: SAGE Publications.

Theoretical Framework

The first theoretical framework in this study is the REAPS model, which was originally designed to meet the specific needs of gifted students in a variety of educational settings. Using the REAPS model positively influences the school culture with effective practices such as action research, small group work, hands-on activity, and real-world problem solving. Culture is a word that has often been used colloquially but is difficult to define. Griswold (1994) defined "school culture" as consisting of a group of people who have interacted with each other and journeyed toward shared meanings and assumptions. School culture is the pattern of values, beliefs, and traditions that have been shaped over time (Thompson, 1993). Therefore, in any school, the collective members (e.g., students, teachers, and staff) have adapted to their school's unique culture and thus have a shared common background. Adapting the REAPS model as a school-wide teaching process becomes an important base of the school culture over time.

The second major theoretical framework used in this study is Amabile's (1983; 1996) model of creative performance, which contains three components: domain-relevant skills (i.e., domain-specific), creativity-relevant skills (i.e., domain-general), and task motivation. Domain-relevant skills are those required in a specific field of knowledge (e.g., individuals must know a considerable number of skills to be creative in the specific domain of scientific creativity). Creativity-relevant skills contain the cognitive and personal characteristics that are important for individuals to be creative (e.g., general creativity). Task motivation includes incentives toward the task at hand (Table 1.4). To develop students' creativity, teachers and researchers address the model's three components together in their intervention. In this study, the researcher focused on one cognitive component that was domain-specific (creative problem solving in science) and one that was domain-general (general creativity). Task motivation was discussed in different studies, such as Wu, Pease and Maker's (2015) study about students' perceptions.

Table 1.4

Amabile's model of creative performance

	Creative Problem Solving Components		
	Domain-Relevant Skills (Domain-Specific)	**Creativity-Relevant Skills (Domain-General)**	**Task Motivation**
Includes	Strong knowledge about a specific domain, technical skills required to deal with the complexity, and special domain-relevant talent and desire to work	Appropriate cognitive style, implicit or explicit knowledge of heuristics for generating general ideas, and conducive working style	Attitudes toward the task at hand and perceptions of own motivation for undertaking the task
Depends on	Innate cognitive abilities, strong knowledge, innate perceptual and technical skills, extensive formal and informal education	Training and experience in generating ideas, personality characteristics, and positive attitudes toward creativity	Initial level of intrinsic motivation and presence or absence of salient extrinsic constraints

Note: Adapted from *"Model of Creative Performance"* by Amabile, T. M. (1983). *The social psychology of creativity.* New York: Springer-Verlag.

Significance of the Study

When reviewing the available literature in which researchers have addressed the development of creativity and problem solving ability in students, I did not encounter any studies in which researchers investigated the effect of duration of exposure as an independent variable. This study could be linked to the literature on developing expertise (Sternberg, 1998). However, I reviewed the available literature from studies conducted in elementary schools with attention to their intervention length (ranging from one day to three years), the instruments used to measure the outcomes (domain-specific or domain-general), and the significance of the outcomes (positive changes, some changes, or no changes in students' creative problem solving ability) to make a research-informed conclusion that I could use as a foundation and rationale for conducting this study. Across all of the studies reviewed, I discovered that longer interventions usually resulted in expected positive growth in student-domain-specific creative problem solving ability. However, gains in students' domain-general creative problem solving ability were produced by both longer and shorter interventions. This initial observation is consistent with Amabile's (1983) model, especially pertaining to her explanation that domain-relevant skills include aspects such as specific knowledge and technical skills, which must be developed in school before being applied creatively. Therefore, the results of this study were evaluated for consistency with my observations about the effects of different durations of intervention exposure.

This study provides several practical, theoretical, and methodological contributions to the existing research on the development of creative problem solving and to literature on the REAPS model. For example, previous researchers tested the effects of the REAPS model in several small-scale studies that each included one or two classrooms. However, C. June Maker, Robert Zimmerman, Randal Pease, and Myra Janes designed the overall study to use the REAPS model as an educational approach to differentiate the school curricula. Additionally, in this study, a new variable—creative problem solving in science—was examined in conjunction with general creativity, which allowed for the assessment of the effects of the model while considering Amabile's (1983; 1996) idea of domain-relevant skills (e.g., science) and creativity-relevant skills (e.g., general creativity) as essential components of creative problem solving.

From a methodological perspective, the current study contributes to existing research on the development of creative problem solving and to literature on the REAPS model in its design feature of testing two levels of exposure to the intervention (long and short duration) within a quasi-experimental design (Singleton & Straits, 2005). Because students from all grade levels and classes participated in two nonequivalent groups (i.e., long and short duration of exposure to the REAPS model), I was able to investigate the potential effects of different lengths of exposure to the REAPS model. Examining the effects of the REAPS model in a new environment (i.e., Australia) provided an additional advantage, as well as a contribution to the body of research on development of creativity in that country.

Statement of Purpose

The primary purpose of this study was to investigate the effects of two different lengths of duration of exposure to the REAPS model (i.e., long and short) in developing students' general creativity and creative problem solving in science. The secondary purpose of the study was to explore which aspects of creativity were most affected by the duration of exposure to the REAPS model.

Research Questions

1. What were the differences in general creativity between students who were exposed to the REAPS model for a duration of five quarters and those who were exposed to it for two quarters?
2. What were the differences in creative problem solving in science between students who were exposed to the REAPS model for a duration of five quarters and those who were exposed to it for two quarters?
3. Which aspects of creativity changed the most during the study?

CHAPTER II: REVIEW OF THE LITERATURE

The DISCOVER, TASC, and PBL Models

The Real Engagement in Active Problem Solving (REAPS) model has been shown to be practical, effective, and adaptable in aiding teachers in developing students' creative problem solving ability (Alhusaini, et al., in press; Maker & Pease, 2008; Maker & Zimmerman, 2008). The three models that comprise REAPS—Discovering Intellectual Strengths and Capabilities while Observing Varied Ethnic Responses (DISCOVER), Thinking Actively in a Social Context (TASC), and Problem-Based Learning (PBL)— complement each other: PBL emphasizes substantive content that connects to real-world problems, DISCOVER provides guidance to teachers in designing different types of problems, and TASC contributes a structured problem-solving methodology (Maker, et al., 2015b).

While the REAPS model was developed to address the needs of gifted students, all students in general education classrooms can benefit from its implementation. Renzulli (1998) argued that a good educational model for gifted students should also benefit other students in general education classrooms. For instance, Kim, VanTassel-Baska, Bracken, Feng, and Stambaugh (2014) examined the effect of the Integrated Curriculum Model (ICM) on science content knowledge and reasoning skills of 1,651 students. Also, VanTassel-Baska, Bracken, Feng, and Brown (2009) assessed 2,771 students' growth in reading comprehension and critical thinking after using the William and Mary language arts curriculum. In both studies, researchers found that all students in general education classrooms benefitted from the implementation of the ICM and William and Mary language arts curricula.

In this chapter, previous empirical studies of the DISCOVER, TASC, and PBL models are reviewed to delve deeper into understanding each model alone as well as to establish a research-based rationale for conducting this study. Specifically, the relevant literature in which researchers used the DISCOVER, TASC, and PBL models to develop students' creative problem solving ability are presented with close examination of the following three major aspects: (a) the grade and ability levels of study participants; (b) the length of time for which the intervention was applied, as well as the academic content area included in the intervention; and (c) the outcomes of the intervention. The question that guided this literature review was the following:

1. How effective have the DISCOVER, TASC, and PBL models been in developing students' creative problem solving ability?

Methods for Selecting Studies

As a member of the DISCOVER research team at the University of Arizona, in collaboration with a group of researchers, I conducted two extended literature reviews (Alhusaini & Maker, 2011; Maker, Alhusaini, Zimmerman, Pease, Schiever, & Whitford, 2014), which I used as sources for the current review. For the purposes of the current literature review, however, I reanalyzed the articles focusing on different aspects. I also conducted a search for other relevant articles using Academic Search Complete, which includes 725 worldwide databases—accessed through the University of Arizona's library. Finally, I reviewed various landmark theoretical and practical texts, as well as some unpublished studies.

Locating Studies

First source. Alhusaini and Maker (2011) first conducted a keyword search of the database Academic Search Complete, accessed through the library of the University of Arizona. They searched for studies in which researchers investigated the effectiveness of using DISCOVER's open-ended problem solving to develop students' creative problem solving ability. Following keyword searches, a hand search was conducted of issues of three well-known journals in the field of giftedness and creativity published from 2006 to 2011. Twenty of 208 studies were selected using specific evaluation criteria (see Alhusaini & Maker, 2011). For the purpose of the current study, another search inclusion criterion was that the study had to be conducted at the elementary school level (i.e., from first to sixth grade). Applying this criterion reduced the final number of studies to 10 (Cheng, Wang, Liu, & Chen, 2010; Hertzog, 1998; Hicks, 1980; Houtz, Rosenfield, & Tetenbaum, 1978; Maker, Jo, & Muammar, 2008; Maker, Muammar, Serino, Kuang, Mohamed, & Sak, 2006; Maker, Rogers, & Nielson, 1996; Russo, 2004; Tallent-Runnels & Yarbrough, 1992; Zimmerman, Maker, Gomez-Arizaga, & Pease, 2011).

Second source. In the second literature review, Maker, et al. (2014) began with hand searches followed by keyword searches in six well-known journals in the field of education of giftedness and creativity from 2005 to 2014. They reviewed 1222 abstracts and selected 367 for further review based on several criteria (Maker, et al., 2014). The researchers then conducted a search of Academic Search Complete for studies addressing the effects of various academic curricula on gifted students. The keyword searches yielded 195 articles, out of which 82 were selected for inclusion. The total number of articles included for initial evaluation was 449 out of 1417. The articles were then classified into three categories: theory, practice, and research.

The research category classified by Maker, et al. (2014) included 81 empirical studies obtained from hand searches and 82 empirical studies obtained from keyword searches. From these 163, studies for the current study were selected, based on the following criteria: (a) The study design had to be experimental, qualitative, or action research; (b) the intervention specifically had to use the DISCOVER, PBL, and TASC models to teach an academic content area; (c) the study had to be conducted in a school setting; (d) it needed to be appropriate for the elementary school level; and (e) it had to be high quality research.

When evaluating the literature identified by Maker, et al. (2014), particular focus was placed on studies in which the researchers used the DISCOVER, PBL and TASC models. Of the 163 studies evaluated, 17 contained specific research using the TASC model, of which 10 studies remained after application of the inclusion criteria (Ball & Henderson, 2009; Davies, 2008; Faulkner, 2008; Fitton & Gilderdale, 2008; Goddard, 2008; Holyoake, 2008; Humphries, 2008; Lakey, 2009; Leyland, 2009; Wallace, 2008). Of the 16 studies in which the PBL model was examined, six studies were retained (Araz & Sungur, 2007; Azano, Missett, Callahan, Oh, Brunner, & Moon, 2011; Hung, Hwang, Lee, Wu, Vogel, Milrad, & Johansson, 2014; Koch, Kumpf, & Zumbach, 2004; Li, 2012; Swanson, 2006). This process yielded a total of 16 out of the initial 163 studies to be analyzed for this literature review.

Third source. Several seminal studies found by hand search were included in this review. Specifically, an online search for early publications authored by the founder of the TASC model, Belle Wallace, was conducted, and one study was identified for inclusion (Adams & Wallace, 1991). Three books that included empirical research findings from use of the TASC model authored by Wallace and colleagues were also selected for review (Wallace, 2003; Wallace, Cave, & Berry, 2009; Wallace, Maker, Cave & Chandler, 2004). Four studies whose authors addressed the PBL model were added: a master's thesis (Stephens, 2010), a PhD dissertation (Scott, 2005), a new empirical published study (Tsal, Shen, & Lu, 2015), and proceedings from a conference presentation of an empirical study (Lee, Hwang, Hung, & Lin, 2014). Three studies in press were included (Alhusaini, Maker, & Alamiri, in press; Gomez-Arizaga, Bahar, Maker, Zimmerman, & Pease, 2016; Wu, Pease, & Maker, 2015), as well as two practical articles (Maker & Zimmerman, 2008; Reinoso, 2011). The third literature source yielded an additional 12 manuscripts for inclusion in this review.

Analyses and Findings

Of the literature reviewed in this chapter, no studies were identified in which the researchers specifically studied the effects of different durations of exposure to the interventions as an independent variable. Therefore, each study was examined for length of the intervention (i.e., long or short), instruments used to measure outcomes (i.e., domain-specific or domain-general), and significance of the results (i.e., positive changes, some changes, or no changes in students' aspects of creative problem solving ability). The studies were analyzed based on the reported effects of using each model (i.e., DISCOVER's open-ended problem solving, TASC, and PBL) and Amabile's (1983; 1996) model of creative performance was used to determine if researchers measured creative problem solving using a domain general or a domain specific framework.

The Effects of Using Open-Ended Problem Solving

The story of the problem solving types began in the middle of the twentieth century. As a response to the overuse of traditional tests to judge students' cognitive abilities, Guilford (1950) developed the Structure of Intellect theory, in which he identified a variety of cognitive abilities including divergent thinking and convergent thinking. Getzels and Csikszentmihalyi (1967) developed a theoretical and practical perspective of problem solving types that ranged from convergent thinking (i.e. Type I) to divergent thinking (i.e. Type III). Maker and several of her colleagues adapted the idea of problem solving types in a practical way by expanding them to include six types instead of three to complete one of the most ambitious educational projects, of which the goal was to meet all students' needs by assessing and then offering them the appropriate curricula (Maker, 1993; Maker, et al., 2008; Maker, et al., 1996; Maker & Schiever, 2010).

In ten studies (Cheng, et al., 2010; Herzog, 1998; Hicks, 1980; Houtz, et al., 1978; Maker, et al., 2008; Maker, et al., 2006; Maker, et al., 1996; Russo, 2004; Tallent-Runnels & Yarbrough, 1992; Zimmerman, Maker, Gomez-Arizaga, & Pease, 2011), researchers examined the use of open-ended problem solving when teaching students. Table 2.1 includes brief summaries of the studies arranged alphabetically by the researchers' surnames.

Although the studies had been previously evaluated for quality (Alhusaini & Maker, 2011), for the current review, they were reevaluated by using the scale developed by Maker et al. (2014), which has shown greater accuracy than Alhusaini and Maker's scale when using the quality indicators developed by Odom, et al. (2004). Using a scale ranging from 0 to 2 (with 0 indicating not present; 1, some information provided; and 2, a high level of information or appropriateness), a rating was assigned for each criterion for each study. A summary of the ratings based on quality indicators for experimental and qualitative designs are presented in Tables 2.2 and 2.3. All ten studies were found to be of high quality based on the indicators used; Table 2.4 is a summary of the analyses of the selected studies.

Table 2.1

Studies of the effects of using open-ended problem solving

Study	Purpose	Participants	Design	Intervention
1. Cheng, et al. (2010)	Investigated the effects of a training program in the Chinese language to develop students' creative problem solving in writing	64 fourth grade students in two classrooms	Experimental, two group posttest design	Five weeks of implementing a Chinese writing program in which open-ended problem solving was integrated with the content of language
2. Hertzog (1998)	Explored methods of curriculum differentiation for gifted students by examining students' responses to open-ended problem solving	11 third and fourth grade students	Qualitative study, observation and document analysis	One academic year through which gifted students were presented with different open-ended problem solving in various academic content areas
3. Hicks (1980)	Examined whether or not creative thinking could be enhanced in fourth grade students by using open-ended problem solving activities	23 fourth grade students	Experimental, one group pretest-posttest design	Eight weeks of intervention in which open-ended problem solving was integrated with the content of reading
4. Houtz, et al. (1978)	Studied the development of creative problem solving ability in gifted and general education students in one elementary school	233 students from second through sixth grade	Experimental, adapted design	Ten weeks of implementing a problem solving program that included open-ended problem solving with all academic content areas

Continued

Table 2.1

Studies of the effects of using open-ended problem solving (Continued)

Study	Purpose	Participants	Design	Intervention
5. Maker, et al. (2008)	Studied the relationship between development of creativity and implementation of the DISCOVER model	1986 students from kindergarten to sixth grade	Experimental, three-group adapted design	Three years of implementing the DISCOVER model during which open-ended problem solving was integrated with all academic content areas
6. Maker, et al. (2006)	Examined the effectiveness of the DISCOVER model in developing students' general creative problem solving	2983 students from kindergarten to sixth grade	Experimental, three-group adapted design	Three years of implementing the DISCOVER model during which open-ended problem solving was integrated with all academic content areas
7. Maker, et al. (1996)	Examined the effectiveness of the DISCOVER model on students' problem solving ability	46 students including 27 males and 19 females	Experimental, two group pretest-posttest design	One year of implementing the DISCOVER model during which open-ended problem solving was integrated with all academic content areas
8. Russo (2004)	Examined the differences in creativity between gifted and general education students after teaching them open-ended problem solving using a FPS program	37 students in fifth and sixth grade	Experimental, one-group pretest-posttest design	Six months of teaching the students open-ended problem solving activities using a FPS program integrated with all academic content areas

Continued

Table 2.1

Studies of the effects of using open-ended problem solving (Continued)

Study	Purpose	Participants	Design	Intervention
9. Tallent-Runnels and Yarbrough (1992)	Examined whether gifted students participating in a FPS program would feel a greater sense of control over their futures than other students	338 gifted and general education students in fourth to sixth grade	Experimental, one-group posttest design	One year of implementing a FPS program during which open-ended problems were integrated with the content of social science
10. Zimmerman, et al. (2011)	Examined the use of concept maps as a tool to solve problems in earth science as a part of implementing the REAPS model with third grade students	50 students, including 25 from each of two classes	Experimental, two group pre- and posttest adapted design	One year of teaching the students earth science using the REAPS model during which open-ended problems were integrated with science

Note: Studies were numbered from 1 to 10, ordered alphabetically by the researchers' surnames; the purpose, participants, design, and intervention were provided as a summary about each study; DISCOVER = Discovering Intellectual Strengths and Capabilities while Observing Varied Ethnic Responses; FPS = Future Problem Solving.

Table 2.2

Evaluating the studies on open-ended problem solving based on the quality indicators of experimental designs

	Study								
Quality Indicators of Experimental Design	**1**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Participants									
• Sufficient information provided	2	2	2	2	2	2	2	2	2
• Criteria for inclusion reported	2	2	2	2	2	2	2	2	2
Intervention									
• Procedure described clearly	2	2	1	2	2	2	2	2	2
• Fidelity of the intervention evaluated	1	0	1	2	2	2	0	0	1
Variables									
• Used valid and reliable measures	2	2	1	2	2	2	2	2	2
• Local reliability reported	0	2	1	1	1	1	2	0	2
• Used appropriate measures	2	2	2	2	1	2	2	2	2
Data Analysis									
• Study designed appropriately	2	1	2	2	2	2	2	2	2
• Applied appropriate analysis	2	1	2	2	2	2	2	2	2
• Effect size reported	2	0	0	2	2	0	0	1	1
Total Quality Indicators	**17**	**14**	**14**	**19**	**18**	**17**	**16**	**15**	**18**
%	**85**	**70**	**70**	**95**	**90**	**85**	**80**	**75**	**90**

Note: Studies were numbered 1 to 10, ordered alphabetically by the researchers' surnames (see Table 2.1); the selected quality indicators of experimental designs were adapted from Maker and Alhusaini (2011), and Maker, et al. (2014); the cut-point was 70%; the 10 studies were considered high-quality research; ratings were assigned using the following scale: 0 = the indicator was not found, 1 = the indicator was found to a limited degree, 2 = the indicator was found, and % = percentage of quality indicators in each study.

Table 2.3

Evaluating the studies on open-ended problem solving based on the quality indicators of qualitative designs

	Study
Quality Indicators of Qualitative Designs	**2**
Observation or Interview Designs	
• Participants selected for observation(s) or interview(s) were appropriate and described adequately.	2
• The setting(s) or context(s) selected were appropriate and described adequately	2
• Sufficient time was spent	2
• The researcher fit well into the site	2
• The research had a minimal impact on the setting	1
• Field notes were systematically collected or interviews were recorded and transcribed.	1
Content Analysis Designs	
• Meaningful documents were found and their relevance was established	1
• Documents were obtained and stored in a careful manner	0
• Documents were sufficiently described and cited	1
• Sound measures were used to ensure confidentiality of private documents	2
Quality Indicators of Data Analysis for All Qualitative Designs	
• Results were sorted and coded in a systematic and meaningful way	2
• Sufficient rationale was provided for what was included in the report	2
• Documentation of methods to establish trustworthiness and credibility were clear	2
• Reflections about researchers' personal perspectives were provided	1
• Conclusions were substantiated by sufficient quotations from participants	2
Total Quality Indicators	**23**
%	**77**

Note: Studies were numbered from 1 to 10, ordered alphabetically by the researchers' surnames (see Table 2.1); the selected quality indicators of qualitative designs were adapted from Maker and Alhusaini (2011), and Maker, et al. (2014); the cut-point was 70%; the studies were considered to be high-quality research; ratings were assigned using the following scale: 0 = the indicator was not found, 1 = the indicator was found to a limited degree, 2 = the indicator was found, and % = percentage of quality indicators found in each study.

Table 2.4

Analysis across studies that used open-ended problem solving

Study	Participants								Exposure to Intervention					Outcome				
	Grade Levels						Ability		Duration		Content Area			Measurement		Results		
	1	2	3	4	5	6	GT	GE	L	S	SS	HS	AC	D-S	D-G	PC	SC	NC
1.				√				√		√	√			√		√		
2.			√	√			√		√				√		√	√		
3.				√				√		√	√				√	√		
4.		√	√	√	√	√	√	√		√			√	√			√	
5.	√	√	√	√	√	√		√	√				√		√	√		
6.	√	√	√	√	√	√		√	√				√		√		√	
7.	√	√	√				√	√	√				√	√		√		
8.					√	√	√	√		√			√		√	√		
9.				√	√	√	√		√		√				√	√		
10.			√					√		√		√		√		√		
Total	**3**	**4**	**6**	**7**	**5**	**5**	**5**	**8**	**5**	**5**	**3**	**1**	**6**	**4**	**6**	**8**	**2**	**0**
%	**30**	**40**	**60**	**70**	**50**	**50**	**50**	**80**	**50**	**50**	**30**	**10**	**60**	**40**	**60**	**80**	**20**	**00**

Note: Studies were numbered from 1 to 10, ordered alphabetically by the researchers' surnames (see Table 2.1); 1 = first grade; 2 = second grade; 3 = third grade; 4 = fourth grade; 5 = fifth grade; 6 = sixth grade; GT = Gifted students; GE = general education students; L = long exposure to the intervention; S = short exposure to the intervention; SS = Social Sciences; HS = Hard Sciences; AC = All academic content areas; D-S = domain-specific; D-G = domain-general; PC = positive changes in students' creativity; SC = some changes in students' creativity; NC = no changes in students creativity; "√" = found; % = percentage across studies.

Long duration of exposure to open-ended problem solving. Five studies were classified as long duration based on an intervention length of at least ten months (Hertzog, 1998; Maker, et al., 2008; Maker, et al., 2006; Maker, et al., 1996; Tallent-Runnels & Yarbrough, 1992). While these studies were conducted in different environments using different research methods and measurement systems, their findings seemed consistent: Using open-ended problem solving activities increased students' creative problem solving ability.

Domain-general. Four studies were in this category (Hertzog, 1998; Maker, et al., 2008; Maker, et al., 2006; Tallent-Runnels & Yarbrough, 1992). A variety of measurement systems were used to assess intervention outcomes as domain general, such as observation of students' abilities to generate creative ideas (Hertzog), measurement of self-confidence when solving different future problems (Tallent-Runnels & Yarbrough), and assessment of students' general creative problem solving (Maker, et al., 2006; Maker, et al., 2008).

Hertzog (1998) conducted a qualitative study to explore methods of curricular differentiation with gifted students by examining their responses to open-ended problem solving activities. Tallent-Runnels and Yarbrough (1992) conducted a quantitative study to examine whether gifted students believed they had control over their futures. Although Hertzog did not systematically collect observational data, she concluded that the students were able to solve open-ended problems in all academic content areas, and found that using open-ended problem solving was effective in increasing students' creative problem solving ability. Similarly, Tallent-Runnels and Yarbrough's data collection process was limited in that the authors did not report the reliability of their questionnaire. Tallent-Runnels and Yarbrough claimed that students who participated in the intervention felt strongly that they had control over their futures.

In contrast to Hertzog's (1998) and Tallent-Runnels and Yarbrough's (1992) restriction to gifted participants, Maker, et al. (2006) conducted their study in general education classrooms to assess the impact of using the DISCOVER model for three years on developing students' general creative problem solving as measured by the Test of Creative Thinking Drawing Production (TCT-DP). Similarly, Maker, et al. (2008) investigated the relationship between creativity development as measured by the TCT-DP and implementation of the DISCOVER model. In both studies (Maker, et al., 2006; Maker, et al., 2008), the researchers used an adapted experimental design in which all teachers in four different schools were included in the studies. Teachers were observed and classified into three levels of implementation (high, middle, and low). The researchers compared students' general creative problem solving based on their teachers' levels of implementing the DISCOVER model.

Maker, et al.'s (2008) findings were consistent with Hertzog's (1998) and Tallent-Runnels and Yarbrough's (1992) results in which the main conclusions were that students' general creative problem solving increased and that differences among students as a function of implementation levels were significant. However, the results found by Maker, et al. (2006) were mixed. The researchers did not find overall differences between the students in the first and third years of implementing the DISCOVER model, yet they found significant differences in the second year of implementation. Non-significant results from the first year could indicate that students needed more time to show changes as a result of the new teaching method and that teachers needed more time to learn and use the model. However, the results from the third year were unexpected and could have been a reflection of ineffectiveness of the instrument for measuring students' general creative problem solving over time (e.g., the TCT-DP has a ceiling score of 72 points) or of students not responding seriously to the posttest assessment at the end of the project.

Domain-specific. One study was categorized as using a domain-specific measurement (Maker, et al., 1996). In that study, researchers used the DISCOVER assessments to measure students' creative problem solving in five domains: Spatial Artistic, Spatial Analytical, Logical Mathematical, Oral Linguistic, and Written Linguistic.

Similar to Hertzog (1998) and Tallent-Runnels and Yarbrough (1992), Maker, et al. (1996) examined the effects of the DISCOVER model with gifted students using teachers' levels of implementation as an independent variable (i.e., implementation was categorized dichotomously as either high or low). As in other studies of the DISCOVER model, Maker, et al. differentiated teachers based on level of implementation, but only two teachers were selected: one high and one low implementer. Using a two-group pretest-posttest experimental design, the researchers found that students taught by a high implementer teacher increased in creative problem solving across all domains while those in a classroom with a low implementer teacher did not.

Short duration of exposure to open-ended problem solving. Four studies that were classified in this group had an intervention length of nine months or less (Cheng, et al., 2010; Hicks, 1980; Houtz, et al., 1978; Russo, 2004; Zimmerman, et al., 2011). The results of these four studies were consistent with students' creative problem solving abilities improving due to using open-ended problem solving activities, even given the short duration of exposure to the interventions.

Domain-general. Two studies were in this group (Hicks, 1980; Russo, 2004). Both researchers used the Torrance Tests of Creative Thinking (TTCT) to assess students' general creative problem solving. Hicks (1980) integrated open-ended problem solving in the content of reading while Russo (2004) used open-ended problem solving in all academic content areas.

Similar to Hertzog (1998), Tallent-Runnels and Yarbrough (1992), and Maker, et al. (1996), Russo (2004) studied both gifted and general education students to examine the effects of the Future Problem Solving (FPS) program on students' general creative problem solving ability. Russo used the TTCT to measure students' general creative problem solving. After six months of teaching students to solve open-ended problems, the researcher found that gifted students scored higher on the posttest than general education students who participated in the same intervention. The researcher also found significant differences for gifted students between pretest and posttest scores. Russo found that using open-ended problem solving assists gifted students' development of creative problem solving abilities even in the general education setting.

Similar to Russo (2004), Hicks (1980) used the TTCT to measure students' general creative problem solving abilities, but in a general education setting. Hicks was interested in enhancing creative thinking skills in fourth grade students by focusing on reading content. The researcher used a classical one-group pretest-posttest design similar to Tallent-Runnels and Yarbrough's (1992) and Russo's (2004) research designs. Hicks found that using open-ended problem solving activities in reading increased students' general creative problem solving ability, while controlling for variables such as students' reading levels and IQs.

Domain-specific. Three short-duration studies were categorized as measuring domain specific creative problem solving (Cheng, et al., 2010; Houtz, et al., 1978; Zimmerman, et al., 2011). Both Cheng, et al. and Houtz, et al. used the Consensual Assessment Technique (CAT) or a similar method to measure students' creative problem solving. The CAT was developed by Amabile (1982) to assess creative problem solving ability by judging people's creative works or products. In contrast, Zimmerman, et al. used concept maps to measure students' concepts and the understanding of relationships among concepts in science.

Houtz, et al. (1978) examined the development of creative problem solving in both gifted and general education students. The intervention consisted of seven conceptual stages of the creative problem solving process. Houtz, et al. rated students' products and found overall increases in students' creative problem solving, especially in grades four through six. On the other hand, Cheng, et al. (2010) studied the effect of association instruction on general education students' poetic creativity (i.e., creative writing ability). After five weeks of implementing the writing activities, the researchers used nine judges to rate students' creative writing products as a posttest. Despite differences in study design and the composition of participants, both Houtz and Cheng, et al. found that open-ended problem solving was effective in developing students' domain specific creative problem-solving abilities.

One of the purposes of Zimmerman, et al.'s (2011) study was to investigate whether use of the REAPS model increased teachers' effectiveness. Researchers implemented the intervention in one third-grade classroom over two years. Students' concepts and understanding of relationships of concepts in earth science were recorded in pre- and posttests using concept mapping. The researchers found that students' complex understanding of science increased significantly for both groups after the intervention. They tested the effectiveness and practicality of two methods in the literature and found a high correlation between the two methods. However, although two methods of scoring were used, only one scorer conducted the rating. The findings from Zimmerman, et al. were consistent with Chengs, et al.'s (2010) and Houtz, et al.'s (1978) results.

Conclusion. Ten empirical studies in which the researchers used interventions based on open-ended problem solving using selected quality indicators for experimental and qualitative designs were evaluated (Odom, et al., 2004). To evaluate these quality indicators, the scale developed by Maker, et al. (2014) was adapted, ranging from 0 to 2, with a cut-point of 70%. Based on this system, the 10 studies were rated to be high quality and suitable as an evidence base for the current study (see Tables 2.2 and 2.3).

Seventy percent of the studies that were reviewed were conducted with participants in the fourth grade, indicating a need for future research with students from other grade levels. Additionally, 80% of the total study participants were general education students; future research should include a sufficient number of gifted students to expand the knowledge base regarding the effectiveness of open-ended problem solving as an intervention and make findings more generalizable. Researchers integrated open-ended problem solving into all content areas in 60% of the studies. In 50% of the studies, the interventions were of long duration. In sixty percent of the studies, researchers operationalized creative problem solving as domain-general rather than domain-specific. Overall, positive changes in students' creative problem solving abilities were found in 80% of the studies (see Table 2.4).

Finally, careful examination of the studies showed that open-ended problem solving was effective in both short- and long-term interventions to develop students' domain-general creative problem solving ability when this variable was measured. However, short-term interventions were not as effective when domain-specific creative problem solving ability was measured. In Table 2.5, the researcher clarifies the overall conclusions reached in this section.

Table 2.5

Overall conclusions across 10 studies of open-ended problem solving

Measurement	Long Duration of Exposure			Short Duration of Exposure		
	Total Studies	Positive Changes	%	Total Studies	Positive Changes	%
Domain-General	4	3	75	2	2	100
Domain-Specific	1	1	100	3	2	67

Note: This table was created based on three components of the included studies (i.e., duration, measurement, and results) in Table 2.4; % = percentage of the studies in which researcher(s) found positive change(s) on aspects of students' creative problem solving ability after implementing the open-ended problem solving.

The Effects of Using the TASC Model

The TASC model has been a highly useful approach in the fields of giftedness and creativity because of its utility in facilitating students' problem solving processes across content areas. The majority of evidence for the TASC model has been based on action research study designs and the resulting literature seems to be a conversation among teachers and practitioners. Consequently, the TASC literature base may be difficult to evaluate using the quality indicators for traditional research methods.

The TASC model was designed to achieve ambitious educational objectives. For instance, the most important goals for using the TASC model were to (a) develop students' attitudes toward school and motivation for learning; (b) improve students' self-concepts; (c) assist students to challenge themselves at home, school, or elsewhere; (d) improve students' achievement to increase opportunities for further education; (e) prepare students for decision-making and leadership roles; (f) prepare students for their future roles as good citizens; (g) support low-income youth to adopt positive roles in society (Adams & Wallace, 1991). Wallace (2008) also noted the TASC model was designed to focus on the problem-solving process for gifted students. For instance, gifted students quickly understood the nature of the TASC model through active and practical, hands-on activities related to every day problems that they themselves identified as problematic.

To facilitate the use of the TASC model in all grade levels, Wallace and her colleagues published several practical books (Wallace & Bently, 2002; Wallace, 2001; Wallace, 2002b; Wallace, 2003; Wallace, Cave, & Berry, 2009; Wallace, Maker, Cave, & Chandler, 2004). Wallace also established a webpage: http://tascwheel.com to communicate her ideas to teachers and practitioners. Among all of the published books, only three (Wallace, 2003; Wallace, Cave, & Berry, 2009; Wallace, Maker, Cave & Chandler, 2004) contained empirical conclusions: Students' thinking processes became more automatic after using the model, they worked voluntarily during morning and lunch breaks, they learned how to work in teams, and they were more able to handle depth and complexity. Although these were promising findings, the authors did not provide any supporting citations or information about the research methodologies from which they made their inferences.

In ten of the studies reviewed in this section (Ball & Henderson, 2009; Davies, 2008; Faulkner, 2008; Fitton & Gilderdale, 2008; Goddard, 2008; Holyoake, 2008; Humphries, 2008; Lakey, 2009; Leyland, 2009; Wallace, 2008), investigators used the TASC model. Brief descriptions of these studies are presented in Table 2.6. The quality of the studies was evaluated based on a list of quality indicators developed by the author based on Odom, et al.'s (2004) work; the principles, assumptions, and procedures of action research according to experts in the field (Fraenkel & Wallen, 2010; Kemmis & McTaggart, 2005); and annotated bibliography guidelines for empirical and conceptual articles in education (Clift, 2014).

Based on these sources, the researcher developed a list of quality indicators for evaluating action research. Using a scale of 0-2 developed by Maker, et al. (2014), with 0 indicating not present, 1 indicating some information provided, and 2 indicating a high degree of information or appropriateness, each study was assigned a rating based on each criterion. The results of the quality evaluation for each study are displayed in Table 2.7—all were considered to be high quality action research. The participant information, method of measuring creative problem solving ability, and outcomes for each study are presented in Table 2.8.

Table 2.6

Studies that used the TASC model as an intervention

Study	Purpose	Participants	Design	Intervention
11. Ball and Henderson (2009)	Explored methods of implementing the TASC model to challenge gifted and general education students in an inclusive environment	All students from the ages of 4 to 11 in one elementary school	Action research using observation and interviews as data sources	One day of using the TASC model in an inclusive environment to design and build a garden
12. Davies (2008)	Examined the effects of the TASC model on gifted students' thinking skills, problem-solving strategies, self-concepts, motivation, self-monitoring, and self-evaluation skills	6 students from sixth grade	Action research using observations and surveys as data sources	Six weeks of teaching students six lessons across several academic content areas, such as language, music, dance, design technology, religion, and art
13. Faulkner (2008)	Investigated gifted students' responses when using the TASC model to teach them and meet their specific needs	35 gifted students from sixth and seventh grades	Action research using questionnaires and interviews as data sources	Eight weeks of teaching gifted students math using the TASC model
14. Fitton and Gilderdale (2008)	Studied the effects of implementing the TASC model with low-income elementary school students	300 students from kindergarten to sixth grade	Action research using interviews, observation, and national test results as data sources	Two years of implementing the TASC model in all academic content areas to raise students' achievement, motivation, enthusiasm, and love of learning

Continued

Table 2.6

Studies that used the TASC model as an intervention (Continued)

Study	Purpose	Participants	Design	Intervention
15. Goddard (2008)	Investigated the best methods for using the TASC model with elementary school students from diverse backgrounds	All students' ages, from 5 to 11 years old in one elementary school	Action research using interviews as data source	One week implementation of the TASC model to create visual displays and other projects related to the content of social sciences
16. Holyoake (2008)	Studied effects of the TASC model on teachers and students of third through sixth grades using observational and interview data	All students from the third through sixth grades in one elementary school	Action research, using observation and interviews as data sources	One week of using the TASC model to implement a professional development program to improve students' thinking skills, creativity, and independent learning
17. Humphries (2008)	Explored the effects of using the TASC model in a small-scale case study to develop students' thinking skills through storytelling	A group of students ages 10 to11 from two different elementary schools	Action research using observation as data source	Two weeks using the TASC model in an action research project on language to develop students' creative problem solving abilities
18. Lakey (2009)	Investigated strategies to challenge gifted students to improve their learning capacities, as well as to improve teaching quality	All students in 10 schools (one early childhood, eight elementary, and one middle school)	Action research using observation and interviews as data sources	One year of implementing the TASC model in all academic content areas

Continued

Table 2.6

Studies that used the TASC model as an intervention (Continued)

Study	Purpose	Participants	Design	Intervention
19. Leyland (2009)	Examined the usefulness of the TASC model to teach an English and science lesson by conducting a case study in one classroom	All students in one sixth grade classroom	Action research using observation as data source	Three weeks of using the TASC model to teach time while integrating English and science in the lesson
20. Wallace (2008)	Explored the needs of Zulu students in their apartheid homeland of KwaZulu by developing a range of appropriate thinking skills and empowerment exercises	Total of 28 gifted students from KwaZulu, South Africa	Longitudinal action research project using observation and interviews as data sources	Developed the TASC model through a 14-year action research project with a goal of designing curricula relevant to Zulu culture

Note: Studies were numbered from 11 to 20, ordered alphabetically by the researchers' surnames; the purpose, participants, design, and intervention were provided as a summary about each study; TASC = Thinking Actively in a Social Context.

Table 2.7

Evaluation of the TASC model studies based on the quality indicators of action research

Quality Indicators for Action Research Design	Studies									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
General Background										
• Identifies the framing questions or problems that need to be solved	2	2	2	1	2	1	2	2	2	2
• States the theoretical framework that influenced the researcher	2	2	2	2	2	2	2	2	2	2
• Formulates an action plan to be implemented with students	2	1	2	2	2	2	2	2	2	2
Participants										
• Provides sufficient description of participants	1	0	1	2	1	1	0	1	1	1
• Identifies the teacher's or researcher's relationship to the students	2	2	2	0	1	2	2	2	2	2
Intervention										
• Clearly describes the processes of the implementation	0	2	2	1	2	1	1	1	2	0
• Solicits feedback from a group of experienced practitioners	2	1	1	2	2	2	0	2	1	2
• Documents the steps and necessary changes to implementation	1	1	1	1	0	1	2	1	0	1
Data Collection and Analysis										
• Reports method used to collect quantitative and or qualitative data	2	2	2	2	2	2	2	2	2	2
• Analyzes data appropriately	2	2	0	2	1	2	2	2	1	2
Conclusion										
• Summarizes and interprets the findings	2	2	2	2	1	2	2	2	1	1
• Includes discussion of challenges during the implementation	0	2	1	1	1	1	1	1	2	1
• Includes recommendations for future practices	1	2	1	2	2	1	1	2	1	2
Total Quality Indicators Met	**19**	**21**	**19**	**20**	**19**	**20**	**19**	**22**	**19**	**20**
%	**73**	**81**	**73**	**77**	**73**	**77**	**73**	**85**	**73**	**77**

Note: Studies were numbered from 11 to 20, ordered alphabetically by researchers' surnames (see Table 2.6); the cut-point was 70%; the 10 studies were deemed to be of high quality; ratings were assigned using the following scale: 0 = the indicator was not found, 1 = the indicator was found to a limited degree, 2 = the indicator was found, and % = percentage of quality indicators met in each study.

Table 2.8

Analysis of studies using the TASC model

Study	Participants								Exposure to Intervention					Outcome				
	Grade Levels						Ability		Duration		Content Area			Measurement		Results		
	1	2	3	4	5	6	GT	GE	L	S	SS	HS	AC	D-S	D-G	PC	SC	NC
11.	√	√	√	√	√	√	√	√		√	√				√	√		
12.						√	√	√		√			√		√	√		
13.						√	√			√		√		√			√	
14.	√	√	√	√	√	√		√	√				√	√		√		
15.	√	√	√	√	√	√		√		√	√				√	√		
16.			√	√	√	√		√		√			√		√	√		
17.					√	√		√		√	√			√		√		
18.	√	√	√	√	√	√	√	√	√				√		√	√		
19.						√		√		√	√	√		√		√		
20.	√	√	√	√	√	√	√		√				√		√	√		
Total	**5**	**5**	**6**	**6**	**7**	**10**	**5**	**8**	**3**	**7**	**4**	**2**	**5**	**4**	**6**	**9**	**1**	**0**
%	**50**	**50**	**60**	**60**	**70**	**100**	**50**	**80**	**30**	**70**	**40**	**20**	**50**	**40**	**60**	**90**	**10**	**00**

Note: Studies were numbered 11 to 20, ordered alphabetically by researchers' surnames (see Table 2.6); 1 = first grade; 2 = second grade; 3 = third grade; 4 = fourth grade; 5 = fifth grade; 6 = sixth grade; GT = Gifted students; GE = general education students; L = long exposure to the intervention; S = short exposure to the intervention; SS = Social Sciences; HS = Hard Sciences; AC = All academic content areas; D-S = domain-specific; D-G = domain-general; PC = positive changes on students' aspects of creativity; SC = some changes on students' aspects of creativity; NC = no changes on students' aspects of creativity; "√" = found; % = percentage across studies.

Long duration of exposure to the TASC model. Three studies were classified in this category based on an intervention length of ten months or more of using the TASC model (Fitton & Gilderdale, 2008; Lakey, 2009; Wallace, 2008). These three studies were conducted in different environments with participants from diverse backgrounds but demonstrated consistent findings that the TASC model was effective in increasing students' aspects of creative problem solving abilities.

Domain-general. Two studies were in this group (Lakey, 2009; Wallace, 2008). Both Lakey's and Wallace's studies were conducted with participants described as "disadvantaged gifted students" by the researchers. Wallace's study was a longitudinal action research design with observational and interview data used to examine whether use of the TASC model would improve students' general creative problem solving abilities and ability to generate ideas. Similarly, Lakey used interview and observational data to examine the effect of the TASC model on the attitudes of teachers and students toward the process of creative problem solving.

Wallace (2008) conducted a 14-year longitudinal action research study, in which the overall goal was to assess the needs of the Zulu population in its local context. One of Wallace's objectives was to develop a range of appropriate thinking skills to promote self-esteem, independence, and empowerment by designing curricula that were relevant to, and contextualized in, Zulu culture. Wallace found that the 28 students who participated in the project were affected positively; all students who participated in the study were admitted to universities with full scholarships. In a follow-up meeting, all 28 students reported that their first action when they arrived at the university was to set up a TASC club so that they could teach other students the problem solving and thinking strategies they had learned.

Similar to Wallace, Lakey (2009) conducted action research in which ten schools participated, including one early childhood school, eight elementary schools, and one middle school. Lakey investigated strategies for challenging gifted students to improve their learning capacities and to determine if a focus on problem solving and thinking skills would improve the overall quality of teaching. Lakey included teaching quality as a variable in the study. After one year of implementing the TASC model in all schools, Lakey found that the model was effective in improving both students' and teachers' attitudes toward creative problem solving and also in improving students' use of creative problem solving processes.

Domain-specific. One study was categorized as measuring domain-specific creative problem solving (Fitton & Gilderdale, 2008). In addition to the qualitative data Fitton and Gilderdale gathered and analyzed in their study, the researchers used national test scores to determine students' improvement in reading, writing, and math.

Similar to Wallace (2008), Fitton and Gilderdale (2008) conducted a study with 300 low-income students from kindergarten to sixth grade. The project lasted approximately two years. Fitton and Gilderdale found that students understood the TASC model and were able to demonstrate how the process had supported them. The students achieved well at all levels, and when compared nationally with similar schools in the subjects of reading, writing, and math; its students scored above average on standardized tests. Although Fitton and Gilderdale included very rich and diverse data, the study was conducted with a unique population, limiting the generalizability of the findings.

Short duration of exposure to the TASC model. Seven studies were classified in this category based on an intervention length of 9 months or less (Ball & Henderson, 2009; Davies, 2008; Faulkner, 2008; Goddard, 2008; Holyoake, 2008; Humphries, 2008; Leyland, 2009).

Across all of the studies, students' creative problem solving abilities improved due to the implementation of the model.

Domain-general. Four studies were categorized as measuring domain-general creative problem solving (Ball & Henderson, 2009; Davies, 2008; Goddard, 2008; Holyoake, 2008). In Ball and Henderson's and Holyoake's studies, researchers monitored students' attitudes and skills when working together in the process of solving problems. On the other hand, Davies and Goddard investigated changes in students' creative characteristics as a result of the model's use.

Similar to Wallace (2008) and Lakey (2009), Ball and Henderson (2009) used the TASC model to challenge gifted students. However, Ball and Henderson's intervention duration was only one day, in which all students were allowed to design and create a garden. Researchers believed that this kind of problem solving activity would allow all students to participate regardless of ability or grade level. Similar to Fitton and Gilderdale's (2008) study, Ball and Henderson used both observational and interview data to reach their conclusions, increasing the validity of their findings. Researchers also concluded that when teachers selected a problem that allowed all students to participate, provided resources and materials, and allowed students to discuss and evaluate their work, the TASC model was implemented successfully.

Taking a different approach, Davies (2008) examined whether implementing the TASC model for six weeks would improve gifted students' thinking skills, problem-solving strategies, self-concept, motivation, self-monitoring, and self-evaluation skills. Davies used a survey and structured observation to collect data, and found that the TASC model was easy to use in the lessons once the students were familiar with the eight steps of the process. Similar to the results found by Wallace (2008), the model was found to be effective in involving students in their own learning and in creating their own problems. The researcher also concluded that the model assisted the teacher in deciding on the most appropriate problems for achieving the lesson's objectives, which was consistent with Lakey's (2009) finding that the TASC model was effective in improving teaching quality.

Goddard (2008) conducted a study to determine the best method of implementing the TASC model with elementary school students to affect the social and emotional aspects of students' learning. Unlike Davies (2008), who used a survey and observation, Goddard interviewed selected teachers and students to determine the effectiveness of the model and found that the TASC model was effective in changing characteristics related to students' learning, which was consistent with Davies' findings. On the other hand, Holyoake (2008) investigated the effect of the TASC model on the process of creative problem solving and small group work. Holyoake used observations and interviews to derive her conclusions. The researcher found that students were able to solve their own problems and that they enjoyed working in groups while using the TASC model.

Domain-specific. Three studies were categorized as measuring domain-specific creative problem solving (Faulkner, 2008; Humphries, 2008; Leyland, 2009). Faulkner investigated using TASC to increase gifted students' mathematical abilities, Humphries used the TASC model to improve students' storytelling abilities, and Leyland investigated the effect of the model on students' scientific problem solving.

Studying mathematically gifted students, Faulkner (2008) used both qualitative (i.e., interview) and quantitative (i.e., questionnaire) methods to examine how the TASC model could be modified to meet students' needs. Although the researcher had enough sample data to apply appropriate statistical tests on the quantitative data, he chose to use raw scores and calculated the frequencies and percentages of the students' responses to each question to demonstrate the effectiveness of the model. Faulkner did not analyze the quantitative data appropriately because calculating frequencies did not allow for statistical inference. However, when analyzing the interviews, Faulkner reported that most students recognized the model as belonging to them and 50% of the students reported that they did not find the TASC model to be a helpful method. Also, two of the students interviewed provided negative feedback, such as “I was uncomfortable,” and “I was useless.”

Humphries (2008) used the TASC model to develop students’ language abilities through storytelling. Over a period of two weeks of teaching students storytelling, the researcher found that the TASC model was effective, as evidenced by the students using the steps in a practical way to tell their stories. Humphries stated that the model gave the students the support they needed to be creative and imaginative. Similarly, Leyland (2009) based his conclusions on observational data when he examined how the TASC model could be used to teach the topic of time. Leyland found that using group work in his class was the key element to successful implementation (Ball & Henderson, 2009; Holyoake, 2008). Leyland also found that the TASC model was effective in assisting students to achieve their learning objectives.

Conclusion. Ten empirical studies in which the researchers used the TASC model were rated using the quality indicators for action research designs. A scale of 0 to 2, developed by Maker, et al. (2014), was adapted to judge the quality of research using a cut-point of 70%. Based on these criteria, all of the selected studies were determined to be high-quality action research, suitable for inclusion in the current study (see Table 2.7).

When analyzing the participants across the 10 studies, 100% of the studies were conducted with sixth-grade students; future research should be conducted with populations from other grade levels. Eighty percent of the studies included general education students, indicating a need for future research that focuses on gifted students. In 50% of the studies, researchers used the TASC model to teach all academic content areas, while in only 20% of studies, hard sciences were integrated into the intervention. In 70% of the studies, the interventions were short in duration, and in 60%, researchers were interested in aspects of domain-general creative problem solving. Across all studies, in 90% of the studies, the researchers found positive changes to some aspect of students' creative problem solving abilities (see Table 2.8).

Also, both short- and long-duration implementation using the TASC model were found to be effective in developing aspects of students' domain general and domain specific creative problem solving abilities. However, these findings may be questionable due to the use of only action-research designs.(e.g., action researchers may be prone to emphasize and report positive results). Therefore, future research should include the use of traditional study designs to inform evidence-based practice using the TASC model. The overall conclusions reached in this section are summarized in Table 2.9.

Table 2.9

Overall conclusions across 10 studies using the TASC model

Measurement	**Long Duration of Exposure**			**Short Duration of Exposure**		
	Total Studies	**Positive Changes**	**%**	**Total Studies**	**Positive Changes**	**%**
Domain-General	2	2	100	4	4	100
Domain-Specific	1	1	100	3	2	67

Note: This table was created based on three components of the included studies (i.e., duration, measurement, and results) in Table 2.8; % = percentage of the studies in which researcher(s) found positive change(s) on aspects of students' creative problem solving ability after implementing the TASC model.

The Effects of Using the PBL Model

The PBL model was originally formulated in 1969 at the McMaster University Medical School (Lee & Kwan, 1997). Since then it has gained global popularity in medical school education. Using the PBL model involves learning about a specific topic by solving a real-world problem. Thus, PBL facilitates learning problem solving strategies and knowledge simultaneously, echoing Dewey's (1937) sentiment that "school should be less of a preparation for life and more like life itself" (as cited in Burke, 2010, p. 36). Use of the PBL model could motivate gifted students in solving real-world problems as well as in promoting interdisciplinary learning objectives to meet all students' specific needs and interests (Swicord, 2012).

Ten studies were analyzed in this section (Araz & Sungur, 2007; Azano, Missett, Callahan, Oh, Brunner, & Moon, 2011; Hung, Hwang, Lee, Wu, Vogel, Milrad, & Johansson, 2014; Koch, Kumpf, & Zumbach, 2004; Lee, Hwang, Hung, & Lin, 2014; Li, 2012; Scott, 2005; Stephens, 2010; Swanson, 2006; Tsal, Shen, & Lu, 2015). The studies are summarized briefly in Table 2.10 and are arranged by numbering them from 21 to 30 to ease recognition in the evaluation (Tables 2.11 and 2.12) and analysis (Table 2.13).

The 10 studies selected in this section were not previously evaluated for quality (Maker, et al., 2014). Therefore, an analysis of all 10 studies using the selected quality indicators that Alhusaini and Maker (2011) and Maker, et al. (2014) used in their literature reviews was conducted first. Using a scale of 0 to 2, with 0 indicating not present, 1 indicating some information provided, and 2 indicating a high degree of information provided or a high level of appropriateness, a rating was assigned for each study based on each criterion (Maker, et al., 2014). All ten studies were deemed to have high quality.

Table 2.10

Studies using the PBL model as an intervention

Study	Purpose	Participants	Design	Intervention
21. Araz and Sungur (2007)	Compared the effects of using the PBL model and traditional lecture-based teaching method on Turkish students' achievement and scientific skills	217 elementary school students, 99 boys and 118 girls	Experimental, two group posttest design	For 5 weeks, 126 students participated in the experimental group to study genetics using the PBL model as part of the general science education curriculum
22. Azano, et al. (2011)	Investigated the effects of using a research-based language arts curriculum on third grade American gifted students' achievement	55 teachers with a total of 740 gifted third-grade students from 10 states	Mixed-methods, including an experimental component	For one year, gifted students were taught using educational practices and strategies related to research-based advanced language arts curriculum
23. Hung, et al. (2014)	Examined the effects of using the Ubiquitous Problem-Based Learning System (UPBLS) on both expert and novice Taiwanese students' question-raising performance in field inquiry activities	25 sixth graders (experts) and 18 fifth graders (novices)	Experimental, two group adapted design (Monitoring Progress)	For seven months, all students participated in field observation activities based on the UPBLS model; additionally, novice students participated in an online discussion forum
24. Koch, et al. (2004)	Studied the effects of using a computer-based, multimedia PBL approach on students' knowledge, problem-solving ability, and motivation	49 fourth-grade students from a German elementary school	Experimental, two group pre- and posttest design	For five weeks, 24 students engaged with the PBL model to learn science by working together in small groups as they solved interdisciplinary scenario problems

Continued

Table 2.10

Studies using the PBL model as an intervention (Continued)

Study	Purpose	Participants	Design	Intervention
25. Lee, et al. (2014)	Investigated students' ability to collaborate in field inquiry activities while using the Ubiquitous Problem-Based Learning System (UPBLS)	43 fifth- and sixth-grade elementary students	Experimental, one group adapted design with longitudinal data	For 16 months, students used the UPBLS and participated in online discussion forums, e-library, and on-line statistical information
26. Li (2012)	Exploratory study of patterns of behavior, thought, and a general understanding of implementing the PBL model in Taiwan	35 fourth-grade students, 19 boys and 16 girls	Action research using qualitative data collection	For one year, the PBL model was implemented in a Taiwanese elementary classroom, including a teacher for implementing the model
27. Scott (2005)	Examined the effectiveness of using the PBL model as an instructional method to improve American students' achievement in social studies	52 fifth-grade students in a private elementary school	Experimental, two group pre- and posttest design	For one semester, students participated in the PBL model to study history as they used a five-step PBL process and engaged in small-group work
28. Stephens (2010)	Evaluated whether the PBL model would be a successful method to improve students' knowledge and understanding of social studies	28 third-grade students	Mixed-methods, including an experimental component, two group pre- and posttest design	For four weeks, an action-research intervention was implemented in the subject area of social studies for 80 minutes per week

Continued

Table 2.10

Studies using the PBL model as an intervention (Continued)

Study	Purpose	Participants	Design	Intervention
29. Swanson (2006)	Explored the effects of using language arts, and science curricula on the performance of low and high achieving students in mathematics, science, and language arts	1089 elementary school students in three low SES schools with high proportions of ethnic minority students	Mixed-methods, including an experimental component	For three years, teachers learned to use PBL, inquiry, and critical thinking instruction models, taught one science and one language arts unit, and created and taught their own units
30. Tsai, et al. (2015)	Investigated the effects of using the Flipped-class Problem-Based Learning (F-PBL) model on students' general learning performance and computing skills	144 sixth-grade elementary school students (50 FPBL, 48 PBL, and 46 control group)	Mixed-methods, including an experimental component, three-group adapted design	Over five months, students learned technical computer skills and then engaged with the F-PBL model to create their own e-books

Note: Studies were numbered 21 to 30, ordered alphabetically by the researchers' surnames; the purpose, participants, design, and intervention were provided as a summary about each study; PBL = Problem-Based Learning.

Table 2.11

Evaluation of the studies using the PBL model based on the quality indicators of experimental designs

	Studies								
Quality Indicators of Experimental Design	**21**	**22**	**23**	**24**	**25**	**27**	**28**	**29**	**30**
Participants									
• Sufficient information provided	2	2	2	1	2	2	2	2	2
• Criteria for inclusion reported	2	2	1	1	0	1	1	2	0
Intervention									
• Procedure described clearly	2	1	2	2	2	2	2	2	2
• Fidelity of the intervention evaluated	1	1	2	1	2	2	2	1	1
Variables									
• Used valid and reliable measures	2	2	2	2	1	2	2	2	2
• Local reliability reported	2	2	1	1	1	2	1	2	1
• Used appropriate measures	1	2	2	2	1	1	1	2	2
Data Analysis									
• Study designed appropriately	2	1	2	2	2	2	2	1	2
• Applied appropriate analysis	2	2	2	2	2	2	2	2	2
• Effect size reported	0	2	2	2	2	0	0	2	0
Total Quality Indicators	**16**	**17**	**18**	**16**	**15**	**16**	**15**	**18**	**14**
%	**80**	**85**	**90**	**80**	**75**	**80**	**75**	**90**	**70**

Note: Studies were numbered 21 to 30, ordered alphabetically by the researchers' surnames (see Table 2.10); the selected quality indicators of experimental design were adapted from Maker and Alhusaini (2011), and Maker, et al. (2014); Studies 22 (Azano, et al., 2011) and 29 (Swanson, 2006) used mixed-methods designs and evaluated by only the experimental component of each study; the cut-point was 70%; the 10 studies were all considered to be high-quality research; ratings were assigned using the following scale: 0 = the indicator was not found, 1 = the indicator was found to a limited degree, 2 = the indicator was found, and % = percentage of quality indicators in each study.

Table 2.12

Evaluation of the PBL model studies based on the quality indicators of action research

Quality Indicators for Action Research Design	Study 26
General Background	
• Identifies the framing questions or problems that need to be solved	2
• States the theoretical framework that influenced the teacher or researcher	2
• Formulates an action plan to be implemented with students	2
Participants	
• Provides sufficient description of participants	1
• Identifies the teacher's or researcher's relationship to the students	1
Intervention	
• Clearly describes the processes of the implementation	2
• Solicits feedback from a group of experienced practitioners	0
• Documents the steps and necessary changes to implementation	2
Data Collection and Analysis	
• Reports method used to collect quantitative and/or qualitative data	2
• Analyzes data appropriately	1
Conclusion	
• Thoroughly summarizes and interprets the findings	2
• Includes discussion of challenges to implementation/limitations	1
• Includes recommendations for future research	2
Total Quality Indicators Met	**20**
%	**77**

Note: Studies were numbered 21 to 30, ordered alphabetically by the researchers' surnames (see Table 2.10); the cut-point was 70%; the studies were considered to be high-quality research; ratings were assigned using the following scale: 0 = the indicator was not found, 1 = the indicator was found to a limited degree, 2 = the indicator was found, and % = percentage of quality indicators in the study.

Table 2.13

Analysis of using the PBL model across studies

Study	Participants								Exposure to Intervention					Outcome				
	Grade Levels						Ability		Duration		Content Area			Measurement		Results		
	1	2	3	4	5	6	GT	GE	L	S	SS	HS	AC	D-S	D-G	PC	SC	NC
21.						√		√		√		√		√		√		
22.			√				√		√				√	√		√		
23.						√		√		√			√		√	√		
24.				√				√		√			√		√		√	
25.					√	√		√	√			√			√	√		
26.				√			√		√			√			√	√		
27.					√			√		√	√			√			√	
28.			√					√		√	√				√	√		
29.	√	√	√	√	√		√		√				√	√			√	
30.						√		√		√		√			√	√		
Total	1	1	3	3	3	4	3	7	4	6	2	4	4	4	6	7	3	0
%	10	10	30	30	30	40	30	70	40	60	20	40	40	40	60	70	30	00

Note: Studies were numbered 21 to 30, ordered alphabetically by researchers' surnames (see Table 2.10); 1 = first grade; 2 = second grade; 3 = third grade; 4 = fourth grade; 5 = fifth grade; 6 = sixth grade; GT = Gifted; GE = general education students; L = long exposure to the intervention; S = short exposure to the intervention; SS = Social Sciences; HS = Hard Sciences; AC = All academic content areas; D-S = domain-specific; D-G = domain-general; PC = positive changes to students' aspects of creativity; SC = some changes to students' aspects of creativity; NC = no changes to students' aspects of creativity; "√" = found; % = percentage across studies.

Long duration of exposure to the PBL model. Four studies were classified in this category based on an intervention length of ten months or more of using the PBL model (Azano, et al., 2011; Lee, et al., 2014; Li, 2012; Swanson, 2006). These studies differed in several areas, such as composition of participants and research methodology. However, their outcomes were consistent in indicating effectiveness of PBL to increase various aspects of students' creative problem solving abilities.

Domain-general. Two studies were categorized as measuring domain-general creative problem solving (Lee, et al., 2014; Li, 2012). Lee, et al. measured students' collaborative learning competencies by using the Ubiquitous Problem-Based Learning System (UPBLS). Similarly, Li conducted action research to investigate students' behaviors when attempting to solve problems.

Lee, et al. (2014) argued that students and teachers have been limited by time and space when using the traditional PBL model. Therefore, they created a virtual learning environment and examined its effects on fifth- and sixth-grade students' skills in collaboration in field inquiry activities. Using UPBLS, students participated in three field inquiry activities including writing or editing notes, records, and reports. The lessons had several components, such as an online discussion forum, online statistical information, and an e-library. After 16 months of implementing the UPBLS, researchers developed a rubric and evaluated students' competency in collaboration using their online discussions as data. They found that students' skills in collaborative work improved significantly over time.

Li (2012) conducted action research and collected data via observations, interviews, audio and video recordings, and an open-ended questionnaire. Similar to Lee, et al. (2014), Li explored patterns of teachers' and students' behaviors and thoughts and also sought to gain an understanding of the use of the PBL model in Taiwan. For one year, one teacher and her fourth grade students used the PBL model integrated with math content. Li reported many challenges at the beginning of the implementation, such as students demonstrating off-task and disruptive behaviors, conflicts between students, and the teacher feeling angry. By the end of the intervention, the teacher had learned strategies to facilitate group work activities. The teacher ceased to provide students with the solutions to their problems immediately, which she had done at the beginning of the intervention.

Domain-specific. Two studies were categorized as measuring domain-specific creative problem solving (Azano, et al., 2011; Swanson, 2006). Azano, et al. and Swanson used mixed methods designs including large experimental components to investigate teachers' effects on students' academic performance in specific content areas.

Similar to Li (2012), in whose study the participants were a classroom teacher and her students, Azano, et al. (2011) investigated factors that might influence teachers' fidelity of implementation of a research-based language arts curriculum. Researchers examined the degree to which teachers' fidelity of implementation affected students' academic performance. Azano and colleagues included gifted students from 10 states: Virginia, Maryland, South Carolina, Colorado, Kentucky, Florida, Pennsylvania, Connecticut, Georgia, and Texas. Researchers controlled for students' academic performance by using the Iowa Tests of Basic Skills (ITBS) as a pretest. After a year of implementing the intervention, researchers developed two criterion-referenced academic tests and used them as a posttest and found that students taught by high fidelity teachers scored higher than those who were taught by low fidelity teachers.

Similarly, Swanson (2006) examined teachers' effects on students' academic performance. The primary research objective was to examine the effects of implementing the problem-based curricula in language arts and science on the performance of low, average, and high achieving students in math, science, and language arts. In the first year, teachers learned about inquiry based models including the PBL model. In the second year, teachers taught pre-designed science and language arts units. In the third year, teachers taught pre-designed science and language arts units, as well as units that they developed by themselves. Using three sections of the Metropolitan Achievement Test-7 (MAT-7) as pre- and posttests each year, Swanson did not find significant differences among students in different levels. The researcher did find similar patterns to those identified by Maker, et al. (2006) when using the DISCOVER model: In the second year, almost all students in all grade levels showed significant improvements in the three sections; however, at the end of the project almost 50% of the results were not statistically significant.

Short duration of exposure to the PBL model. Six studies were classified in this category based on an intervention length of 9 months or less of using the PBL model (Hung, et al., 2014; Stephens, 2010; Tsai, et al., 2015; Araz & Sungur, 2007; Koch, et al., 2004; Scott, 2005). These studies also differed in composition of participants and research methods, however all found the PBL model to be effective in increasing some aspect of students' creative problem solving abilities.

Domain-general. Three studies were categorized as measuring domain-general creative problem solving ability (Hung, et al., 2014; Stephens, 2010; Tsai, et al., 2015; Koch, et al., 2004). Hung and colleagues were interested in measuring students' ability to increase the number of questions they could generate, which is conceptually similar to idea generation in Amabile's model. Stephens examined students' attitudes and characteristics. In Tsai, et al.'s study, researchers measured general academic performance, while Koch, et al. tested several variables, one of which was students' general academic achievement.

Hung, et al. (2014) also used the UPBLS, a virtual learning environment developed based on the PBL model. During the intervention, students wrote or edited their notes, records, and reports and participated in an online discussion forum. Hung and colleagues were interested in the questions students could generate after participating in field inquiry activities. Students were divided into groups classified as experts or novices for the field inquiry activities. Researchers developed a rubric to evaluate the questions students posed in the online discussion forum, and found that after seven months of the intervention, all students' abilities to generate questions were significantly enhanced. The researchers did not find significant differences between the experts and novices, consistent with Renzulli's (1998) argument that a good educational model for gifted students should also benefit other students in general education classrooms.

Stephens (2010) became interested in the PBL model during her program of studies, and could not find a sufficient amount of research regarding PBL effectiveness with elementary school students. Thus, Stephens designed a study to evaluate whether or not the PBL model would be a successful instructional method for teaching third grade social studies. She used an experimental design, collected observational data about the teachers, and developed a survey using a Likert scale as pre- and posttests to measure students' attitudes about community problems. Although the duration of the intervention was very short (i.e., four weeks), Stephens found that the PBL model was a successful teaching method and that students in the experimental group enjoyed the student-centered learning experiences. This finding was consistent with Hung and colleagues' results in indicating that the PBL model was a useful teaching method with elementary school students.

One of the most interesting and up-to-date methods in the field of education has been using the flipped classroom strategy. Using this approach, students are required to learn on their own, prior to their class time, and subsequently to use their class time to discuss what they have learned, teach each other, and/or ask for help or feedback from their teachers. Using the Internet has made the strategy of flipped classrooms possible to implement. However, more empirical research is needed to establish an evidence base in the literature so that the flipped classroom strategy can be adapted on a wider scale.

Interestingly, Tsai, et al. (2015) combined the flipped classroom strategy with the PBL model to create the "F-PBL model". These researchers examined the effects of the F-PBL model on students' academic performance and divided the sample into three groups (i.e., F-PBL, traditional PBL, and control). During the intervention, students in the three groups worked in small groups to produce e-books. Researchers collected both qualitative (i.e., interview) and quantitative (i.e., test scores) data. After five months of the intervention, Tsai, et al. found that students who participated in the F-PBL model demonstrated better academic performance than those in the other groups, and that all students learned the computing skills required to complete the task. Although Lee, et al. (2014) and Hung, et al. (2014) focused on UPBLS, a traditional virtual learning environment, and Tsai, et al. used the F-PBL, an innovative teaching strategy, the results of all three studies were consistent in that PBL was shown to be a flexible and effective teaching model.

Similar to other researchers studying the integration of technology into the implementation of the PBL model, Koch, et al. (2004) examined the effect of a multimedia computer-based PBL model on German elementary school students' cognitive and meta-cognitive ability, motivation, self-directed learning, and achievement. The researchers used a classical experimental design (i.e., two group pre- and posttest). Students in the control group were taught using lecture-based instructional methods while those who were in the experimental group were taught using the multimedia computer-based PBL model, an interactive learning environment. Koch and colleagues reported that students in the experimental group scored significantly higher than those in the control group on all tested variables. The researchers did not find significant interaction effects among the tested variables, which could be a function of the small sample size.

Domain-specific. Two studies were categorized as measuring domain-specific creative problem solving ability (Araz & Sungur, 2007; Scott, 2005). Araz and Sungur measured students' learning performance in science, while Scott investigated academic performance in history.

Araz and Sungur (2007) investigated the effect of the PBL model on Turkish students' academic achievement and performance skills in the genetics unit of a science class. They used a classical experimental research design with two groups: one that was taught using the PBL model, and the other using a lecture-based method. The researchers controlled for students' reasoning ability as well as teachers' effects as the two teachers were teaching both groups but were using different teaching methods with each group. At the end of the project, the researchers administered the genetics achievement test, which they developed to assess students' achievement and performance skills. Araz and Sungur found that the students who participated in the unit taught with the PBL model achieved significantly higher scores than those in the control group.

On the other hand, Scott (2005) examined the effects of using the PBL model on American students' academic achievement in history. Scott used a classical experimental design with two groups and found statistically significant differences between them, indicating the PBL model was effective in improving students' academic achievement in history. Additionally, Scott conducted a pilot study using the PBL model to teach science content prior to implementing her experimental research with history content. In the pilot study, students in the control group scored significantly higher on an academic achievement test than those who were in the experimental group. Based on these results, Scott recruited more students, executed better planning for her teaching units, and then integrated the PBL model with history content.

Conclusion. Ten empirical studies in which the researchers used the PBL model were evaluated using selected quality indicators for experimental and qualitative designs (Odom, et al., 2004). A scale of 0 to 2, developed by Maker, et al. (2014), was adapted to judge the quality of the studies using a cut-point of 70%. As a result, the 10 selected studies were deemed high-quality research, and deemed appropriate for inclusion in the evidence base for this study (see Tables 2.11 and 2.12).

Of the 10 previous studies, 40% were conducted with students in the sixth grade, indicating that future research should include participants in lower grade levels. Seventy percent of the studies included general education students; future research should include a focus on gifted students. In 40% of the studies, researchers integrated the PBL model with hard sciences and all academic content. In 60% of the studies, the duration was short. In 60% of the studies, researchers measured domain-general creative problem solving. Overall, positive results were found in 70% of the studies of changes to aspects of students' creative problem solving (see Table 2.13).

Finally, after careful examination of all 10 studies, I observed that students' domain-general creative problem solving ability could be developed by both long- and short-duration interventions using the PBL model, whereas developing students' domain-specific creative problem solving ability was not as easily achieved using PBL. See Table 2.14 for a summary of overall conclusions.

Table 2.14

Overall conclusions across 10 studies using the PBL model

Measurement	Long Duration of Exposure			Short Duration of Exposure		
	Total Studies	**Positive Changes**	**%**	**Total Studies**	**Positive Changes**	**%**
Domain-General	2	2	100	4	3	75
Domain-Specific	2	1	50	2	1	50

Note: This table was created based on three components of the included studies (i.e., duration, measurement, and results) in Table 2.13; % = percentage of the studies in which researcher(s) found positive change(s) on some aspect of students' creative problem solving ability after implementing the PBL model.

Discussion and Conclusion

Effectiveness of the REAPS model has also been examined by a substantial number of researchers, including Zimmerman and colleagues (2011), who found the REAPS model to be effective in increasing students' complex understanding of science concepts; Gomez-Arizaga and colleagues (2016), who found that students were able to articulate clearly their perceptions about their learning experiences; Reinoso (2011), who found that the REAPS model could be adapted to teach sixth-grade Navajo students; Alhusaini and colleagues (in press), who found that the REAPS model was helpful to Saudi teachers in effectively implementing their curricula to develop students' general creativity in problem solving; Maker and Zimmerman (2008), who found that the model was appropriate to be used in a professional development program for Korean teachers; and Wu and colleagues (2015) found that students believed that their experiences in the classrooms in which REAPS was used were valuable, challenging, and enjoyable. Students' perceptions confirmed that when teachers implemented REAPS, they were providing the challenges, hands-on learning, emphasis on higher levels of thinking, problem solving, student interaction, group work on challenging problems, and student choice.

The primary focus of this study was to add to the research on the REAPS model by investigating a new aspect of its implementation: the effects of different durations of exposure to the model on students' general creative problem solving and creative problem solving in science. In this chapter, the researcher reported the variable of intervention duration as it was researched in studies of individual components of the REAPS model to establish a research-based rationale for conducting this study. All studies were evaluated to ensure all were considered high-quality research. During the evaluation the researcher created quality indicators for evaluating action research designs, with the hope that future researchers could use and revise these quality indicators for action researchers to use in improving the quality of their research.

The method developed by Alhusaini and Maker (2011) was used to synthesize the information from the selected articles. It allowed for synthesis of information as well as a means for visually communicating the evaluations. In the analyses tables, presentations of the two characteristics of the study participants (i.e., students' grade level and ability), the two aspects of the intervention (i.e., duration and academic content area), and the two aspects of the outcomes (i.e., measurement systems and results) were provided. Next, the researcher classified the selected studies for each section into long and short intervention durations, and within each section further categorized studies as either domain-general or domain-specific. Finally, a descriptive analysis of the studies was provided by expanding upon relevant information that was not included in the tables and by examining the similarities and differences among the studies.

The researcher summarized each of the three sections to draw a clear conclusion about each of the three models composing REAPS—DISCOVER, TASC, and PBL— that can be used in future research. In the 30 total reviewed studies, 63% of the participants were sixth-grade students and 77% were general education students. Sixty percent of the researchers implemented a short-duration intervention, 50% of researchers integrated their intervention with all academic content areas; 60% of researchers measured aspects of domain-general creative problem solving, and 80% of researchers found positive changes in various aspects of creative problem solving as a result of the intervention (see Table 2.15).

Table 2.15

Summary of the analyses in tables 2.4, 2.8, 2.13 across the three sections

Model	Participants								Exposure to Intervention					Outcome				
	Grade Level						Ability		Duration		Content Area			Measurement		Results		
	1	**2**	**3**	**4**	**5**	**6**	**GT**	**GE**	**L**	**S**	**SS**	**HS**	**AC**	**D-S**	**D-G**	**PC**	**SC**	**NC**
OEPS	3	4	6	7	5	5	5	8	5	5	3	1	6	4	6	8	2	0
TASC	5	5	6	6	7	10	5	8	3	7	4	2	5	4	6	9	1	0
PBL	1	1	3	3	3	4	3	7	4	6	2	4	4	4	6	7	3	0
Total	**9**	**10**	**15**	**16**	**15**	**19**	**13**	**23**	**12**	**18**	**9**	**7**	**15**	**12**	**18**	**24**	**6**	**0**
%	**30**	**33**	**50**	**53**	**50**	**63**	**43**	**77**	**40**	**60**	**30**	**23**	**50**	**40**	**60**	**80**	**20**	**00**

Note: OEPS = Open-ended Problem Solving; TASC = Thinking Actively in a Social Context; PBL = Problem Based Learning; 1 = first grade; 2 = second grade, 3 = third grade; 4 = fourth grade; 5 = fifth grade; 6 = sixth grade; GT = Gifted students; GE = general education students; L = long exposure to the intervention; S = short exposure to the intervention; SS = Social Sciences; HS = Hard Sciences; AC = All academic content areas; D-S = domain-specific; D-G = domain-general; PC = positive changes on students' aspects of creativity; SC = some changes on students' aspects of creativity; NC = no changes on students aspects of creativity; % = percentage across 30 empirical studies.

Table 2.16 is also provided to summarize the overall conclusions of each section. Across the 30 reviewed studies, the longer interventions usually resulted in expected positive growth in aspects of domain-specific creative problem solving. However, both longer and shorter interventions were effective in producing gains in aspects of domain-general creative problem solving. This initial conclusion is consistent with Amabile's (1983) model, especially her explanation that domain-relevant skills include components such as specific knowledge and technical skills, which must be developed in school before being applied creatively. This observation needed to be studied empirically. Based on the available literature, the current study is the first in the field in which the effects of different durations of exposure to the intervention on domain general and domain-specific creativity were investigated.

Table 2.16

Overall conclusions of all 30 studies across the three sections

Measurement	**Long Duration of Exposure**			**Short Duration of Exposure**		
	Total Studies	**Positive Changes**	**%**	**Total Studies**	**Positive Changes**	**%**
Domain-General	8	7	88	10	9	90
Domain-Specific	4	3	75	8	5	63

Note: This table was created based on three sections of each study (i.e., duration, measurement, and results) in Tables 2.4, 2.8, and 2.13, thus it summarizes Tables 2.5, 2.9, and 2.14; % = percentage of the studies in which researcher(s) found positive change(s) on aspects of students' creative problem solving ability after implementing the intervention.

CHAPTER III: METHOD

Background

This study was conducted on primary data that were collected as part of a larger study entitled *"Real Engagement in Active Problem Solving: Differentiation for Diverse Learners in Regular Classrooms,"* which will be referred to throughout this dissertation as the *Australian Project*. C. June Maker, Robert Zimmerman, and Randal Pease from the United States of America, and Myra Janes from Australia designed the overall study. Two research assistants from Saudi Arabia, Abdulnasser Alhusaini and Fahad Alfaiz; two research assistants from Turkey, Kadir Bahar and Sema Tan; one research assistant from Korea, Sonmi Jo, and one research assistant from Taiwan, I-Chen Wu, collaborated to develop individual studies within the overall design. Data from tests, interviews, and observations were gathered and analyzed in several studies.

The quantitative studies included in the Australian Project were adapted quasi-experimental designs (Singleton & Straits, 2005), in which two groups were compared based on the duration of exposure to the REAPS model (i.e., long or short). The dependent variables were students' pre- and posttest scores on general creativity, creative problem solving in science, creative problem solving in math, and concept maps. Although the quasi-experimental design was not a true experimental design because participants were not selected or assigned randomly, it is considered to be one of the most appropriate research designs for educational settings. The principal investigators also developed the intervention using a participatory action research approach, which has been a useful method to improve the adaptability of the intervention in different environments, cultures, and grade levels.

Research Methodology and Design

In the current study, I used quantitative data to answer my three research questions. This study is considered a quasi-experimental quantitative design (McMillan, 2008; Tabachnick & Fidell, 2013). The REAPS model was the intervention and the independent variable of this study. The dependent variables were the students' pre- and posttest scores on general creativity and creative problem solving in science.

The research design of this study is summarized in Table 3.1. Researchers must be aware that quasi-experimental designs may contain limitations to any inferential claims that can be made from study findings—such as nonrandom selection and assignment and other threats to internal validity (Singleton & Straits, 2005). On the other hand, this design encompasses many strong components. For example, the two-group pretest-posttest design has been shown to be the strongest among quasi-experimental designs, as it allows researchers to control for preexisting differences between groups, minimize the test-retest threat to internal validity, and measure participants' gains (Fraenkel & Wallen, 2010). The design used in this study was also more ethical in that no student was denied the intervention.

Table 3.1

The experimental research design used in the current study

Groups	**Pretest**		**Duration of REAPS Model Implementation**										**Posttest**	
	TCT-DP	**TCPS-S**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Feb**	**Mar**	**Apr**	**May**	**TCT-DP**	**TCPS-S**
1. Long	√	√											√	√
2. Short	√	√											√	√

Note: TCT-DP = Test of Creative Thinking-Drawing Production; TCPS-S = Test of Creative Problem Solving in Science; Long = Long duration (five quarters), which is approximately 10 months of exposure; Short = Short duration (two quarters), which is approximately four months of exposure; √ = The test was administered.

Setting and Sampling

Setting

The setting for the Australian Project was a public elementary school in the eastern region of Australia that has been in operation for more than 100 years. Children enter kindergarten at age five and graduate from elementary school after completing the sixth grade. The academic year is based on a quarter system with students completing five terms per year. The school has an inclusive admissions policy open to international students, Australian citizens, students with disabilities, gifted students, and those who have transferred from public or nongovernmental schools. The school also has a learning support service for students who speak English as a second language (ESL) and students with disabilities. The board of studies has developed curricula in six key learning areas: English; Mathematics; Science and Technology; Human Society and its Environment; Creative and Performing Arts; and Personal development, Health, and Physical Education.

Background Information about the Australian Project

In December of 2012 the DISCOVER research team at the University of Arizona terminated the REAPS model project in Tucson, Arizona, United States and redirected its efforts to implementing REAPS as a differentiation model especially for gifted students in one school. The principal of the school expressed an interest in implementing the REAPS model in her school. In March of 2013, C. June Maker and Randal Pease visited the school and observed seven teachers to assess whether the teachers used a teaching model similar to REAPS and whether they would be receptive to using the REAPS model. Maker and Pease took extensive field notes during the observations (see Appendix F) and photographed the classrooms. Finally, the researchers administered an open-ended questionnaire to each teacher and held a group discussion of the answers.

First, the principal investigators decided to implement the REAPS model with seven cluster classes containing gifted students. In June of 2013, Maker returned to Australia to work with all teachers in the administration of pretests to students. Another investigator on the project, Robert Zimmerman, joined her in Australia and both researchers conducted a five-day professional development workshop for the teachers who would be implementing REAPS for the study (i.e., three days of hands-on work in solving real-world problems, and two days of developing teaching plans). Maker and Zimmerman worked with the seven teachers to develop their teaching units based on the REAPS model (see Appendix D, Developing a Teaching Unit Using the REAPS Model and Appendix E, Example of a Teaching Unit Developed by Using REAPS). Maker, Zimmerman, and Pease reviewed all teaching units prior to implementation.

Pease returned to Australia at the end of 2013 to observe the teachers, video-record students' final presentations, and interview five to six students from each classroom (see Wu, Pease, & Maker, 2015). The principal and teachers decided to implement the REAPS model in all 21 of the school's classrooms in February 2014 because they saw the value for all learners based on the success of the intervention with the seven cluster classes for six months. All principal investigators of the Australian Project approved this decision. One of the most important of these methods for this study was that teachers planned their REAPS teaching units in grade-level teams. Thus, the seven teachers who implemented REAPS for the research project were asked to educate 14 additional teachers about the model and its implementation. All students were posttested in May 2014 using the same instruments. In July 2014, Maker, Zimmerman, and Pease traveled to Australia to observe all teachers, conduct interviews, and review the teaching plans of the 14 teachers who started implementing REAPS later. All teachers were invited to communicate their questions about using the model to the principal investigators.

I used data from two groups of students for the current study. These were separated by the duration of exposure (short or long) to the REAPS model. The first group (long duration) included students whose teachers implemented the model for five quarters (i.e., approximately 10 months) and participated in the first professional development workshop. The second group (short duration) included students whose teachers used the model for two quarters (i.e., approximately 4 months) and received their primary training in the REAPS model from the other teachers rather than from the principal investigators. Informed consent was obtained from all students' parents or legal guardians (see Appendix A, Letter From School to Parent/Legal Guardian). Parents or legal guardians were informed about the key aspects of the project in a letter sent from the school (see Appendix C, Parent/Legal Information Sheet).

Participants

Students whose pre and posttest data for both tests were available were selected for this study. The total sample was 360 students (i.e., 115 long duration and 245 short duration). The distribution of students across grade levels and groups is presented in Table 3.2.

Table 3.2

Participant information

Grade Level	Participants in Grade Level	Duration of Exposure to REAPS	
		Long Duration	Short Duration
1 to 2	78	21	57
2 to 3	78	36	42
3 to 4	67	18	49
4 to 5	73	19	54
5 to 6	64	21	43
Total	**360**	**115**	**245**

Note: The academic year begins in January and ends in December; students were pretested in June 2013 while they were in their lower grade and posttested in May 2014 while they were in their upper grade; long duration = four quarters (i.e., approximately 10 months of exposure); short duration = two quarters (i.e., approximately five months of exposure).

Intervention

In January of 2013 the DISCOVER research team at the University of Arizona developed a logic model to facilitate the development of the Australian Project. A research proposal for the project was submitted to the Australian Human Research Ethics Committees (HREC), which is equivalent to the Institutional Review Board (IRB) in the United States of America because the intervention was to be implemented with all students at one school. The principal provided feedback about the logic model and proposal for the project. In the following sections, I summarize the REAPS logic model, including assumptions, inputs, processes, and outcomes. I also provide a brief summary of the implementation process to aid in clarification of the project for future research.

Assumptions

The assumptions of the REAPS model are to (a) develop the most effective problem solving skills, (b) engage students in small groups in solving open-ended problems of relevance to their countries, regions, and local communities; (c) assist students to be responsive to and responsible for their environments and their society; (c) differentiate curricula to meet the needs of gifted students, which has been a universal challenge; (d) differentiate the content, processes, products, and learning environment of a general education classroom to meet the learning needs of all students; and (e) encourage hands-on activities and group work, which enables diverse students to participate in classroom activities and demonstrate their strengths.

Inputs

The inputs of the REAPS model were to (a) integrate various resources available both in the school and local community into the learning process; (b) take advantage of the longitudinal and cumulative research that has been conducted on the REAPS model; (c) seek funding from multinational corporations, governmental organizations, and private agencies in various countries; (d) develop a proposal jointly with agencies, schools, and the DISCOVER research team; (e) use national and local curricula to form the foundation; (f) involve students of all ages when adapting the model; and (g) collaborate with teachers, administrators, and other school personnel in adapting the model to each classroom and integrating it into the school culture.

Processes

The processes involved in the REAPS model were as follow: (a) students worked in small groups; (b) teachers used a model that was flexible for both them and their students; (c) a structure was provided for solving open-ended problems that was easily accessible to students; (d) students were involved in hands-on activities to make problems easy to understand and fun to solve; (e) in group activities, students learned and joined in the activities at their own pace and using their own strengths; and (f) a student-centered model was employed.

Outcomes

The desired outcomes for teachers who implemented the REAPS model were the following: (a) implement new ways of differentiating curricula and instruction for all students;

(b) develop differentiated instruction; (c) change their beliefs about differentiating curricula and instruction for all students; and (d) change their perceptions of students' abilities, potential, and behaviors. For students exposed to the REAPS model, desired outcomes included the abilities to (a) develop creativity, achievement, self-efficacy, meta-cognition, problem solving skills, and task commitment; (b) learn inter and intrapersonal skills from working in groups; (c) take ownership of their learning, insights, and the development of their products; and (d) become responsible problem solvers.

Implementation Process

The REAPS model was implemented using a participatory action research approach, chosen to improve the adaptability of the REAPS model to local environments and cultures. Taking this action research approach, teachers implemented the main components of the intervention in accordance with the instruction they received. However, teachers were encouraged to make modifications during their implementations when needed. Teachers' modifications were based on group consensus when possible, were adopted to improve the practice or to solve an urgent problem, and were to be documented clearly. Any major changes to the intervention required the approval of the study's principal investigators. The principal investigators ensured all instructors were competent in administering the main aspects of the model by holding group discussions with teachers, reviewing teachers' units and lesson plans (see Appendix D, Developing a Teaching Unit Using the REAPS Model and Appendix E, Example of a Teaching Unit Developed by Using REAPS), observing teachers during implementation of the REAPS model, and conducting interviews with students from different grade levels (see Wu, et al., 2015).

Operational Definitions of Variables

General Creativity

General creativity is defined as competence in generating unconventional figures from six given fragments that possess an overall meaning, and can be measured using 14 criteria: continuations; completions; new elements; connections made with lines; connections made that contribute to a theme; boundary-breaking that is fragment-dependent; boundary-breaking that is fragment-independent; perspective; humor, affectivity, emotionality, and expressive power of drawing; unconventionality A (i.e., unconventional manipulation); unconventionality B (i.e., symbolic, abstract, and fictional); unconventionality C (i.e., symbol-figure-combination); unconventionality D (i.e., non-stereotypical and use of given fragments or figures); and speed (Urban & Jellen, 1996).

Creative Problem Solving in Science

Mohamed (2006) developed the Scientific Creativity Test (SCT) based on a comprehensive review of multiple theories, including Gardner's Naturalist Intelligence (1983, 1999); Osborn's Problem Solving Model (CPS) (1952), especially the concepts of problem-finding and solution-finding; Amabile's componential model of creativity (1982), especially the domain-relevant skills and creativity-relevant skills (i.e., cognitive and personal); Inhelder and Piaget's concrete operational stages, especially classification skills and the development of hypotheses (1952); Wolfinger's science process skills, especially the basic, intermediate, and advanced processes (2000); Sternberg and Lubart's investment theory of creativity, especially intellectual abilities and knowledge (1995, 1996); and Maker's DISCOVER assessment, particularly the problem continuum (1993; 2001). The SCT thus has a strong theoretical foundation. The test is a measure of students' creativity in science by using both social psychology (Amabile, 1983; 1996; Cszikenmentihalyi, 1990) and cognitive frameworks (Gardner, 1983; 1999; Guilford, 1950; Sternberg & Lubart, 1995).

Cognitive. For the cognitive dimension of the SCT (i.e., Task 1, item [a], item [b], and Task 2), Torrance's definition of creativity was used, in which creativity is understood as,

> …a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypotheses about the deficiencies; testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results (Mohamed, 2006, p. 39).

In this context, creativity can be measured using Guilford's (1950) divergent thinking skills: fluency, flexibility, originality, and elaboration.

Social psychology. For the social psychology dimension of the SCT (i.e., Task 1, item [c]), Amabile's (1983; 1996) Consensual Assessment Technique (CAT) of assessing creativity as a product judged by experts was used. Amabile (1983) defined creativity as "the interaction of three components: domain-relevant skills, creativity-relevant skills, and task motivation. Domain-relevant skills entail the knowledge about the domain, technical skills, and specific talents related to the domain. Creativity-relevant skills include working styles, thinking styles, and personality traits. Task motivation entails the aspiration to accomplish something for its own sake" (p. 36).

Measurement of Dependent Variables

General Creativity

The Test of Creative Thinking-Drawing Production (TCT-DP). The research team used the TCT-DP to measure students' general creativity. Urban and Jellen (1989; 1996) developed the TCT-DP as a cross-cultural assessment. They field tested the instrument with 569 elementary school students in 11 countries from different political, economic, and educational systems. The TCT-DP was developed to measure 14 aspects of creativity, as presented in Table 3.3. Urban and Jellen analyzed the reliability and validity of the TCT-DP and found it to have high inter-rater reliability, between .89 and .97. To establish discriminant validity of the TCT-DP, Urban and Jellen compared the assessment to measures of achievement and IQ and found medium to low correlations between scores on the TCT-DP and these tests. They concluded that the TCT-DP was a suitable instrument for examining the effects of creativity development programs. The TCT-DP has been considered an economical test, as students need less than 15 minutes to complete it. Using data from this study, the correlation between the researcher's scores and the scores of another qualified educator was .83, $p = 0.01$.

In previous studies of the TCT-DP, researchers found that the number of factors, the factor structure, and the factor loadings have varied between studies (Dollinger, Urban, James, 2004; Jo, 2009). Maker and colleagues (2015a) explored the evidence for the construct validity of the TCT-DP using the pretest data for all students in the Australian Project database ($N = 556$) and found that the TCT-DP included five factors that accounted for 66.14% of the overall variance. A strong correlation was found between the two forms of the TCT-DP (A and B) as a pretest ($r = 0.73$, $p = 0.01$). A strong correlation also was found between the two forms of the TCT-DP (A and B) as a posttest ($r = 0.77$, $p = 0.01$). Thus, Maker and colleagues suggested that the TCT-DP is a reliable instrument.

Table 3.3

The TCT-DP scoring system

	Criterion	Definition	Points Range
1.	**Continuations**	Any use, continuation, or extension of the six given figural fragments	**0 to 6**
2.	**Completions**	Any additions, completion, complements, supplements made to the used, continued or extended fragments	**0 to 6**
3.	**New element**	Any new figure, symbol or element	**0 to 6**
4.	**Connections made with a line**	Between one figural fragment or figure and another	**0 to 6**
5.	**Connections made to produce a theme**	Any figure contributing to a compositional theme or gestalt	**0 to 6**
6.	**Boundary breaking that is fragment dependent**	Any use, continuation or extension of the small open square located outside the square frame	**0, 3, or 6**
7.	**Boundary breaking that is fragment independent**	Any use of the small open square located outside the square frame	**0, 3, or 6**
8.	**Perspective**	Any breaking away from two-dimensionality	**0 to 6**
9.	**Humor and affectivity**	Any drawing which elicits a humorous response, shows affection or emotion, or strong expressive power	**0 to 6**
10.	**Unconventionality A**	Any manipulation of the material	**0 or 3**
11.	**Unconventionality B**	Any surrealistic, fictional and/or abstract elements or drawings	**0 or 3**
12.	**Unconventionality C**	Any usage of symbols or signs	**0 or 3**
13.	**Unconventionality D**	Usage of non-stereotypical, unconventional figures	**0 or 3**
14.	**Speed**	A breakdown of points, beyond a certain score-limit, according to the time spent on the drawing production	**0 to 6**
Total Score		Sum of the scores of all 14 criteria	**0 to 72**

Note: This table was developed based on two sections: "*Diagnostic Concept, Design and Constriction of the TCT-DP*" and "*Detailed Instruction for Evaluation*" by Urban, K., & Jellen, G. (1996). *Test for creative thinking-drawing production (TCT-DP).* Lisse, Netherlands: Swets & Zeitlinger.

Creative Problem Solving in Science

The Test of Creative Problem Solving in Science (TCPS-S). For the Australian Project, the principal investigators modified the Scientific Creativity Test (SCT) developed by

Mohamed (2006) to create an instrument that could be administered to a wider range of students in different grade levels and in a reasonable amount of time. Studies of the psychometric properties of the new instrument are currently being conducted. The SCT consists of three subtests: Problems and Solutions, Grouping of Flowers, and Design an Experiment, with a consistency of scores coefficient of .89 that was used to establish its reliability. Mohamed analyzed the concurrent validity of the instrument and found that the SCT had a correlation of .42 with teachers' ratings of students' scientific ability; a correlation of .42 with science content knowledge; and a correlation of .51 with scientific creativity.

The major differences between the SCT and the modified version, the TCPS-S, are presented in Table 3.4. The goal of the research was to create a measure that could be administered quickly by teachers to examine the effectiveness of the REAPS model. To develop the TCPS-S, the Problems and Solutions and Grouping of Flowers subtests were selected and modified. The Design an Experiment subtest was removed because science experiments were difficult to conduct for lower grade level students, who lacked scientific proficiency, and science experiments were more related to scientific knowledge than creativity.

For the Finding Problems, Finding Solutions, and Grouping Flowers subtests, the scorers first checked the scientific accuracy of all responses and then scored the responses based on divergent thinking skills: fluency, flexibility, originality, and elaboration (see Table 3.5). Ten percent of the total sample was selected to check the inter-rater reliability; we found high correlations ranging from .89 to .99. The TCPS-S was based on the problem continuum designed by Maker and Schiever (2010). The subtests of Task 1, Problems and Solutions (a), (b), and (c) were all Type VI, as the problem was undefined and the method and solution were unknown to both presenter and solver. The subtests of Task 2, Grouping of Flowers, were all

Type IV, as the presenter and the solvers knew the problem but the problem could be solved in multiple ways and the presenter and solvers knew the range of solutions. The TCPS-S included open-ended rather than closed problems, thus was an appropriate measure of students' creative problem solving in science.

For the Designing Solutions subtest, the researchers rated students' creative scientific solutions using the CAT (Amabile, 1982). Two raters scored all students' creative scientific solutions independently using the CAT. The correlation between their scores was .88. Using the same method, they rated the technical quality of students' drawings. These ratings had a correlation of .94. The correlation between the ratings of creative scientific solutions and ratings of technical quality of drawings was .27, which showed that the drawing ability of students did not influence the ratings of students' creativity (Amabile, 1982), establishing the validity of using the CAT. Maker and colleagues (2015a) conducted analyses to establish the construct and concurrent validity of the TCPS-S using the pretest data for all students in the database (N = 556) and found that the TCPS-S had three factors that accounted for 63.96% of the overall variance. The correlation between the total scores of the TCT-DP and the TCPS-S was $r = 0.44$, $p = 0.01$. The three factors of the TCPS-S were correlated with the total score on concept maps between $r = 0.54$ to $r = 0.40$, $p = 0.01$. Maker and colleagues concluded that the TCPS-S was a promising instrument to measure students' creative problem solving in science.

Table 3.4

Comparison of SCT and TCPS-S

Items	SCT	TCPS-S	Reason for Change
Name	The Scientific Creativity Test (SCT)	The Test of Creative Problem Solving in Science (TCPS-S)	To create a more accurate title reflecting problem-solving
Time	1 hour	45 Minutes	To shorten the time
Practice Activity 1	Not specified	In a large group, students identify environmental problems in pictures and then list as many solutions as possible to one of them.	To assist students in understanding the nature of the task
Task 1 (a)	Students list as many environmental problems as they can see in local pictures of Tucson, Arizona.	Students list as many environmental problems as they can see in local pictures of Sydney, Australia.	Task remains the same for both tests but pictures changed to reflect local context
Task 1 (b)	Students individually pick one of the environmental problems, then they <u>list possible solutions</u>.	Students individually pick one of the environmental **problems**, then they list possible solutions.	To emphasize the word “problem”
Task 1 (c)	Students m<u>ake a scientific device for, or a model of, one solution</u>. When finished, students <u>write a description and draw a picture of the device or model</u>.	Students select one **solution** then either (a) make a drawing, (b) write a description, or (c) make a drawing and write a description.	To emphasize the word “solution” and to make the task more practical
Practice Activity 2	Not specified	Students classify pictures into groups of like vegetables, then students orally describe the similarity of vegetables within each group, then students name each group.	To assist students in understanding the nature of the task
Instructions	Students think about how specific flowers from Arizona are alike and different.	Students think about how specific flowers from Australia are **alike and different.**	To make the task more clear for younger students and to reflect local content

(Continued)

Table 3.4

Comparison of SCT and TCPS-S (Continued)

Items	SCT	TCPS-S	Reason for Change
Task 2 (a)	Students put together in groups flowers **that are alike in some way,** then they name each group appropriately. <u>Finally, they write numbers from the cards on the chart beside the name of the group, making as many groups as they wish.</u>	Students put together in groups flowers **that are alike in some way**.	To make the task more clear
Task 2 (b)	Students move flowers already in one group into a different possible group.	For each group of flowers, students provide as many appropriate names as possible, describing how the flowers are all alike**.**	To make the task more clear and to be able to assess accurately fluency of names and elaboration
Task 2 (c)	Students think about what completely different groups they can make. For example, if they grouped together the flowers based on color, they could not use this way of grouping again. Students write the numbers of the cards under the name of the group in the same way they did in item (a).	Students write the numbers from the cards in the circle under the names of the group.	To make the task more clear
Task 2 (d)	Students draw a diagram or a sketch that shows the relationships among as many groups as they can.	Students inform the teacher if they need additional answer sheets.	To encourage students to make as many groups as possible
Task 3 (a) and (b)	Design an Experiment	This subtest was removed for the TCPS-S.	To make the test more appropriate for a variety of ages of students

Table 3.5

Scoring system for the TCPS-S

Item	Measured Component	Procedure	Point Range
Task 1 (a and b)	Fluency	How many scientifically valid responses were written?	**1 point each**
	Flexibility	How many categories could be calculated among all of the scientifically valid responses?	**3 points each**
	Originality	How many responses were statistically infrequent and different from what other people might produce?	**5 (below 2%), 3 (2-5%), and 1 (6-10%)**
Task 1 (c)	Creative Product	Hennessey and Amabile (2010) defined creativity as a product, idea, or problem solution that was valuable to a person or society, and judged by experts.	**1 to 7 levels**
Task 2 (a, b, c, and d)	Fluency	How many scientifically valid responses were written?	**1 point each**
	Flexibility	How many categories could be calculated among all of the scientifically valid responses?	**3 points each**
	Originality	How many responses were statistically infrequent and different from what other people might produce?	**5 (below 2%), 3 (2-5%), and 1 (6-10%)**
	Elaboration	How many meaningful details were added to the responses?	**3 points each**

Note: Scientific accuracy of all responses was checked before scoring. All invalid responses were removed before the calculation of points.

The Consensual Assessment Technique (CAT). Students' open-ended scientific solutions were rated using the CAT (Amabile, 1982) to assess creativity. The CAT has been used to assess creativity as products for nearly 30 years (Hennessey & Amabile, 2010). The judgment of creativity as products must be done by experts who are familiar with the particular product type. Students' scientific solutions met the requirements for using the technique: (a) all the experts had experience with the area of judgment; (b) the experts assessed students independently; (c) the experts were asked to assess other dimensions at the same time as creativity; (d) the experts were instructed to rate students' products in comparison to each other, rather than to compare them to quality indicators they might have had for work in their respective areas; and (f) agreement was found between the experts, as judgments were not considered reliable if an unacceptable level of agreement was found (Amabile, 1996). A summary of the dependent variables is presented in *Figure* 3.3.

For the Australian Project, the judges first assessed students' scientific creative solutions and then assessed for technical quality. The research team reviewed the Judges' Guidelines to Assess Students' Products (Alhusaini & Maker, 2010). The procedure for judgment was organized in six steps so that the judges rated the students' solutions at each grade level together, and the same judges remained constant throughout the evaluations. The judges were instructed to use the following 12 processes twice to judge the two dimensions of creativity and the technical quality of their drawings:

1. Read all the students' solutions for the first time.
2. Do not write on students' sheets or make any marks.
3. Take notes on a separate sheet.
4. Write the numbers 1 through 7 onto sticky notes, and stick all of them on the table in front of you so that they resemble a scale ranging from high (7) to low (1).
5. Read the students' solutions a second time, then physically put the students' solutions into the 7 piles under the numbers.
6. You must have a distribution of scores, so make sure you have at least one student's solution under each number.
7. Reread the students' solutions in each pile separately and ensure that all the students' solutions in that particular pile are of similar quality, and rearrange

some of them until you feel confident that each pile has solutions of similar quality.

8. Write students' ID numbers on each pile.
9. Describe in writing the differences in quality between pile number 7 and pile number 1.
10. Review all students' solutions to make sure all of them have been judged.
11. Count the students' sheets to make sure you do not lose or otherwise misplace any sheet.
12. Put the students' solutions and your notes in the file, and give the file to the coordinator.

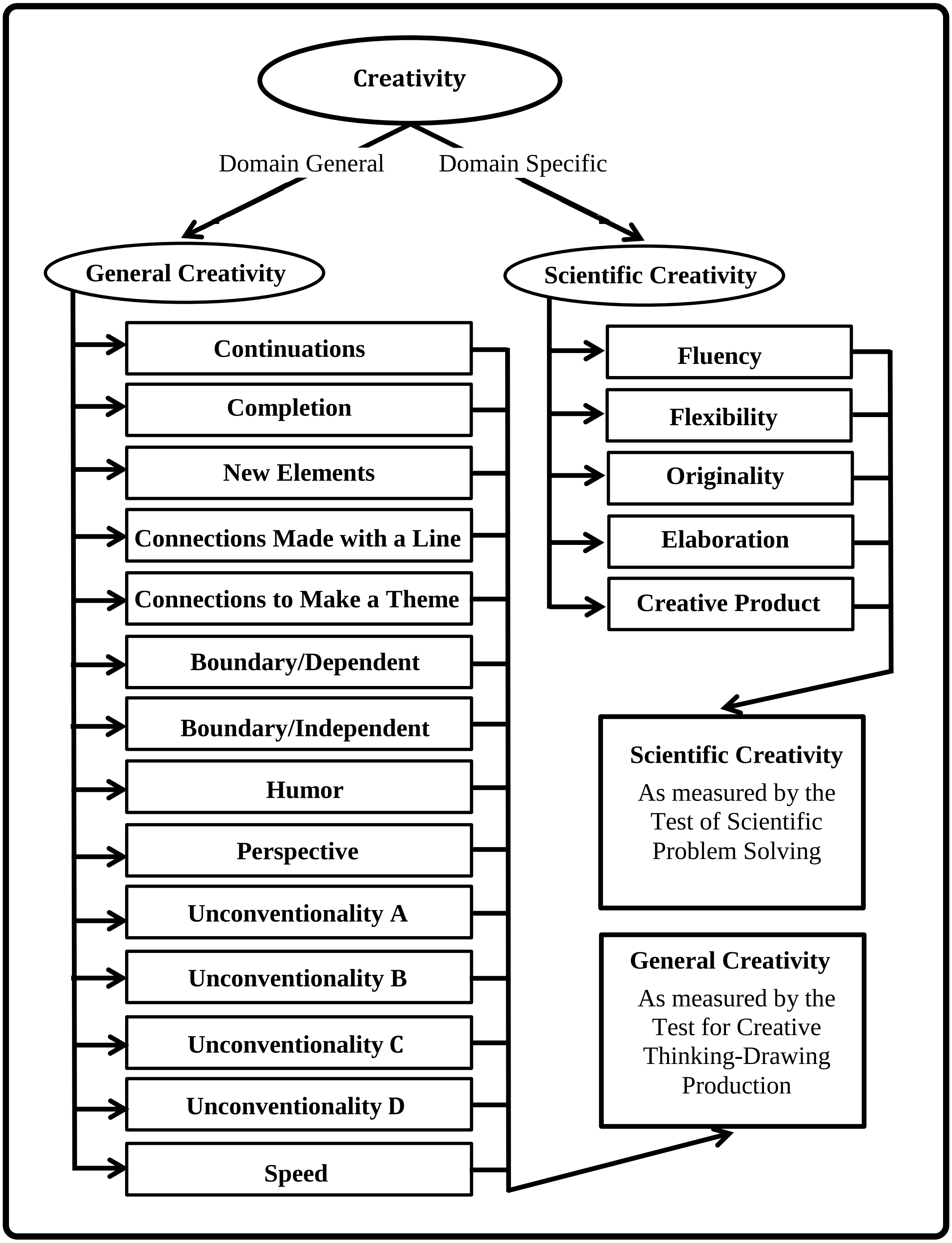


Figure 3.1: Mapping the dependent variables conceptually and operationally

Data Analysis

To answer the research questions, statistical analysis as described below using SPSS software version 21 was applied. Both visual and statistical evidence were used by the researcher to ensure that the data met all of the statistical assumptions of normality. For this study, the focus was on the analysis of the main effects of the REAPS model on each of the dependent variables separately, rather than in examining the interaction between the dependent variables. Also, due to the fact that participants in the study were from six different grade levels, with different numbers of students in each group, controlling for pretest scores was more of a priority than investigating the possible gain by using repeated measures analyses.

To answer Research Questions 1 and 2, a one-way analysis of covariance (ANCOVA) was conducted to control for differences in pretest scores between the two groups and calculate group differences at posttest. Using a one-way ANCOVA enabled accurate answers for each of the two research questions. To answer Research Question 3, Maker and colleagues (2015a) conducted an Exploratory Factor Analysis (EFA) using the pretest data of all students in the Australian Project database (N = 556) and these researchers found that the TCT-DP included five factors that accounted for 66.14% of the overall variance. Maker and colleagues also found that the TCPS-S had three factors that accounted for 63.96% of the overall variance. The change scores for each cognitive aspect of creativity were calculated by subtracting the pretest from the posttest score for each student and a Binary Logistic Regression was used on the change scores to see which of the eight cognitive aspects of creativity changed during the exposure to the REAPS model (long and short).

CHAPTER IV: RESULTS

The purpose of this study was to examine the effects of two different levels of exposure to the REAPS model on developing students' general creativity and creative problem solving in science. Additionally, which aspects of creativity (i.e., generating ideas, generating different types of ideas, generating original ideas, adding details to ideas, generating ideas with a social impact, finding problems, generating and elaborating on solutions, and classifying elements) changed the most during the study.

Data Screening and Preliminary Analysis

Handling Missing Data

The academic year in Australia begins in January and ends in December. Because of the start date of the project, students were pretested in June 2013, while in their lower grade levels, and posttested in May 2014, while in their upper grade levels. Consequently, some students did not complete the posttest because they graduated or moved to a different school. Other students had not enrolled in the school when the project started, so they did not complete the pretest. When incomplete data are minimal, Tabachnick and Fidell (2013) recommended censoring data from cases with missing values. Therefore, analyses of all cases of students who were pretested during the sixth grade were removed, as these students would have graduated from the school before the administration of posttests. The same procedure was followed for students who were in kindergarten when pretests were administered and were present only for posttests. Data for an additional one to five students per classroom were also removed because either pre- or posttest data were missing. Of an initial 556 student cases in the database, 360 viable cases were available for analysis, or 65% of all students over two academic years.

Assessing the Normality of the Data

The distributions of students' TCT-DP and TCPS-S scores were assessed for normality by examining the skewness (distributional symmetry) and kurtosis (peakedness around the mean relative to a normal distribution) values of the data (Tabachnick & Fidell, 2013; Howell, 2013). Data from most social science studies do not exhibit skewness and kurtosis values of zero, which would indicate a perfect normal distribution. Therefore, some methodologists and statisticians have recommended thresholds of ± 0.5 (Runyon, Coleman, & Pittenger, 2000) or ± 1.00 (George & Mallery, 2003; Morgan, Griego, & Gloeckner, 2001) as indicative of departures from normality. Another method for determining skewness and kurtosis is to multiply the standard error by three and use this value as a threshold, with absolute values of skewness and kurtosis that fall below the threshold indicating the assumption of normality has been met. Yet another method for assessing skewness and kurtosis was presented by Cramer (1998), who proposed using a *z*-score table to locate the probability values, multiplying them by 2, and assessing each *z*-score for skewness and kurtosis. Methodologists and statisticians have recommended that experimental researchers should explore the normality of pretest data distributions using several methods, however, abnormality in posttest data is usually expected, especially when examining the whole sample.

Skewness and kurtosis statistics for the distributions of pre- and posttest scores on the two dependent variables are presented in Table 4.1 for the purposes of using these data in future or replication studies. Acknowledging that some readers may express concern about the normality of the data, particularly on the variable of creative problem solving in science, I argue that because the TCPS-S scores were a measure of students' creativity in a specific domain (i.e., science), the skewness of the data is not problematic for the distribution of this variable, as students had not yet learned the content to be able to apply knowledge creatively. In addition, I wanted to avoid transforming the data, especially because the same distributional patterns occurred in both groups.

Descriptive Statistics

Descriptive statistics for total pretest and posttest scores for the two dependent variables are presented in Table 4.2. While Maker, et al. (2015a) have already presented extensive analysis and description of the criteria for both the TCT-DP and TCPS-S, graphs of the pre- and posttest data provide a visual representation as well as an overview of mean score results on each of the criteria for scoring the TCT-DP (see *Figure* 4.1) and the TCPS-S (see *Figure* 4.2).

Table 4.1

Skewness and kurtosis values for total scores on both measures

Section: A
Skewness and Kurtosis Values for Pretest Data

Group	**Measure**	***N***	**Skewness**		**Kurtosis**	
			Statistic	***SE***	**Statistic**	***SE***
1. Long duration of exposure to the REAPS model	TCT-DP	115	-0.24	0.23	-0.34	0.45
	TCPS-S		1.48	0.23	5.49	0.45
2. Short duration of exposure to the REAPS model	TCT-DP	245	0.09	0.16	-0.31	0.31
	TCPS-S		1.60	0.16	3.90	0.31

Section: B
Skewness and Kurtosis Values for Posttest Data

Group	**Measure**	***N***	**Skewness**		**Kurtosis**	
			Statistic	***SE***	**Statistic**	***SE***
1. Long duration of exposure to the REAPS model	TCT-DP	115	0.30	0.23	-0.48	0.45
	TCPS-S		0.88	0.23	0.85	0.45
2. Short duration of exposure to the REAPS model	TCT-DP	245	-0.50	0.16	1.75	0.31
	TCPS-S		1.21	0.16	3.30	0.31

Note: *N* = Sample size; *SE* = Std. Error; TCT-DP = Test of Creative Thinking-Drawing Production; TCPS-S = Test of Creative Problem Solving in Science.

Table 4.2

Descriptive statistics for total scores on both measures

Section: A
Descriptive Statistics for Pretest Data

Group	Measure	*N*	Min.	Max.	*M*	*SD*
1. Long duration of exposure to the REAPS model	TCT-DP	115	25	88	58.55	12.73
	TCPS-S		11	189	57.61	25.52
2. Short duration of exposure to the REAPS model	TCT-DP	245	22	86	50.32	11.90
	TCPS-S		5	205	52.24	31.04

Section: B
Descriptive Statistics for Posttest Data

Group	Measure	*N*	Min.	Max.	*M*	*SD*
1. Long duration of exposure to the REAPS model	TCT-DP	115	43	103	68.21	12.77
	TCPS-S		25	186	80.36	32.26
2. Short duration of exposure to the REAPS model	TCT-DP	245	00	96	65.92	13.28
	TCPS-S		11	220	64.63	28.00

Note: *N* = Sample size; Min. = Minimum; Max. = Maximum; *M* = Mean; *SD* = Standard Deviation; TCT-DP = Test of Creative Thinking-Drawing Production; TCPS-S = Test of Creative Problem Solving in Science.

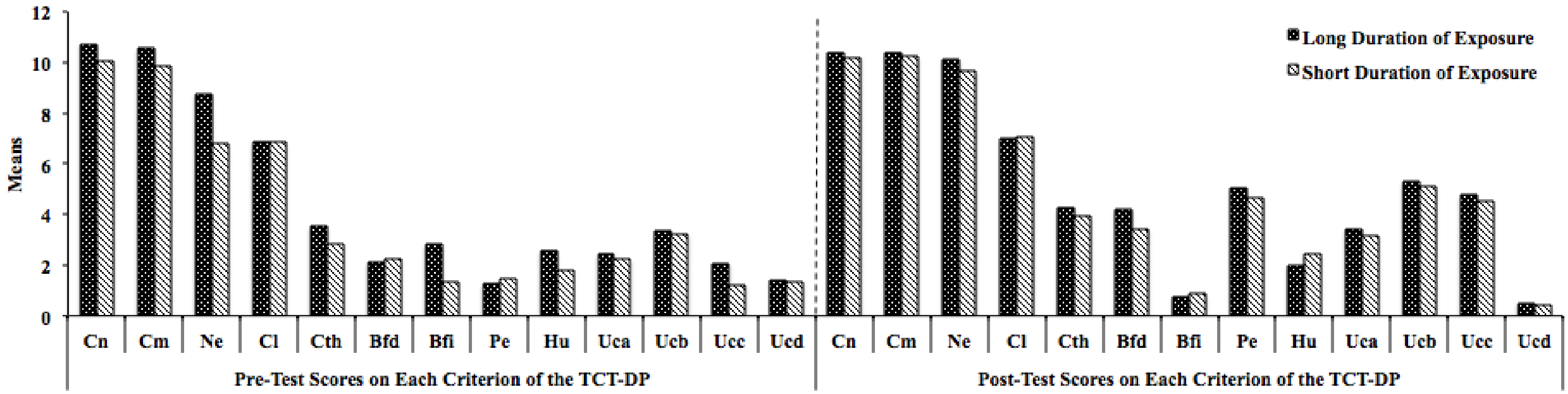


Figure 4.1: Data from both duration groups based on each criterion of the TCT-DP

Note: Cn = Continuations; Cm = Completions; Ne = New elements; Cl = Connections made with lines; Cth = Connections made that contribute to a theme; Bfd = Boundary-breaking being fragment-dependent; Bfi = Boundary-breaking being fragment-independent; Pe = Perspective; Hu = Humor, affectivity, emotionality, and expressive power of drawing; Uca = Unconventionality A (i.e., unconventional manipulation); Ucb = Unconventionality B (i.e., symbolic, abstract, and fictional); Ucc = Unconventionality C (i.e., symbol-figure-combination); Ucd = Unconventionality D (i.e., non-stereotypical and use of given fragments or figures); and Sp = Speed, which was not assessed in the Australian Project.

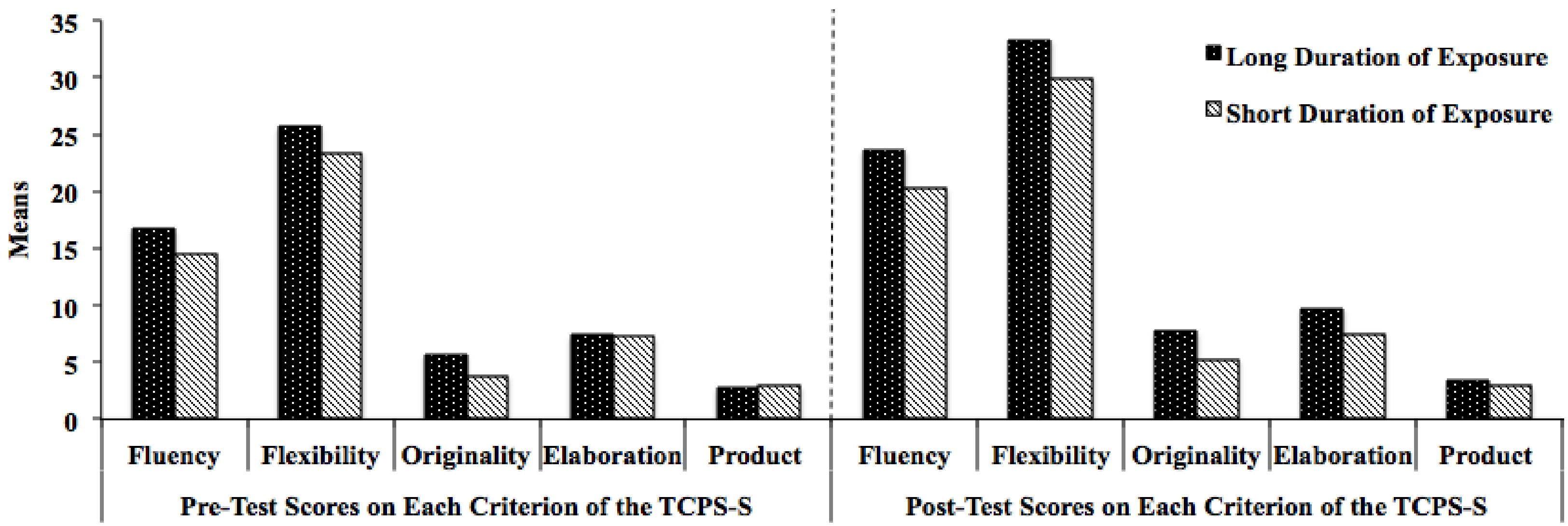


Figure 4.2: Data from both duration groups based on each criterion of the TCPS-S

Research Question 1

What were the differences in general creativity between students who were exposed to the REAPS model for a duration of four quarters and those who were exposed to it for a duration of only two quarters?

The primary goal of the current study was to investigate the difference in general creativity between students who were exposed to the REAPS model for a long duration and those who were exposed for a short duration. Students' general creativity was measured using both Form A and B of the TCT-DP. Using the scoring guidelines, which are presented in Table 3.3, the DISCOVER research team scored students' performance on this test.

To answer Research Question 1, after meeting the assumption of homogeneity of regression, $F(1, 356) = 2.63$, $p = 0.11$, $\eta^2 = 0.01$, a one-way ANCOVA was conducted to determine whether or not the differences in the post-test scores of the TCT-DP between the two groups were statistically significant while controlling for the pretest scores. No statistically significant differences in the posttest scores of the TCT-DP between students who were exposed to the REAPS model for a long duration ($N = 115$, $M = 68.21$, and $SD = 12.77$) and those who were exposed to the REAPS model for a short duration ($N = 245$, $M = 65.92$, and $SD = 13.28$) were found, while controlling for their pretest scores in the long duration ($N = 115$, $M = 58.55$, and $SD = 12.73$) and the short duration ($N = 245$, $M = 50.32$, and $SD = 11.90$), with a small effect size of 0.1%, $F(1, 357) = 0.39$, $p = 0.54$, $\eta^2 = 0.001$. The assumption of homogeneity of variance for the one-way ANCOVA also has been met based on Levene's Test, $F(1,358) = 1.36$, $p = 0.25$. *Figure* 4.3 is presented to visualize this finding.

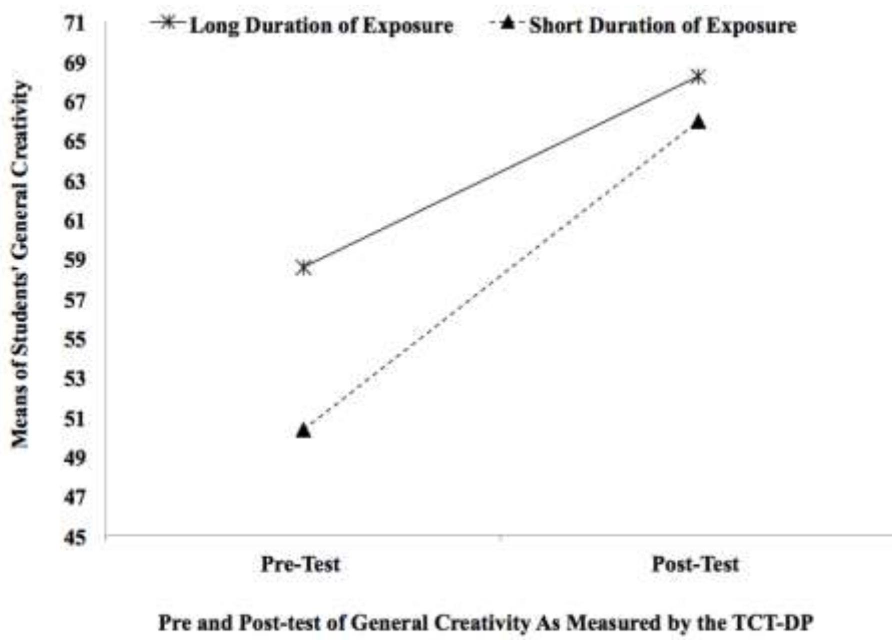


Figure 4.3: Group differences in general creativity

Research Question 2

What were the differences in creative problem solving in science between students who were exposed to the REAPS model for a duration of four quarters and those who were exposed to it for a duration of only two quarters?

The second primary aim of the study was to investigate the difference in creative problem solving in science between students who were exposed to the REAPS model for a long duration, and those who were exposed to it for a short duration. Students' creative problem solving in science was measured by using the TCPS-S. Using the scoring guidelines that are presented in Table 3.5, the DISCOVER research team scored students' performances on this test.

To answer Research Question 2, after meeting the assumption of homogeneity of regression, $F(1, 356) = 2.78$, $p = 0.096$, $\eta^2 = 0.01$, a one-way ANCOVA was performed to determine whether or not the differences in the posttest scores of the TCPS-S between the two groups were statistically significant while controlling for the pretest scores. The researcher found statistically significant differences in the posttest scores of the TCPS-S between students who were exposed to the REAPS model for a long duration (N = 115, M = 80.36, and SD = 32.26), and those who were exposed to the REAPS model for a short duration (N = 245, M = 64.63, and SD = 28.00), while controlling for their pretest scores in the long duration (N = 115, M = 57.61, and SD = 25.52) and the short duration (N = 245, M = 52.24, and SD = 31.04), with a small effect size of 0.6%, $F(1, 357) = 20.84$, $p = 0.001$, $\eta^2 = 0.06$. The assumption of homogeneity of variance for the one-way ANCOVA also has been met based on Levene's Test, $F(1,358) = 2.99$, $p = 0.09$. *Figure* 4.4 is presented to visualize this finding.

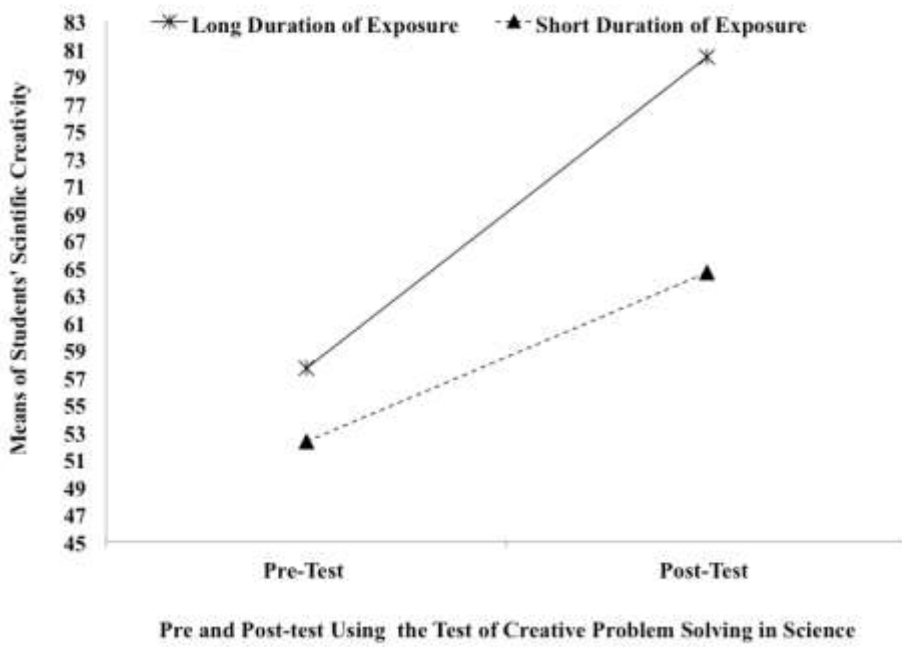


Figure 4.4: Group differences in creative problem solving in science

Research Question 3

Which aspects of creativity changed the most during the study?

During the process of validating the TCT-DP, Maker, et al. (2015a) found that the TCT-DP involved five factors, which accounted for 66.14% of the overall variance. A summary of the analysis including the conceptual definitions is presented in Table 4.3. The researchers also found that the TCPS-S included three factors, which accounted for 63.96% of the overall variance. A summary of this analysis and the conceptual definitions are shown in Table 4.4.

Because the data for eight cognitive aspects of creativity have not yet been analyzed in this study, their normality was analyzed by exploring the skewness and kurtosis values in both groups as shown in Table 4.5 and the descriptive statistics for each cognitive aspect of creativity are presented in Table 4.6. Finally, the researcher calculated the change scores for each cognitive aspect of creativity by subtracting the pretest from the posttest for each student (see Table 4.7, skewness, kurtosis, and descriptive statistics for the change scores).

Because of the use of a binary logistic regression on the change scores to determine which of the eight aspects of creativity changed during the treatment, the researcher checked the assumptions for using regression analyses. For instance, multicollinearity (i.e., high correlation among independent variables) has been a very serious problem when using any regression analysis (Pallant, 2010). In this study, the researcher investigated whether the change scores for the eight cognitive aspects of creativity were highly correlated or not. The correlations were low, between $r = -0.01$ and $r = 0.27$ (see Table 4.8).

Table 4.3

Conceptual definitions of the five cognitive aspects of creativity as measured by the TCT-DP

Criterion	Urban and Jellen's (1996) Operational Definition	Factor Loading	Aspect of Creativity	My Conceptual Definition
Cn	• One point is given for each continuation made of the six figural fragments.	0.92	**Generating Ideas**	Generating as many ideas as possible to complete the task
Cm	• One point is given when any of the continued fragments uses additional points, lines, markings and or textures.	0.88		
Bfd	• If the "Small Open Square" is connected, completed, and or extended in any form or fashion, six points are awarded.	0.69		
Bfi	• Six points are received for any extensions, figures, and or elements that break the boundary or lie outside the "Large Square Frame."	0.52		
Cl	• Each drawn connection between two continued fragments and or new elements is given one point.	0.76	**Generating Different Types of Ideas**	Completing the task by producing different themes
Cth	• Elements and figures "connected" in order to produce themes.	0.60		
Ucd	• Three points are given for a non-stereotypical utilization of given fragments.	0.70	**Generating Original Ideas**	Completing the task in a unique way
Ne	• One point is awarded when new and supplementary elements or figures are added to the existing Cn's and Cm's.	0.59	**Adding Details to Ideas**	Adding and combining ideas to finish the task, and presenting the product in an elegant way
Bfi	• Six points are given for any extensions, figures, and or elements that break the boundary or lie outside the "Large Square Frame."	0.50		

(Continued)

Table 4.3

Conceptual definitions of the five cognitive aspects of creativity as measured by the TCT-DP (Continued)

Criterion	Urban and Jellen's (1996) Operational Definition	Factor Loading	Aspect of Creativity	My Conceptual Definition
Pe	• Any attempt that is made to break away from two-dimensionality toward three-dimensionality is given one point.	0.62		
Ucc	• If a combination of symbols, signs, words, numbers, and or cartoon elements exists, three points are awarded.	0.62		
Hu	• Each drawing that elicits a humorous, affective, emotional response, or demonstrates a special expressive power is given up to six points.	-0.64	**Generating Ideas with a Social Impact**	Manipulating ideas in a socially effective and unique way
Uca	• Lateral or circular (more than 45 degrees) use of the testing sheet, folding of the testing paper to achieve a special effect, or use of reverse side are given three points.	0.79		
Ucb	• Three points are given for abstract or surrealistic elements or symbolic themes.	0.67		

Note: This table was created to simplify the results of the EFA; TCT-DP = Test of Creative Thinking-Drawing Production; Cn = Continuations; Cm = Completions; Ne = New elements; Cl = Connections made with lines; Cth = Connections made that contribute to a theme; Bfd = Boundary-breaking being fragment-dependent; Bfi = Boundary-breaking being fragment-independent; Pe = Perspective; Hu = Humor, affectivity, emotionality, and expressive power of drawing; Uca = Unconventionality A (i.e., unconventional manipulation); Ucb = Unconventionality B (i.e., symbolic, abstract, and fictional); Ucc = Unconventionality C (i.e., symbol-figure-combination); Ucd = Unconventionality D (i.e., non-stereotypical and utilization of given fragments or figures); and Sp = Speed, which was not assessed in the Australian Project.

Table 4.4

Conceptual definitions of the three cognitive aspects of creativity measured by the TCPS-S

Item	Criterion	Maker, et al.'s (2015a) Operational Definitions	Factor Loading	Aspect of Creativity	My Conceptual Definition
Factor 1 Task 1 (a) (Identifying Problems)	**Fluency**	• How many scientifically valid problems were identified?	0.86	**Finding Problems**	Identifying and telling others about environmental problems
	Flexibility	• How many categories could be calculated among all of the scientifically valid problems?	0.83		
	Originality	• How many problems were statistically infrequent and different from what other students might produce?	0.73		
Factor 2 Task 1 (b) (Generating Solutions)	**Fluency**	• How many scientifically valid solutions were generated?	0.64	**Generating and Elaborating on Solutions**	Suggesting many solutions for solving environmental problems, and adding details to a selected solution
	Flexibility	• How many categories could be calculated among all of the scientifically valid solutions?	0.74		
	Originality	• How many solutions were statistically infrequent and different from what other students might produce?	0.75		
Task 1 (c) (Adding Details to a Selected Solution)	**Creative Product**	• Hennessey and Amabile (2010) defined creativity as a product, idea, or problem solution that was valuable to a person or society, and judged by experts based on scale with 7 levels.	0.48		

(Continued)

Table 4.4

Conceptual definitions of the three cognitive aspects of creativity measured by the TCPS-S (Continued)

Item	Criterion	Maker, et al.'s (2015a) Operational Definitions	Factor Loading	Aspect of Creativity	My Conceptual Definition
Factor 3 Task 2 (a, b, c, and d) (Grouping Flowers)	**Fluency**	• How many scientifically valid flowers groups were written?	0.86	**Classifying Elements**	Categorizing and organizing items and elements in different ways
	Flexibility	• How many categories could be calculated among all of the scientifically valid flowers groups?	0.89		
	Originality	• How many flowers groups were statistically infrequent and different from what other students might produce?	0.77		
	Elaboration	• How many meaningful details were added to the flowers groups?	0.70		

Note: This table was created to simplify the results of the EFA; TCPS-S = Test of Creative Problem Solving in Science.

Table 4.5

Skewness and kurtosis values for the eight cognitive aspects of creativity

Section: A
Skewness and Kurtosis Values for the Long Duration of Exposure Group (N = 115)

Aspect of Creativity	Pretest				Posttest			
	Skewness		Kurtosis		Skewness		Kurtosis	
	Statistic	*SE*	Statistic	*SE*	Statistic	*SE*	Statistic	*SE*
Generating Ideas	0.19	0.23	-1.42	0.45	0.20	0.23	-1.47	0.45
Generating Different Types of Ideas	-0.37	0.23	-0.57	0.45	-0.76	0.23	0.63	0.45
Generating Original Ideas	1.04	0.23	-0.01	0.45	2.74	0.23	6.94	0.45
Adding Details to Ideas	0.45	0.23	-0.12	0.45	-0.24	0.23	-0.70	0.45
Generating Ideas with a Social Impact	-0.41	0.23	-0.63	0.45	-0.13	0.23	2.62	0.45
Finding Problems	1.08	0.23	2.47	0.45	0.36	0.23	-0.50	0.45
Generating and Elaborating on Solutions	0.86	0.23	1.86	0.45	0.37	0.23	-0.24	0.45
Classifying Elements	1.88	0.23	6.77	0.45	1.50	0.23	2.37	0.45

Section: B
Skewness and Kurtosis Values for the Short Duration of Exposure Group (N = 245)

Aspect of Creativity	Pretest				Posttest			
	Skewness		Kurtosis		Skewness		Kurtosis	
	Statistic	*SE*	Statistic	*SE*	Statistic	*SE*	Statistic	*SE*
Generating Ideas	0.99	0.16	0.19	0.31	0.15	0.16	-0.75	0.31
Generating Different Types of Ideas	-0.24	0.16	-0.15	0.31	-0.96	0.16	0.86	0.31
Generating Original Ideas	1.54	0.16	2.98	0.31	3.03	0.16	8.85	0.31
Adding Details to Ideas	0.60	0.16	0.09	0.31	-0.19	0.16	-0.58	0.31
Generating Ideas with a Social Impact	-0.20	0.16	-0.74	0.31	-0.13	0.16	0.73	0.31
Finding Problems	0.66	0.16	-0.09	0.31	0.58	0.16	-0.11	0.31
Generating and Elaborating on Solutions	1.28	0.16	2.17	0.31	0.95	0.16	1.25	0.31
Classifying Elements	2.34	0.16	7.71	0.31	2.24	0.16	11.14	0.31

Note: N = Sample size; *SE* = Standard Error.

Table 4.6

Descriptive statistics for the eight cognitive aspects of creativity

Section: A
Descriptive Statistics for the Long Duration of Exposure Group (*N* = 115)

Aspect of Creativity	**Pretest**				**Posttest**			
	Min.	**Max.**	***M***	***SD***	**Min.**	**Max.**	***M***	***SD***
Generating Ideas	14	39	26.29	6.88	14	39	25.70	7.46
Generating Different Types of Ideas	0	20	10.40	4.94	0	19	11.27	3.36
Generating Original Ideas	0	6	1.41	1.92	0	6	0.52	1.39
Adding Details to Ideas	0	36	14.89	7.86	4	36	20.68	7.26
Generating Ideas with a Social Impact	0	16	8.38	4.05	0	24	10.77	3.27
Finding Problems	0	60	18.65	10.06	8	55	27.63	10.87
Generating and Elaborating on Solutions	1	43	15.90	6.70	2	34	17.07	7.01
Classifying Elements	0	110	25.26	15.67	0	120	33.65	23.62

Section: B
Descriptive Statistics for the Short Duration of Exposure Group (*N* = 245)

Aspect of Creativity	**Pretest**				**Posttest**			
	Min.	**Max.**	***M***	***SD***	**Min.**	**Max.**	***M***	***SD***
Generating Ideas	13	42	22.49	5.76	0	36	24.74	7.14
Generating Different Types of Ideas	0	21	9.72	4.17	0	19	11.03	3.53
Generating Original Ideas	0	12	1.34	1.98	0	6	0.43	1.24
Adding Details to Ideas	0	39	10.87	7.05	0	36	19.77	7.49
Generating Ideas with a Social Impact	0	18	7.24	4.24	0	22	10.77	3.28
Finding Problems	0	43	16.60	8.89	4	53	23.27	9.95
Generating and Elaborating on Solutions	1	43	12.69	7.19	1	52	15.53	8.55
Classifying Elements	0	145	21.95	22.53	0	162	26.78	18.69

Note: *N* = Sample size; Min. = Minimum; Max. = Maximum; *M* = Mean; *SD* = Standard Deviation.

Table 4.7

Skewness, kurtosis, and descriptive statistics for the change scores of the eight cognitive aspects of creativity

Section: A
Change Scores for the Long Duration of Exposure Group (*N* = 115)

Aspect of Creativity	Skewness and Kurtosis Values							
	Skewness		Kurtosis		Descriptive Statistics			
	Statistic	*SE*	Statistic	*SE*	Min.	Max.	*M*	*SD*
Generating Ideas	-0.19	0.23	0.23	0.45	-20	16	-0.58	6.49
Generating Different Types of Ideas	-0.19	0.23	-0.13	0.45	-17	13	0.87	5.69
Generating Original Ideas	-0.36	0.23	0.55	0.45	-6	6	-0.89	2.32
Adding Details to Ideas	-0.39	0.23	0.70	0.45	-23	26	5.79	8.35
Generating Ideas with a Social Impact	0.18	0.23	-0.45	0.45	-9	13	2.38	5.03
Finding Problems	-0.41	0.23	2.36	0.45	-38	34	8.98	10.64
Generating and Elaborating on Solutions	-0.38	0.23	-0.65	0.45	-30	20	1.17	8.81
Classifying Elements	1.23	0.23	2.96	0.45	-35	97	8.39	22.04

Section: B
Change Scores for the Short Duration of Exposure Group (*N* = 245)

Aspect of Creativity	Skewness and Kurtosis Values							
	Skewness		Kurtosis		Descriptive Statistics			
	Statistic	*SE*	Statistic	*SE*	Min.	Max.	*M*	*SD*
Generating Ideas	-0.07	0.16	0.42	0.31	-24	20	2.24	7.36
Generating Different Types of Ideas	-0.48	0.16	0.55	0.31	-15	14	1.31	4.86
Generating Original Ideas	-0.48	0.16	2.19	0.31	-12	6	-0.91	2.39
Adding Details to Ideas	-0.11	0.16	-0.15	0.31	-16	31	8.89	8.36
Generating Ideas with a Social Impact	-0.13	0.16	-0.21	0.31	-13	19	3.53	5.78
Finding Problems	0.53	0.16	0.56	0.31	-17	43	6.67	11.28
Generating and Elaborating on Solutions	0.41	0.16	1.95	0.31	-36	46	2.84	10.21
Classifying Elements	-1.09	0.16	4.01	0.31	-86	60	4.83	19.43

Note: *N* = Sample size; *SE* = Standard Error; Min. = Minimum; Max. = Maximum; *M* = Mean; *SD* = Standard Deviation.

Table 4.8

Inter-correlations among the change scores of the eight cognitive aspects of creativity

Aspect of Creativity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Generating Ideas	1.00							
2. Generating Different Types of Ideas	0.27**	1.00						
3. Generating Original Ideas	0.08	0.09	1.00					
4. Adding Details to Ideas	0.21**	0.01	0.09	1.00				
5. Generating Ideas with a Social Impact	0.07	0.04	0.03	0.07	1.00			
6. Finding Problems	0.09	0.07	-0.03	0.06	0.06	1.00		
7. Generating and Elaborating on Solutions	0.10	0.09	0.01	-0.05	0.09	0.04	1.00	
8. Classifying Elements	-0.01	-0.04	-0.06	0.02	0.09	0.13*	0.02	1.00

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

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

To answer Research Question 3, a binary logistic regression with the method *enter* was applied to examine which of the change scores of the eight cognitive aspects of creativity (i.e., generating ideas, generating different types of ideas, generating original ideas, adding details to ideas, generating ideas with a social impact, finding problems, generating and elaborating on solutions, and classifying elements) changed during the intervention. The logistic regression model was statistically significant, $\chi^2(8) = 31.99$, $p = 0.001$. The model explained 12% (Nagelkerke R^2) of the variance in the duration of exposure to the REAPS model and correctly classified 69.4% of the students. Aspects of creativity that were changed were generating ideas, adding details to ideas (from the TCT-DP), and finding problems (from the TCPS-S). The result of the Hosmer and Lemeshow Test that was not significant showed that the regression model fits the data well, $\chi^2(8) = 12.28$, $p = 0.14$. In Table 4.9, a summary of the logistic regression analysis is presented.

Table 4.9

Summary of the logistic regression analysis

Aspect of Creativity	***β***	***SE β***	***Wald***	***E^β***
1. Generating Ideas (TCT-DP)	0.05**	0.02	7.80	1.05
2. Generating Different Types of Ideas	-0.00	0.02	0.00	0.99
3. Generating Original Ideas	-0.04	0.05	0.54	0.96
4. Adding Details to Ideas	0.04**	0.02	7.57	1.04
5. Generating Ideas with a Social Impact	0.04	0.02	2.29	1.03
6. Finding Problems (TCPS-S)	-0.03**	0.01	5.18	0.98
7. Generating and Elaborating on Solutions	0.02	0.01	1.93	1.02
8. Classifying Elements	-0.01	0.01	2.35	0.99
Constant	0.51**	0.19	6.96	1.66
Model $\chi^2 = 31.99$, $p = 0.001$				
$R^2 = 0.12$				
$N = 360$, $n1 = 115$, $n2 = 245$				

Note: β = beta coefficient; $SE\ \beta$ = Standard Error of β; *Wald* = *Z*-ratio; E^β = Exponentiated β; N = Total sample size; $n1$ = Students in the long duration of exposure group; $n2$ = Students in the short duration of exposure group; ** = Significant at the 0.001 level; * = Significant at the 0.05 level.

CHAPTER V: DISCUSSION

The DISCOVER research team hoped to accomplish two goals in the Australian Project, (a) introduce Australian teachers and researchers to the REAPS model and (b) evaluate the effects of the model on developing various aspects of students' creative problem solving in a new environment. In this study, the primary focus was to (a) examine the effects of two different durations of exposure to the REAPS model on developing students' general creativity as measured by TCT-DP scores and creative problem solving in science as measured by TCPS-S scores and (b) explore which cognitive aspects of creativity were the most affected by a long duration of exposure to the REAPS model.

Reflection

Of the many teaching models to which I have been introduced during my doctoral studies, the REAPS model was the most interesting because it was comprehensive, practical, and effective. Implementing the REAPS model and expanding its applications is one of my goals for future scholarship. Toward that end, I plan to conduct additional research in Saudi Arabia, where the Ministry of Education is currently establishing 13 schools for gifted students in which the model will be used as the main teaching method (see Maker et al., 2014). Recently, the REAPS model has been implemented successfully in many countries, such as the United States, Korea, Saudi Arabia, and Australia. The model has also been presented, and well-received, in many local and international conferences held around the world, such as in the United Arab Emirates, Israel, New Zealand, Turkey, and Denmark.

Working as a research assistant on implementing and developing the REAPS model in the USA allowed me to link my major area of interest in Education of Gifted Students to my minor of Curriculum and Instruction. This experience helped me gain substantive knowledge in the education of gifted students and exposed me to many fieldwork and research opportunities.

Testing and developing general creativity in elementary school students has been my area of expertise for over 19 years. Initially introduced to Amabile's innovative work on testing creativity as a product using the CAT (Alhusaini & Maker, 2010; 2015; Alhusaini, Maker & Deil-Amen, 2014) at the start of my doctoral program in 2010/2011, I have been engaged purposefully in scientific discourse regarding domain specificity of giftedness and creativity for the last five years. In the fields of giftedness and creativity, researchers still argue whether giftedness and creativity are located in single domains or across several (Hong & Milgram, 2010; Silvia, Kaufman, & Pretz, 2009). Among these arguments, I was strongly convinced by Amabile (1983; 1996) purporting that creativity could be seen in three components: creativity relevant skills (i.e., domain-general), domain-relevant skills (i.e., domain-specific), and task motivation. A Google Scholar search conducted on November 1, 2015 resulted in 10,601 scholarly peer-reviewed publications in which Amabile's first two books were cited, evidencing the salience of her work in the field. Thus, I believe that studying the two cognitive components of Amabile's model in a quasi-experimental study is a timely and relevant academic endeavor.

I taught science for one semester as an instructor of gifted students in Saudi Arabia, which remains one of my most memorable professional experiences. Science is a subject in which gifted students can not only discover the world around them, but also learn skills related to other disciplines, such as writing, reading, math, and public speaking. At the end of my semester of teaching science, the students presented what they had learned in a science fair to their parents, other students, and visitors. At that time, I did not know of any reliable and valid instruments that could be used to measure students' creative problem solving in science other than subjectively judging students' final presentations or, more objectively, examining informal national achievement test scores. The fields of giftedness and creativity have suffered for many years from a lack of instruments that accurately measure scientific creativity at the elementary school level (Mohamed, 2006). Consequently, working on a research project to develop and test a measure of elementary school students' creative problem solving abilities in science has fulfilled one of my academic dreams.

Before ending my story, I would like to emphasize that I am a researcher who has always been primarily interested in analyzing and interpreting quantitative data. Although I published an empirical study using qualitative data (Alhusaini, Maker, & Deil-Amen, 2014), I always considered myself to be a quantitative researcher. Numbers and figures have always attracted me more than narrative descriptions. Thus, I believe that conducting my dissertation by analyzing existing data from the Australian Project fulfilled my academic interests, drew upon my strongest research skills, and positioned me well for future work. I was extremely fortunate to have superior scholars on my committee: Dr. C. June Maker, Dr. Renée Clift, Dr. Walter Doyle, Dr. Shirin Antia, and Dr. Carl Liaupsin, who guided me, helped me to focus my thoughts, and taught me the scientific methods necessary for successfully completing this study. Throughout this project, I felt I could bring my problems to my committee members and solicit feedback from them without fear of judgment. Although I have previously thanked my committee members in the acknowledgements of this dissertation, I would like to reiterate my deep appreciation to each one of them.

Discussion of Findings

Statistically significant differences in general creativity were not observed between the long and short duration groups of REAPS implementation. However, in a two-group pretest-posttest design, a lack of statistically significant difference between the groups could be attributable to a significant increase in students' general creativity in both groups and does not eliminate the possibility that the intervention was effective. This could occur if, for example, I had conducted two different one-group pretest-posttest experimental studies with two different durations of the intervention in each (Fraenkel & Wallen, 2010). In the first study, the REAPS model could hypothetically have been implemented for 10 months. A paired sample *t* test analysis might show a statistically significant increase in students' general creativity as $t(114) = -7.49$, $p = 0.001$. Then, let us assume I replicated the first study, but this time implemented the REAPS model for only four months. A paired sample *t* test analysis could show a statistically significant increase in the students' creativity as $t(244) = -15.64$, $p = 0.001$. In both hypothetical studies the duration between the pretest and posttest would have been less than one year, so maturity would not be a threat to internal validity. In the current study, a non-statistically significant difference in general creativity between the two groups does not necessarily indicate that the model was ineffective in developing general creativity, but could also imply that creativity in both groups increased significantly.

Based on the literature review in Chapter II, I concluded that general creativity is a variable very sensitive to the treatment. Researchers in most cases could see the change in students' creativity within a few months, especially when using the DISCOVER, TASC, and/or PBL models. For example, Alhusaini, et al. (in press) found a significant improvement in students' creativity with only nine weeks of implementing the REAPS model in Saudi Arabia. However, researchers should also understand that the TCT-DP score has a ceiling, so if the mean of a group of the students was high at pretest, finding evidence of improvement in the posttest would be difficult (see Maker, et al., 2006). Nonetheless, Eberle (1996) argued that teachers forced their students to (a) learn the assigned work, (b) remember what they already know, and (c) retain all that they learn. However, to develop students' creativity, teachers must allow their students to (a) explore what they do not know, (b) review what they already know, and (c) create whatever they want. I agree with Eberle's ideas. General creativity could be improved even without implementing a systematic advanced teaching model. If teachers understand creativity conceptually and know the essential requirements for developing this ability in their students, each teacher could design his or her own successful teaching model.

Based on the results of this study, I believe that developing students' general creativity may be a prerequisite to developing their creative problem solving in science. This is why most previous researchers suggested that a longer duration of intervention most likely would develop aspects of creativity in a specific domain (see Chapter II, overall conclusion). Hypothetically, if the researchers analyzed students' scores on the TCPS-S as two separate studies, they would find that each of the two groups improved significantly in creative problem solving in science. For instance, a paired sample t test analysis shows a statistically significant increase in the students' creative problem solving in science in the long duration intervention, t (114) = -6.79, p = 0.001; also, a statistically significant increase was found in the students' creative problem solving in science in a short duration intervention, t (244) = -7.98, p = 0.001. However, students in the short duration group cannot reasonably compete with those who were exposed to an intensive and long intervention using real-world problem solving. I believe this is why I found a statistically significant difference between the two groups.

When reviewing the available literature, I did not find a specific study in which researchers investigated which cognitive aspects of creativity were the most affected by the intervention. In fact, I found that researchers used the term "aspects of creativity" to indicate very different things. For instance, the term “aspects of creativity” was used to indicate students’ knowledge, achievement, personality traits, thinking styles, thinking skills, and behavioral characteristics. Nonetheless, the results of the EFA (see Maker, et al., 2015a) were compelling, as the TCT-DP, which was developed to measure 14 criteria, tended to a limited degree to assess divergent thinking skills: generating ideas, generating different types of ideas, generating original ideas, adding details to ideas, generating ideas with a social impact. Also, the TCPS-S, which was developed to measure divergent thinking skills, tended to assess students’ performance in science, such as finding problems, generating and elaborating on solutions, and classifying elements. When analyzing the data, I found that the cognitive aspects of creativity that were the most affected by a long duration of exposure to the REAPS model were generating ideas, adding details to ideas (from the TCT-DP), and finding problems (from the TCPS-S). All of the three identified cognitive aspects depend on the ability to produce many ideas (i.e., fluency), which is the core skill in creativity (Guilford, 1950; Osborn, 1963).

Limitations

When reading Chapter III, reviewers can visualize the challenges that the DISCOVER research team faced during the Australian Project. Managing an overseas research project with very limited time and funding resources is difficult for any skilled research team. Thus, limitations in the research design and data collection are expected. In the following section I will highlight the most important threats to internal and external validity that existed in the larger study and consequently in the current study.

Threats to Internal Validity

Although designing the intervention using an action research approach was appropriate to ensure the usability of the model in its new environment, the intervention was less controlled than it would be in a traditional quasi-experimental study. Future researchers interested in the same population should design their interventions to be more controlled so that they can clearly establish a causal relationship. Another threat to internal validity was that of the 21 teachers who participated in this study, only seven participated in an official professional development workshop to learn about the REAPS model at the beginning of the project. The principal investigators were confident that the 21 teachers mastered the main components of the REAPS model using different resources. However, assessment of the fidelity of the intervention in the Australian Project could have been more reliable by using two observers to monitor all 21 teachers repeatedly to scientifically measure the fidelity of the intervention.

Other threats to internal validity that existed in this study came from assessing the dependent variables. For instance, although the TCT-DP has been found to be a reliable test, its validity has been questioned. The TCT-DP correlated 0.21 to 0.44 ($p = 0.01$) with tests of closed problems, such as achievement and IQ tests (Urban & Jellen, 1996; Urban, 2005). *Figure* 5.1 illustrates the relationship between divergent and convergent thinking. Also, when conducting factor analysis, the numbers and components of the factors were not consistent across studies (Dollinger, Urban, James, 2004; Jo, 2009; Maker, et al., 2015a). Future researchers should consider using other valid tests to measure students' general creativity, such as the Torrance Tests of Creative Thinking (TTCT). I believe that the most valid methods to measure students' general creativity have included divergent thinking skills: fluency, flexibility, originality, and elaboration (Guilford, 1950; Torrance, 1990). I agree that the TTCT has some reliability problems (Alhusini, 2007), but this can be solved when using form A for the pretest and form B for the posttest. The CAT is not recommended for measurement of domain-general creativity because this particular technique was originally designed to measure domain-specific creativity.

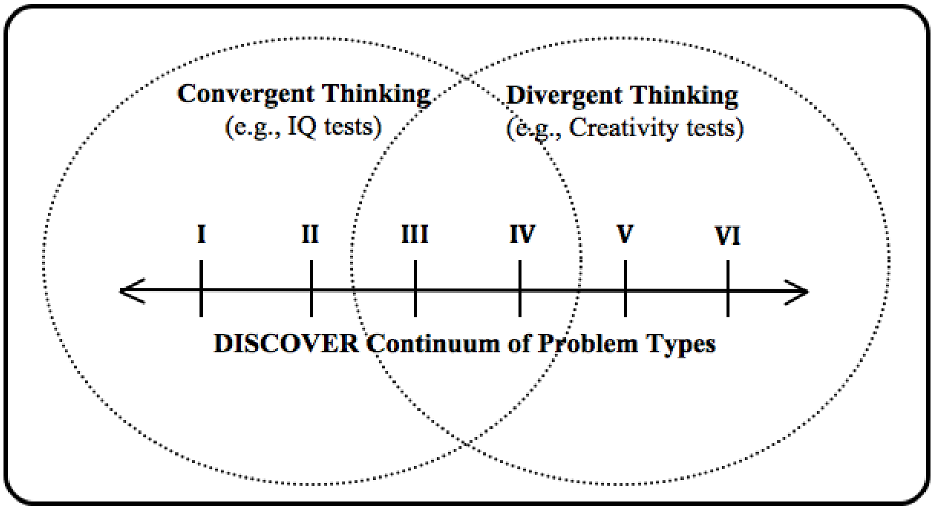


Figure 5.1: The relationship between divergent and convergent thinking

Note: The figure was introduced by Maker, C. J. (1993). Creativity, intelligence, and problem-solving: A definition and design for cross-cultural research and measurement related to giftedness. *Gifted Education International, 9*, 68-77.

The TCPS-S also had threats to internal validity in this study. For instance, Task 1 of the TCPS-S is dependent on students' English proficiency. Non-English speakers, students with disabilities, and students in early grades might have very creative ideas but be less able to write them. Future researchers could administer the test verbally, especially for students who do not speak English. One could also interview all students or at least those who are not proficient in English, or have other known disabilities, after the assessment to better understand the meaning of their responses. Finally, more research on the validity and reliability of the TCPS-S is needed; I also highly recommend that future researchers develop two forms of the TCPS-S. The DISCOVER research team attempted to do this when assessing high school students by providing them two sets of pictures: flowers and insects. This attempt should be expanded to develop two equal forms of the TCPS-S.

Threats to External Validity

The population of this study consisted of only elementary school students in New South Wales, Australia (*N* = 449,809) and the target population was elementary school students in North Sydney (*N* = 58,603) (see NSW Education & Communities, 2013). One school, located in a middle-income neighborhood, was selected. Out of 556 students whose ID numbers were entered in the project database, the 360 students whose pre and post test data for both tests were available were selected for this study. Although the principal investigators included all students in one elementary school, the school was selected based on a convenience sampling strategy. Selecting random samples is very seldom practiced when conducting research in public school systems. Generalizability of the results of this study is limited due to the chosen sampling strategy. Additionally, students were not randomly assigned to the different intervention groups. Future researchers should use the results of this study while considering that they are not generalizable to the target population. I strongly recommend that future researchers conduct a small-scale study using the same target population, but using random selection and random assignment to assess whether the results from the current study are replicable. Nonetheless, the results from this study provide valuable information to the principal, staff, and teachers of the school, and to researchers, as the positive effects of the intervention on the students were notable.

Major Contributions

The researcher of this study provides many promising contributions to the fields of giftedness and creativity. Despite the fact that this study is the one of the first to examine the effects of the REAPS model in developing Australian students' general creativity and creative problem solving in science, (a) its research design was unique among other studies using quasi-experimental designs in the field of giftedness and creativity; (b) the researcher used the TCPS-

S, which made this study the first quasi-experimental research in which the TCPS-S was used since it was originally developed by Mohamed (2006); (c) using both tests, the TCT-DP and TCPS-S, made possible the examination of two cognitive components of Amabile's (1983; 1996) model of creativity performance in one study and with the same participants.

Methodological Contribution

Over the years, the DISCOVER research team, led by C. June Maker, has been interested in combining traditional quasi-experimental research designs with ethical practices. In Maker and colleagues' (1996) study, the researchers used teachers' levels of implementation as an independent variable (i.e., high or low), which was similar to the experimental static-comparison design with two groups: experimental and control (Fraenkel & Wallen, 2010). In Maker and colleagues' (2006; 2008) studies, teachers' implementation levels were expanded to three (i.e., high, middle, and low). The ethical quasi-experimental research approach, used by the DISCOVER research team, means that all teachers are encouraged to use the intervention in their classrooms; thus, the intervention is not withheld from any students. However, after observing teachers in the classroom, the researchers found that some used the intervention well, some attempted to use the intervention, and some were not interested in using the intervention or did not implement it well.

This study seems to be the third generation quasi-experimental ethical design (e.g., all students received the treatment but for different durations). In the Australian Project, the DISCOVER research team moved from observing and ranking teachers' levels of implementation (Maker, et al., 1996; 2006; 2008) to using the length of the intervention as an independent variable, which is a reliable and practical way of conducting ethical quasi-experimental designs overseas. The principal investigators approved the school personnel's decision to implement the REAPS model school-wide and adapted the design to make the research possible. I strongly believe that researchers in the fields of giftedness and creativity should conduct high quality experimental studies to enhance the development of the field, but also to consider using ethical practices by providing their interventions to all students. From my perspective, ethical practices do not prevent researchers from conducting high quality experimental research. The true experimental design was developed originally and used successfully in the hard sciences, such as agriculture, while its use in the social sciences, such as education, has been difficult and ethically questionable.

By conducting this study, I provide a research background for future researchers interested in improving teaching practices or developing students' creative problem solving, especially in Australia. Therefore, I believe that the next research project should replicate this study in different schools in Australia and possibly other countries, with the REAPS model being used to develop all three components of Amabile's (1983; 1996) model, including students' motivation. I also believe that conducting qualitative or mixed-method studies of the use of the REAPS model, as well as examining its effects on teaching quality, teacher satisfaction, student self-concept, teacher and student decision-making, and teacher classroom management, will strengthen the overall implementation of the model. In the future, I would also appreciate reading a quasi-experimental ethical study in which three levels of duration (i.e., short, middle, and long) were used. I strongly believe that using two levels of the intervention duration was an innovative idea, but I recommend that the next generation of this research design be three levels of exposure.

Practical Contribution

Over the years, researchers in the fields of giftedness and creativity have measured students' creative problem solving in science using general creativity tests, questionnaires, and/or science achievement tests (Hocevar, 1980; Runco, 1987) due to lack of instruments for measuring scientific creativity (Mohamed, 2006) and difficulty in demonstrating evidence of validity and reliability in most domain specific measures (Sak & Ayas, 2013). The need for developing scientific creativity tests and using them in quasi-experimental studies has increased. In the past 10 years very few tests have been developed to measure students' creative problem solving in science (Mohamed, 2006; Mukhopadhyay, 2013; Sak & Ayas, 2013). In the current study, the researcher collaborated with other members of the DISCOVER research team to develop the TCPS-S, which is a promising test that can be used to measure students' scientific creativity. Additionally, in this study I used the TCPS-S for the first time in a quasi-experimental research design to demonstrate to other researchers in the fields of giftedness and creativity the capabilities and practicality of this test for measuring the effects of the intervention.

Before adapting any educational model in a new culture, some basic steps have to be executed, such as understanding both cultures and working with a group of teachers and practitioners from an action research perspective—which may require some changes to the original model based on the new culture and environment (Alhusaini, et al., in press). The principal investigators of the Australian Project believed that implementing the REAPS model using a participatory action research approach would be the most effective method, as action research allows teachers to simultaneously practice, implement, and modify the model. The principal investigators encouraged teachers to be hands-on active learners and problem solvers by adding their own adaptations to ensure the best implementation of the model in their classrooms. In this study, I presented a practical and scientific way of using an action research approach when adapting an intervention. The usefulness of action research should not be disregarded simply because some action research has historically been viewed by some as less rigorous than other types of research.

Theoretical Contribution

In this study, the REAPS model was adapted successfully in Australia. Using the REAPS model influenced the culture of the school as reflected by the students' perceptions of action research, small group work, hands-on activities, and real-world problem solving (Wu, et al., 2015). One of the important features found in all three components of the REAPS model (i.e., DISCOVER, TASC, and PBL) that also transferred to the REAPS model is flexibility, which allowed teachers to learn, modify, and use the model to develop students' creativity. When using the REAPS model, the learning process is more meaningful and enjoyable as students are encouraged to be hands-on active learners and investigators. Although problem solving is emphasized in the DISCOVER, TASC, and PBL models, each model has a unique aspect that fits with the others and makes their integration useful; for instance, the DISCOVER model includes the structure of problem types that can be solved using the steps embedded in the TASC model in a process of inquiry, as described in the PBL model, in which groups of students are actively engaged in solving problems and are facilitated by their teachers (Gomez-Arizaga & Maker, 2009).

In the development of her model of creative performance, Amabile's (1983; 1996) explanation seems similar to Renzulli's (2011) definition of gifted performance in many ways (e.g., having three factors, having two cognitive dimensions, and one conative element).

Renzulli visualized gifted performance as consisting of three interacting rings: above average ability, task commitment, and creativity. According to Renzulli, the interaction or overlap between the three rings is what constitutes gifted performance. Similarly, Amabile visualized her model of creative performance in a table that also included three components: domain-relevant skills (i.e., domain-specific), creativity-relevant skills (i.e., domain-general), and task motivation (see Table 1.4). However, in contrast to Renzulli's three-ring conception of gifted performance, Amabile did not suggest assessing the interaction or overlap in the three components in her model of creative performance. Thus, Amabile's three components can be seen as theoretically and practically discrete, but when she explains creative performance holistically, the components merge. Task commitment in Renzulli's conceptualization is a long-term conative element, which can be observed by teachers, parents, and classmates throughout many tasks; however, task motivation in Amabile's conceptualization is specific to the task at hand. Renzulli's and Amabile's conceptualizations are presented in *Figure* 5.2.

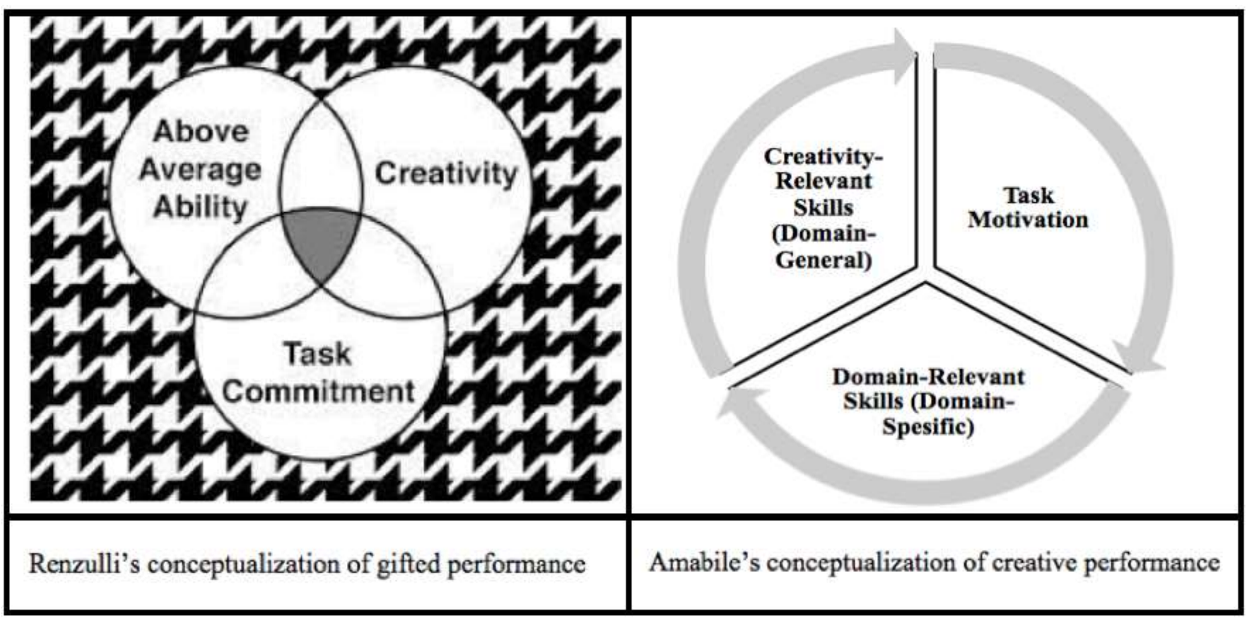


Figure 5.2: Comparison between Renzulli's and Amabile's conceptualizations

Amabile (1983; 1996) explains creative performance as the merging of domain-relevant skills, creative-relevant skills, and task motivation, and she asserts that the basis of the model is domain-relevant skills. However, the foundation of Amabile's model might be better classified as creative-relevant skills because based on the results of this study, I found that cognitive aptitude was required to engage the students in a complex thinking process such as domain-specific creativity (i.e., science). I also believe that Amabile's model contains two cognitive components and one conative dimension. In this study, task motivation, which is the conative dimension, seems to be the central component of the process of creative performance when using the REAPS model. In this study, I investigated only the two cognitive components; however, Wu, et al. (2015) analyzed qualitative data from the Australian Project to investigate students' perceptions of REAPS. Reviewing the results of the current study in conjunction with the results of Wu and colleagues' study, I believe that the REAPS model initially affects students' general creativity, which has been found in the previous studies to be sensitive and easy to develop. Then, students' motivation increases while they work in small groups to explore ideas and solve open-ended problems, and next it affects students' domain-specific creative problem solving, such as with science content. A conceptual visualization of the process of students' creative performance when using the REAPS model is presented in *Figure* 5.3. Future researchers should conduct studies to examine and challenge this explanation. I also encourage other members of the DISCOVER research team to collect data on students' task motivation in future studies of its implementation.

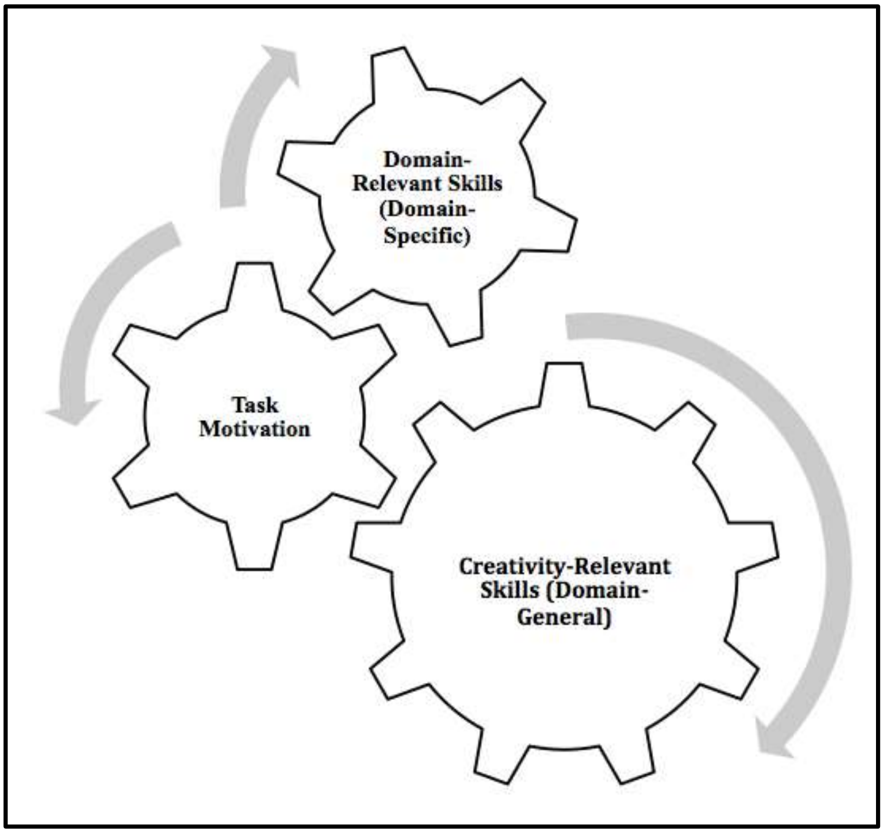


Figure 5.3: The process of students' creative performance when using the REAPS model

Final Thoughts

I was interested in examining the effects of two different durations of exposure to the REAPS model in developing students' general creativity and creative problem solving in science after the model was implemented in a new environment. I also sought to identify the aspects of creativity that were most affected by the long duration of exposure. Throughout this study, the REAPS model, the independent variable, and the two cognitive components of Amabile's (1983; 1996) model of creative performance (the dependent variables) were used as theoretical frameworks.

When I reviewed each of the previous studies in the literature, I was unable to draw any substantive conclusions; but upon rearranging, organizing, and developing intensive strategies to analyze and synthesize the available literature together as one body of research, I made a research-informed conclusion that the longer interventions usually resulted in expected positive growth in students' domain-specific creativity, but both longer and shorter interventions were effective in developing students' domain-general creative problem solving. This conclusion was consistent with Amabile's model of creative performance. Domain-specific problem solving requires specific knowledge and technical skills that need to be learned and developed before applying them creatively to solve real-world problems. This conclusion was confirmed by the results of this study. I did not find statistically significant differences between the two groups on the TCT-DP. However, I found statistically significant differences between the groups on TCPS-S scores. Generating ideas, adding details to ideas, and finding problems were the aspects changed during the intervention.

Educators in the fields of giftedness and creativity should focus their future work on how to improve the quality of teaching to develop all students' creative problem solving and engage them in real-world problems. To successfully meet the ongoing challenges faced by our global society today, teaching real-world problem solving is the best answer.

APPENDIX A

LETTER FROM SCHOOL TO PARENT/LEGAL GUARDIAN

15 August 2014

Dear Parents and Carers

Please find attached an information sheet and a permission note which explains the ***Real Engagement in Problem Based Learning Project*** that students from Years 1 – 6 have been undertaking over the past 18 months.

World renowned educator Dr June Maker has been supporting the school with this project and has been assisting us in collecting data from across all grades in the school. The data will be used in a research report that will be published in educational journals and that will inform how our school facilitates student problem solving and, critical and creative thinking.

We received signed permission from most parents/carers in 2013 however, we would like to keep this permission current and therefore request that you sign the attached permission note again.

If your child is in Year One this year or started at North Sydney Demonstration School within the last 12 months then parents/carers will not have signed this form previously.

I ask that you return a signed permission form to the school office by **Friday 29th August**.

Kind Regards

Principal

APPENDIX B

PARENT/LEGAL GUARDIAN CONSENT FORM

Page 1

THE UNIVERSITY OF ARIZONA.

CONSENT FORM FOR PARENTS IN GROUP A CLASSES

Research Project: Real Engagement in Active Problem Solving: Differentiation for Diverse Learners in Regular Classrooms

I (*print name*)__________________________________give consent to the participation of

my child (*print name*) ________________________ in the research project described below.

TITLE OF THE PROJECT: Real Engagement in Active Problem Solving: Differentiation for Diverse Learners in Regular Classrooms

CHIEF RESEARCHER: junemaker@email.arizona.edu or junemaker@hotmail.com

In giving my consent I acknowledge that

1. The procedures required for the project and the time involved have been explained to me and any questions I have about the project have been answered to my satisfaction.
2. I have read the Parent Information Sheet and have been given the opportunity to discuss the information and my child's involvement in the project with the researchers.
3. I have discussed participation in the project with my child and my child assents to their participation in the project.
4. I understand that that my child's participation in this project is voluntary; a decision not to participate will in no way affect her or his academic standing or relationship with the school and my child is free to withdraw his or her participation in the research (analysis of test results) at any time.
5. I understand that my child's involvement is strictly confidential and that no information about my child will be used in any way that reveals my child's identity.

6. I understand that my child's test results will be analyzed to determine the effects of a special program, and that these test results will be stored in a place and in a way that protects my child's anonymity.

7. I understand that audio recordings will be made as part of the study if my child is selected for an interview. These recordings will take place during the school day and in a quiet area of the classroom. Other children will be in the classroom, but not interfering with my child's interview.

Please cross out any activity that you do not wish your child to participate in.

Signed……………………………………………………………………………..

Name……………………………………………………………………………….

Date…………………………………………………………………………………

Any complaints about the research may be registered with the Director Educational Services, Talavera Road, MACQUARIE PARK NSW 9886 7000

APPENDIX C

PARENT/LEGAL GUARDIAN INFORMATION SHEET

THE UNIVERSITY OF ARIZONA.

PARENT/CAREGIVER INFORMATION SHEET

Research Project: Real Engagement in Active Problem Solving: Differentiation for Diverse Learners in Regular Classrooms

You and your child are invited to take part in a study being conducted by Dr. C. June Maker, Dr. Robert Zimmerman, and Mr. Randal Pease, of the University of Arizona, USA, and Ms. [redacted]

It is part of a project designed to adapt, modify, and test the effectiveness of an educational teaching program developed in the USA.

We are asking you if it is okay for you and your child to take part in this project.

We are trying to find out how the teaching program needs to be changed (if at all) to make it more useful and appropriate in Australia, and to find out if the use of this teaching method can increase students' creativity (general, scientific, and mathematical), their understanding of science concepts, and their achievement. We want to know if the use of this approach helps teachers differentiate their instruction to meet the needs of diverse learners, especially those who are gifted.

The information from the study will be used to decide whether to use this teaching method in the [redacted], how to adapt or change it to fit our school community, and whether to teach others how to implement it. We will report the results to you at parent meetings and will distribute a report to you. We also will report the results in educational journals, at educational conferences, and in teacher workshops.

We will ask your child to take some educational tests that are very similar to tests they usually take in school: a test of general creativity in which they will complete an incomplete picture; a test of scientific creativity in which they will identify science problems and design ways to solve them; a test of mathematical creativity in which they will solve several math problems and create math problems; and a concept mapping exercise in which they will draw diagrams of the ways science ideas are related. The tests will take approximately 2 hours (over a period of one week) and will occur twice each year. Your child also will take the usual tests of learning progress given at certain times during the school year.

Because your child is in a class with a number of students who are on Individualised Learning Plans, your child also will experience the new educational method, which will include solving real life problems individually and in groups. These will be part of the normal teaching of all subjects, but may be used mostly in science classes.

Participation in the classes and the educational program is a normal part of your child's education, but your child's participation in the research is voluntary. Your child will take the tests as part of the normal gathering of information about children's abilities, but the researchers will analyze the results of your child's tests only if both you and your child agree. If you decide not to take part, it will not affect your child's results or progress at school, and if you or your child change your mind about taking part, even after the study has started, just let the teacher and the school principal know, and any information already collected about your child will not be used in the research. Please notify the principal, [redacted], and your child's teacher if you wish to withdraw your child from the project.

If you and your child decide to participate, no one will be able to identify you or your child from the results of the study. Only the researchers will have access to this information, and it will not have identifying information about you or your child. The test scores will be stored on a password-protected computer and all test materials will be stored in a protected file in the primary researcher's office. These scores and materials will be kept for as long as the project lasts.

Six children from each classroom will be interviewed about their experiences as part of this program. They will make drawings and will talk about their drawings. Audio recordings of your child's responses will be made. As soon as they are transcribed, the audio recordings will be deleted. The transcriptions will not have your child's name on them. Only the interviewer and the individual who transcribes the recordings will hear your child's voice.

These recordings will be collected on a date to be specified, and the researchers will interview your child individually in a quiet area of the classroom while other children are present. Only the researchers will have access to the transcriptions of the recordings and the child's drawings.

We will use the recordings to find out how children think and feel about their participation in the new educational program. We believe that the children's perceptions are important in making decisions about the value of new teaching methods.

If your child is selected for an interview, we also will want to interview you about your perceptions of your child's participation in the program. Audio recordings of your responses will be made. As soon as they are transcribed, the audio recordings will be deleted. The transcriptions will not have your name on them. Only the interviewer and the individual who transcribes the recordings will hear your voice.

These recordings will be collected on a date to be specified, and the researchers will interview you individually in a place that is quiet and comfortable for you. Only the researchers will have access to the transcriptions of the recordings.

We will use the recordings to find out how parents think and feel about their child's participation in the new educational program. We believe that children's and parent's perceptions are important in making decisions about the value of new teaching methods.

You also will be asked to respond to questionnaires about the use of the new teaching method. When questionnaires are distributed, by responding to the questionnaire, you will be giving your permission for your responses to be analyzed by the researchers.

If you would like to check that you are OK with the information or recordings from the study, or if you have any questions, please ask the principal, [redacted] about the process.

When you have read this information, [redacted] will be available to answer any questions you may have at this time. If you would like to know more at any stage, please feel free to contact:

C. June Maker, junemaker@email.arizona.edu or junemaker@hotmail.com

[redacted]

This information sheet is for you to keep.

APPENDIX D

DEVELOPING A TEACHING UNIT USING THE REAPS MODEL

- FIRST -

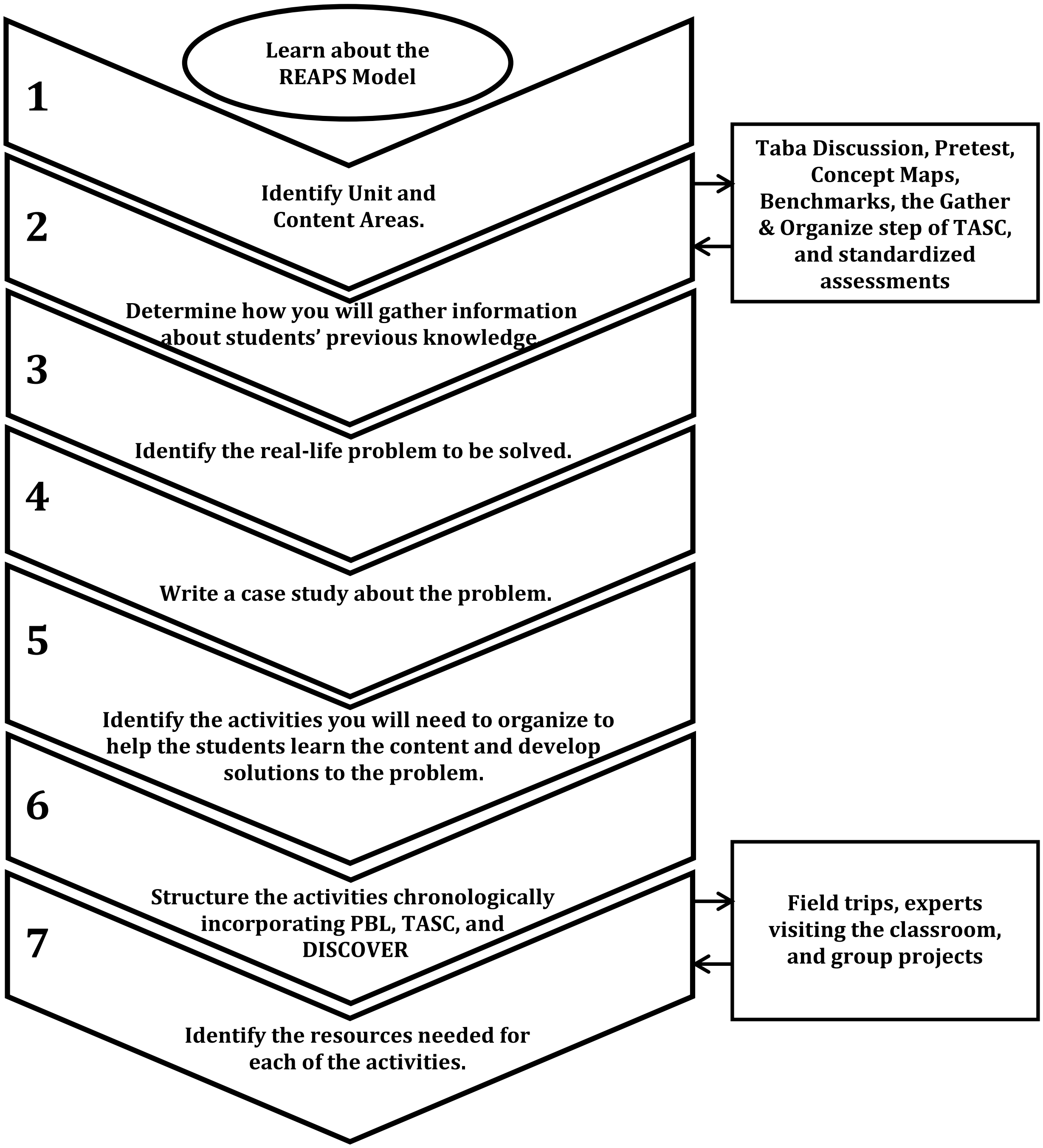
Guidelines for Planning Teaching Units Based on the REAPS Model

C. June Maker, Ph.D.; Robert H. Zimmerman, Ph.D.; and Randal J. Pease, M.A

University of Arizona, Tucson, USA

1. The first important factor to identify is the unit of study that is going to be taught and the content areas included in that unit. Identify the Macro Concept(s), the Benchmark(s), the Focus Question(s) and the Discipline-Based Concepts developed through the unit. The research team's list of Macro Concepts, the targeted Arizona State Standards, and textbooks or other references related to the content area are the guides to use in this part of the design because they include the important concepts that need to be mastered by the students by the end of that unit.
2. After the unit and its content areas are identified, the next step is to determine how you will gather information about students' previous knowledge about the concepts to be developed during the unit. The pre-assessment tools we recommend for this step are the Hilda Taba Teaching Strategies, concept maps, interviews, benchmark assessments, the gather and organize step of TASC, and standardized assessments.
3. After the teacher has identified the areas of study or the students have chosen a specific area of study, the next step is to identify the real-life problem to be solved.
4. Write a case study about the problem.
5. Knowing the content area and general information about your students, identify the activities you will need to organize so that the students will learn the content of the unit and develop solutions for the real-life problem in the case study.
6. Using the unit format table, sequence these activities chronologically and identify the REAPS model component (PBL, TASC, DISCOVER) for each activity. For example, if you want the students to describe a specific phenomenon thoroughly by themselves, the three components of REAPS would be organized as follows: (a) **DISCOVER**: problem type III + type of intelligence (e.g. spatial artistic, oral linguistic); (b) **TASC**: Students identify the main components and definitions of the phenomenon; and (c) **PBL**: identify problems that contribute to that particular phenomenon.
7. After all the activities have been sequenced and structured following the REAPS pattern, think about the resources needed for each of the activities, including fieldwork, experts visiting the classroom, and group projects.

Flow Chart of Steps in Planning Teaching Units Based on the REAPS Model



- SECOND -

Format for Teaching Units

Macro Concept(s): Simply list the Macro Concept. In most cases you will have only one.

Focus Question(s): This is the overall focus question for the unit. In most cases, you will have only one.

Framework Benchmark(s): List here the Framework Benchmark(s) from the relevant sections (Benchmarks in Literacy and Numeracy, Benchmarks in Personal and Social Capabilities) that provide the connection of this unit to the Curriculum Framework. More than one area usually will be included. Describe briefly how the unit activities help to achieve the benchmarks identified, especially the ways the various knowledge, skills, and processes are combined to develop the overall purpose of the unit.

Discipline-Based Concepts: List the discipline-based concepts developed in the unit. These are taken from the appropriate content areas of the framework and are related to the Macro Concept(s) and Framework Benchmark(s) that are the overall purposes.

Process Concepts: List here the process connections to the content. Here, use the charts Randy and June developed showing the connection between the Benchmarks in Personal and Social Capabilities and the steps of Thinking Actively in a Social Context (TASC).

Product Concepts: List here the product connections to the content. Here, use the charts Randy and June developed as a way to get ideas. These charts show how the Benchmarks in Literacy and Numeracy and the Benchmarks in Personal and Social Capabilities are related to Discovering Intellectual Strengths and Capabilities while Observing Varied Ethnic Responses (DISCOVER).

Materials: List the materials needed for the unit.

Activities: Using the table format that follows, arrange all the activities in chronological order, including pre- and post assessments. In the columns, explain briefly how each activity is connected to each of the three interacting models.

Activity (In Sequence)	**PBL Component**	**TASC Component**	**DISCOVER Component**

- THIRD -

Guidelines and Format for Developing Lesson Plans Based on the Curriculum Framework

Prior to beginning Unit: Describe here the activities to complete prior to beginning the unit. These would include the assessments and procedures as well as any units that are prerequisites.

Unit Resources: Here include references, people, web sites, and other resources for the unit.

Lesson One: Title

Purpose: Here, put the content purpose(s) stated as relationships among Macro Concept, Benchmark(s), and Discipline-Based Concepts.

REAPS Components

TASC: List the TASC step.
PBL: List the aspect of PBL incorporated into the lesson.
DISCOVER: Tell which problem type and which intelligence(s) are developed through the lesson.

Materials: List the materials needed for the lesson.

Steps: List the steps that need to be followed in the lesson in chronological order using a numbering format. Be specific.

Lesson Two: Title

Lesson Three: Title

Develop at least three lessons with the same components. More lessons should be developed if they are needed to show how the unit would develop, or to show different key components of it.

APPENDIX E

EXAMPLE OF A TEACHING UNIT USING THE REAPS MODEL

Matter and Energy
Grades 3-4

Macro Concept: Change and Consequence

Focus Question: How do matter and energy interact in our world and what are their consequences?

Framework Benchmark(s)

- Identification of states of matter: solid, liquid and gas
- Exploring the physical properties of materials determine their use
- Observing the addition or removal of heat causes in physical state in everyday solids and liquids
- Exploring the changes in physical state are reversible or irreversible
- Discovering energy sources can also cause changes of state: pressure/force, chemical
- Recording and graphing the environment impact of plastics [on landfills, oceans, and the human community]
- Explore the alternatives to plastic consumption
- Creating and responding to a range of written texts including texts to inform and persuade
- Plan, rehearse, and deliver presentations on learning area topics, incorporating some learned content and appropriate visual and multimodal elements

Everyday we see or use things that have been melted or frozen, heated or cooled. All around us are items that we find both useful and attractive that have molded into different shapes using heating and cooling. The overall goal of this unit will increase understandings of materials and how they change state under different conditions. Furthermore, students will be encouraged to use higher order thinking skills that require problematic knowledge to consider how matter and its change affect the community and world they live in and the materials use.

Discipline-Based Concepts

- With guidance, identify questions in familiar contexts that can be investigated scientifically and predict what might happen based on prior knowledge
- Science knowledge helps people to understand the effect of their actions
- Compare results with predictions, suggesting possible reasons for findings
- Represent and communicate ideas and finding in a variety of ways such as diagrams, physical representations and simple

reports

Process Concepts

Students will develop real-life problem solving skills through the construction of an ecosystem that would have as many of the characteristics of the real one as possible.

The process concepts are related to the Macro Concepts, the Benchmarks, and the Discipline-Based Concepts. This chart shows how these concepts are related to each step of the TASC model.

Step	**GC Area/Level**	**Standard**
Gather/Organize	GC-CCT: 6	Organize information from multiple sources (for example establishing issues of a similar nature in literature and film)
	GC-CCT: 6	Sequence, paraphrase, elaborate or condense information from a range of sources
Identify	GC-CCT: 6	Pose questions that identify and describe issues beyond their immediate world (for example questioning conventional responses to local and world events, asking who, when and why)
	GC-CCT: 6	Prioritize ideas and select information to form a considered and/or creative response to an issue (for example giving reasons for preferring a photo or a memory to recall an occasion)
Generate	GC-CCT: 6	Recognize there are multiple choices for solving a problem and imagine outcomes of these possibilities (for example generating and building on varied possible solutions to a problem that affects their lives)
	GC-CCT: 6	Engage in challenging situations, and persist with generating new approaches when initial ideas do not work (for example persisting with an idea when conducting an investigation and seeing 'failures' as challenging)

Step	GC Area/Level	Standard
Decide	GC-CCT: 6	Justify actions and solutions against identified criteria (for example examining their own and peer responses to an issue)
	GC-IU: 6	Imagine and ask: ‘How do I imagine others might feel?’ (for example in scenarios concerning difference imagining how others might feel, putting themselves in the other person’s shoes)
Implement	GC-PSC: 6	Work in teams, encouraging others and recognizing their contributions, negotiating roles and managing time and tasks (for example working collaboratively to suggest improvements in methods used for group investigations and projects)
	GC-CCT: 6	Consider alternative courses of action when presented with new information
Evaluate	GC-CCT: 6	With support, identify and describe thinking and learning strategies they have used (for example deciding the best strategy for solving a problem)
	GC-CCT: 6	Reflect on whether they have accomplished what they set out to do
Communicate	GC-PSC: 6	Build verbal and nonverbal communication skills, such as attentive and reflective listening, participation in class discussions, presentation of group reports (for example contributing to discussions and building on the ideas of others)
	GC-ICT: 6	Create digital solutions, independently or collaboratively, for particular audiences and purposes (for example manipulating images, text, video and sound for presentations; creating podcasts)
Learn from Experience	GC-PSC: 6	Reflect on and apply learning to their everyday lives to consolidate strengths and address challenges (for example when working in small groups, build on their strengths in various roles, and setting goals to develop specific skills)
	GC-PSC: 6	Describe and assess personal strengths and challenges, learning from success and failure (for example keeping a journal of their learning, describing both positive and negative experiences)
	GC-PSC: 6	Demonstrate awareness of personal habits and behavior, and factors influencing their successes and mistakes (for example setting learning and study goals that take into account their challenges and build on their strengths)

Step	GC Area/Level	Standard
All Steps	GC-PSC: 6	Build verbal and nonverbal communication skills, such as attentive and reflective listening, participation in class discussions, presentation of group reports (for example contributing to discussions and building on the ideas of others) Initiate or help to organize classroom and group activities, identifying and addressing a common need
	GC-PSC: 6	Use listening and observational skills to identify and empathize with the feelings and perspectives of others in a range of situations
	GC-PSC: 6	Explain and act on personal roles and responsibilities in their homes, schools and communities (for example considering how personal and community choices influence the use of sustainable sources of energy)
	GC-PSC: 6	Identify the differences between positive and negative relationships and ways of managing these (for example using visual and linguistic cues to describe and interpret relationships between characters in texts)
	GC-PSC: 6	Accept that their point of view is one of many and begin to see themselves as others may see them (for example describing an experience or event from another's viewpoint)
	GC-IU: 6	Demonstrate sensitivity to the feelings and needs of others (for example through a variety of role plays imagining how people can feel when included or excluded)
	GC-IU: 6	Respect the right of others to be different and be accepting of others (for example listening, sharing and responding thoughtfully to the views and ideas of others)

Note: GC-General Capabilities; CCT-Critical and Creative Thinking; PSC-Personal and Social Capability; EB-Ethical Behavior; IU-Intercultural Understanding; ICT-Information, Communication, and Technology.

Product Concepts

The product concepts are related to the Macro Concepts, the Benchmarks, and the Discipline-Based Concepts. This chart shows how these concepts are related to each Intelligence in the DISCOVER model.

Product	All	**L**-Write a scenario that demonstrates a relationship between matter and energy. **LM**-Make a molecular structure diagram showing the change state from a solid, to liquid, to gas. **S**-Create an illustration and/or model to represent the affects of the over use of plastics. **BK**-Dramatize the molecular structures using students' bodies and movement. **N**-Examine how the plastic manufacturing as the indestructible molecular structure is having catastrophic effects on marine life, environment and human safety. **I**-Add a section to your group's oral presentation in which you describe the interactions of people that have resulted from the use of plastics upon community environments. **IAP**-Reflect on your personal reactions to the effects of plastic in your community and the world. Either write an essay or add this information to your group's presentation.

Note: L-Linguistic; LM-Logical Mathematical; S-Spatial; M-Musical; BK-Bodily Kinesthetic; N-Naturalistic; I-Interpersonal; IAP-Intrapersonal

Materials

Students will be provided with a wide array of materials to conduct their experiments, such as reference sources, science notebooks, Need to know chart, marbles, DVD/Internet website, computer laptops or desktops, video cameras, cameras, food and drinking packaging, plastic and paper bags, plastic toys, saucepan, and electric heating element such as a simple stove. Students will design their models using materials such as different types of paper, clay, string, cardboard, magazines, and other items that may be available. I-pads or computer laptops or desktops will be used to assist with the students' presentations.

Activities

In the following section, the unit activities are listed in chronological order. In each of the columns, the ways the activity is connected to each of the three interacting models is explained.

Activities	TASC Component	PBL Component	DISCOVER Component
Students will research what matter is and the three states.	*Identify* the matter and it's three states.	Identify problems that are real to the specific to matter and it's three states.	Naturalistic, Linguistic, and Logical Mathematical Intelligences; Problem Type III.
Students will list the characteristics of a molecular structure of a solid, liquid, and gas.	*Identify* the characteristics of a molecular structure in a solid, liquid, and gas state.	Compare interactions observed of the changes from solid, to liquid, to gas.	Naturalistic, Linguistic, and Interpersonal; Problem Type IV.

Activities	**TASC Component**	**PBL Component**	**DISCOVER Component**
Students will dramatize the molecular structures using students' bodies and movement.	*Gather* and *Organize* information on molecular structures.	Develop skills to support their investigations into the problems related to molecular structures.	Naturalistic, Linguistic, Interpersonal, and Bodily Kinesthetic Intelligences; Problem Type IV.
Students will use notebook videos to further build field of matter and hot it changes state and metalanguage around how the molecules move to change the density of matter.	*Gather and Organize* information about density of matter.	Students use real marbles to demonstrate the more force applied to a group of marbles by a single marble.	Naturalistic, Linguistic, Interpersonal, Logical-Mathematical, and Bodily Kinesthetic Intelligences; Problem Type IV.
Students will identify the physical properties of some natural and processed materials.	*Identify* the physical properties of some natural and processed materials.	Compare plastics to more natural occurring materials used for products.	Naturalistic, Linguistic, and Logical Mathematical Intelligences; Problem Type III.
Students (in small groups) will create a structure (solid) that enables a toy car to be transported across a river.	*Generate* ideas about how a toy car might be transported across a river.	Groups will investigate possible solutions of transporting the toy car across the river	Naturalistic, Linguistic, Interpersonal, Intrapersonal, and Logical-Mathematical Intelligences; Problem Type IV.
Students will list all of the possible ways a toy car might be transported across a river.	*Decide* on the best idea(s) for solving the problem.	Students will explore many dimensions of the problem.	Linguistics, Interpersonal, Intrapersonal, and Logical-Mathematical; Problem Type IV.
Students will construct a possible solution to the toy car transport problem.	*Implement* the chosen solution to the problem.	Students solve the problem from their group's perspective.	Spatial, Linguistic, Interpersonal, Intrapersonal, Logical-Mathematical Intelligences; Types 1-IV.

Activities	**TASC Component**	**PBL Component**	**DISCOVER Component**
Students will practice their toy car transport solutions to the class with the assistance of a student created iMovie.	*Communicate* to other what you have done.	Students communicate solutions to an audience.	Spatial, Linguistic, Interpersonal, Intrapersonal, Logical-Mathematical Intelligences; Types 1-IV.
Individually, students reflect on their experiences in constructing the solutions, the quality of their 'bridge', and their interpersonal interactions. They tell what they would do differently in the future.	*Learn from Experience* by reflecting on strengths, weaknesses, alternative ways of solving problems, and what was learned during the problem solving process.	An analysis of what has been learned; self and peer assessments should be carried out at the completion of the activity.	Spatial, Linguistic, Interpersonal, Intrapersonal, Logical-Mathematical Intelligences; Types V.
Students will list the characteristics of plastics.	*Identify* the ways plastics are produced, used, and distributed.	Develop skills to support their investigations into the problems related to plastics and the environment.	Naturalistic, Linguistic, Interpersonal, and Logical-Mathematical Intelligences; Problem Type III.
Five exploration groups are formed to examine the impact of plastics upon humans, animals, and plants, within the environment: oceans, landfills, and communities.	*Gather and Organize* information to improve understanding on plastic's impact on environment, including humans, animals, plants, oceans, waterways, land, and cities.	Stakeholder groups are identified so that participants investigate the problem from different viewpoints.	Naturalistic, Linguistic, Interpersonal, and Logical-Mathematical Intelligences; Problem Type IV.
In each group, students develop criteria for evaluating the impact of plastics upon the environment.	*Identify* the characteristics that will be used to evaluate ideas, hypothesis, and final solution(s).	Students use their information about matter states, energy, and plastics.	Naturalistic, Linguistic, Interpersonal, Intrapersonal, and Logical-Mathematical Intelligences; Problem Type IV.

Activities	**TASC Component**	**PBL Component**	**DISCOVER Component**
Students gather information in a variety of ways. They will visit online science forum about molecular structures of plastics. Possible guest speakers from the community share expertise with students and students use print and multimedia sources to support their learning.	*Gather and Organize* information to improve understanding of the impact of plastics on humans, animals, and plants, within the environment: oceans, landfills, and communities.	Participants gather information and develop skills to understand the problems of plastics' impact upon environment.	Linguistic, Interpersonal, Logical-Mathematical, and Naturalistic Intelligences; Problem Types I-IV.
Students working in each group meet to develop a 'know, need to know, and sources' chart.	*Gather and Organize* information about students' understanding of the impact of plastics on humans, animals, and plants, within the environment: oceans, landfills, and communities.	Groups identify information and explore the problem of plastics on society and furthermore, the environment.	Linguistic, Interpersonal, Intrapersonal, Logical-Mathematical, and Naturalistic Intelligences; Problem Types I-IV.
Students gather more information to answer their questions through print sources, the internet, and interviews with experts.	*Gather and Organize* information about the problem.	Each group gathers information to use in solving the problem from the perspective of their group.	Linguistic, Interpersonal, Intrapersonal, Logical-Mathematical, and Naturalistic Intelligences; Problem Types I-IV.
Each group of students creates at least three possible solutions to the plastics problem.	*Generate* ideas for solving the problem.	Students apply their knowledge to make several designs that reflect their understanding of the problems with plastics.	Linguistic, Spatial, Interpersonal, Logical-Mathematical, and Naturalistic Intelligences; Problem Types III-V.

Activities	**TASC Component**	**PBL Component**	**DISCOVER Component**
Students compare their solutions, discuss them, and decide on the best solution.	*Decide* on the best idea(s) for solving the problem.	Students apply their knowledge to select the best solution to a problem.	Linguistic, Spatial, Interpersonal, Logical-Mathematical, and Naturalistic Intelligences; Problem Types III & IV.
Groups construct their plastics' solutions that could have an impact on humans, animals, and plants, within the environment: oceans, landfills, and communities.	*Implement* the chosen solution to the problem.	Students solve the problem from their group's perspective.	Linguistic, Spatial, Interpersonal, Intrapersonal, Logical-Mathematical, and Naturalistic Intelligences; Problem V-VI.
Teams evaluate their solutions using the criteria they developed and describe how each criterion was incorporated.	*Evaluate* the solutions using the criteria for evaluating their models that were developed at the *Identify* step.	Participants revise solutions as needed.	Linguistic, Interpersonal, Intrapersonal, Logical-Mathematical, and Naturalistic Intelligences; Problem Type V.
Students practice their presentations in front of the class and the teacher. Students will use their I-pad movies to assist them.	*Communicate* your results. *Evaluate* your presentation.	Participants choose the most effective ways to present their solutions.	Linguistic, Interpersonal, and Naturalistic Intelligences, Problem Type III.
Students present their models to the class and others interested. Their presentations are video-recorded to be shared with their parents.	*Communicate* to others what you have done.	Participants communicate solutions to an audience.	Linguistic, Interpersonal, Intrapersonal, Logical-Mathematical, and Naturalistic Intelligences; Problem Type V.

Activities	**TASC Component**	**PBL Component**	**DISCOVER Component**
Individually, students reflect on their experiences in creating solutions to the plastics issues, and their interpersonal interactions. They tell what they did well, what they would do differently in the future, and what they learned about the impact of plastics on humans, animals, and plants, within the environment: oceans, landfills, and communities.	*Learn from Experience* by reflecting on strengths, weaknesses, alternative ways of solving problems, and what was learned during the problem solving process.	A closing analysis of what has been learned is essential; self and peer assessment should be carried out at the completion of a project and the end of a unit.	Linguistic Spatial, Logical-Mathematical, and Intrapersonal Intelligences, Problem Type V.

APPENDIX F

TEACHERS OBSERVATION FORM

Real Engagement in Active Problem Solving
Fidelity of Implementation

Observer ________________________ **Today's Date** ____________
Teacher ________________________ **Grade/Year** ____________
School ________________________ **Section/Class** ____________
Number of Students ____________________
Beginning Time ____________________ **Ending Time** ____________
Teacher's Unit/Lesson Plan Attached ________________________________

REAPS Project Title

REAPS Problem Synopsis

Prism Abilities

__Logical/Mathematical __Somatic/Bodily __Visual/Spatial __Auditory __Linguistic
__Mechanical/Technical __Scientific __Social __Emotional __Spiritual

DISCOVER Problem Types

______Type I ______Type II ______Type III ______Type IV ______Type V ______Type VI

PBL Stakeholders/Perspectives

TASC Steps

______Gather/Organize

______Identify

______Generate

______Decide

______Implement

______Evaluate

______Communicate

______Learn from Experience

Observer ______________________________ **Today's Date** ____________________
Teacher ______________________________ **Grade/Year** ____________________

Observation Notes

Content

__**Abstractness**
__**Complexity**
__**Variety**
__**Organization**
__**Study of People**
__**Study of Methods**

Observation Notes

Process

__**Higher Levels of Thinking**
__**Open-Endedness**
__**Discovery**
__**Evidence of Reasoning**
__**Freedom of Choice**
__**Pacing**
__**Group Interaction**

Observer ______________________________ **Today's Date** ____________________
Teacher ______________________________ **Grade/Year** ____________________

Observation Notes

Product
__**Real Problems**
__**Real Audience**
__**Transformation**
__**Variety**
__**Self-Selected Formats**
__**Appropriate Evaluation**
__**Photos of Product Attached**

Learning Environment
__**Learner Centered**
__**Encourage Independence**
__**Openness**
__**Accepting**
__**Complexity**
__**Various Groupings**
__**Flexibility**
__**High Mobility**

Description
(Attach photographs of the classroom)

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