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Öğrencilerin Yaratıcılıklarının Geliştirilmesinde Açık Uçlu Problem Çözme Yaklaşımının Kullanım Alanları: Analitik Bir İnceleme

The Uses of Open-Ended Problem Solving in Regular Academic Subjects to Develop Students' Creativity: An Analytical Review

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Öz

Bu çalışmada öğrencilerin yaratıcılıklarını geliştirmek için kullanılan açık uçlu problem çözme yaklaşımı analitik bir şekilde incelenmiştir. Yüksek düzeyde göstergeye sahip yirmi çalışma seçilerek akademik alanlarına göre üç kategoriye ayrılmıştır. Araştırmaların çalışma gruplarında toplam 7707 öğrenci yer almıştır. Uygulamalara ayrılan ortalama zaman yaklaşık 15 aydır. Uygulamaların %90'ında öğrencilerde gözlenebilir gelişmeler kaydedilirken, %10'unda düşük seviyede gelişim gözlenmiştir. Analitik teknik kullanılarak uygulamaların (a) %55'inde ilköğretim öğrencileri ile çalışıldığı; (b) %85'inde IV. Tür ve V. Tür problemlerin kullanıldığı, %65'inde ise VI. Tür problemlerin kullanıldığı; (c) %50'sinde açık uçlu problemlerin bütün akademik alanlara entegre edildiği; (d) %90'ında yaratıcılık, süreç perspektifinden ele alındığı (e) %50'sinde açık uçlu sorular geleneksel olmayan araçlarla ölçüldüğü bulunuştur. İleri araştırmalarda VI. Tür problemlere (problem bulma) odaklanılmalı, açık uçlu problem çözme yaklaşımı farklı akademik alanlarda ve üst sınıflarda da uygulanmalıdır.

Anahtar Sözcükler: açık uçlu problem çözme, yaratıcılığın geliştirilmesi, DISCOVER müfredatı

Abstract

The uses of open-ended problem solving to develop students' creativity were investigated through an analytical review. Twenty studies with high-quality indicators were selected. Participants in all studies were 7707 students. The average time spent in all interventions was approximately 15 months. Students had observable improvement in 90% of the interventions. By using the analytic technique across all studies, the authors found that (a) in 55% of the interventions, elementary school students were included; (b) in 85% of the interventions, problem Types IV and V were used, and in 65% of the interventions problem Type VI was used; (c) in 50% of the interventions, open-ended problems were integrated with all academic subjects; (d) in 90% of the interventions, the perspective of creativity was creativity as process; and (e) in 50% of the studies, open-ended problems were measured using nontraditional instruments. Future researchers should focus on integrating problem finding (i.e. Type VI) and implementing open-ended problem solving in more academic subjects and with students in upper levels of school.

Keywords: open-ended problem solving, creativity, DISCOVER curriculum

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The Uses of Open-Ended Problem Solving in Regular Academic Subjects to Develop Students' Creativity: An Analytical Review

What has made creativity? Many historical explanations have been provided to answer this question. Creativity has been a popular topic in many cultures. Individuals have been interested in finding rational explanations about the origins of creativity, on the basis that insight into creativity's foundations may have helped increase the number of creative people. History has been filled with examples of superstitious and quasi-religious explanations for creativity. Within Arabic discourse, knowledgeable people struggled with many different answers; some suggested that a goblin lived in a creative person's mind, while others suggested that God bestowed creativity. In the past century, Guilford (1950) presented the Structure of Intellect theory in which he identified a variety of cognitive abilities. One of the most important ideas presented through Guilford's theory was that of divergent and convergent thinking.

Based on Guilford's (1950) work, other researchers have developed educational applications. For instance, Torrance (1962) developed the Torrance Tests of Creative Thinking (TTCT) to assess creativity as divergent thinking. On the other hand, Getzels and Csikszentmihalyi (1967) developed a theoretical and practical perspective of problem solving types that ranged from convergent thinking (e.g. Type 1) to divergent thinking (e.g. Type 3). The key idea of Getzels and Csikszentmihalyi's work was that three types of problems existed. The types were based on the presenter's and the solver's knowledge about the problem, method, and solution. For instance, in Type 1, both presenter and solver knew the problem, the method, and the solution. In Type 2, the complexity of the situation increased because the solver did not know the method and the solution. In Type 3, neither the presenter nor the solver knew the problem, the method, or the solution.

The implications of Getzels and Csikszentmihalyi's (1967) work in both assessing and teaching students in school settings were applied in Maker's research, through which she developed the Discovering Intellectual Strengths and Capabilities while Observing Varied Ethnic Responses (DISCOVER) project. 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. Also, they combined those types with the theories of Gardner (1983) and Sternberg (1997) to complete one of the most ambitious educational projects to date, of which the goal was to meet all students' needs by assessing students and then offering them the appropriate curriculum, regardless of their majority or minority status (Maker, 1993;

Maker, 2005; Maker, Jo, & Muammar, 2008; Maker, Rogers, Nielson, & Bauerle, 1996; Maker & Schiever, 2010).

Maker and Schiever (2010) presented the problem continuum in which all of the problem solving ranged from Types I to VI. For instance, in problem Type I, the problem was stated clearly; students solved the problem with only one correct solution. In problem Type II, the problem was specified, but only the presenter knew the method for solving the problem, using only one correct solution. In problem Type III, the problem was specified, but many methods were possible, and the presenter knew the solution. However, in Type IV, the problem was specified, multiple solutions were possible, and the presenter knew the range of possible solutions. In problem Type V, the problem was specified, and neither the presenter nor solver knew the method nor the solution. In problem Type VI, the problem was unknown and neither the presenter nor the solver knew the method nor the solution. The Problem Continuum is shown in Table 1.

Table 1. Problem Continuum

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 Maker & Schiever (2010).

In the last three decades, both the definition and functional understanding of creativity have been improved, and specialists in this field have developed a variety of theories and definitions. As an example of the changes, many researchers argued that creativity was a single domain, while others brought forth evidence that creativity involved many domains (Hong & Milgram, 2010; Silvia, Kaufman, & Pretz, 2009). In our point of view, whether creativity has been considered to be domain general or domain specific, the idea of problem solving types as presented in the Problem Continuum by Maker and Schiever (2010) could be found in both arguments. In this review, we used the problem continuum as a practical means for evaluating the interventions designed to developed creativity, especially in determining the degree of open-endedness in the problems presented (Types IV to VI).

As a theoretical framework, Rhodes (1961) developed the model of four Ps (i.e. Person, Product, Process, and Press), which was one of the first attempts to define creativity as a complex and comprehensive concept; however, Rhodes did not focus on the connections between these elements. In contrast, Alhusaini, Kandil, and Yamin (2008) studied concepts of creativity in many different fields (i.e. education, sociology, psychology, business, and industry), and divided all the concepts into five categories; also, they found connections between them. Alhusaini and Maker (2011) presented that work again under the name of "The Comprehensive Concept of Creativity (CCC)," as a theoretical framework in one of their studies to help people understand creativity as a complex and connected concept.

In this review, the CCC was adapted as a theoretical framework for examining the ways creativity was conceptualized by researchers, including five categories: (a) Creativity as Environmental Socialization, (b) Creativity as a Personality Trait, (c) Creativity as a Process, (d) Creativity as Thinking Skills, and (e) Creativity as Products. These five categories could be seen as the major components of the CCC. For example, students were educated in schools that reflected students' personalities by motivating them to think creatively; the students then used their thinking skills to generate new products to benefit their communities. Approaching this process from the other direction, communities gave these products their approval by using them. The products themselves were, of course, the result of people's creative skills, which were processes reflecting the creative people's personalities that were, in turn, based on their environments (Figure 1).

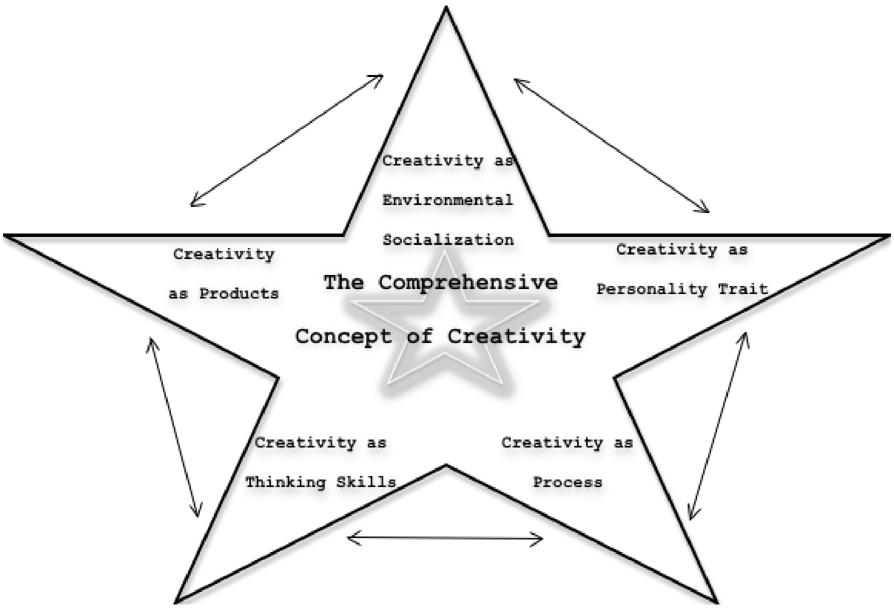


Figure 1. The Comprehensive Concept of Creativity (CCC)

The compatibility between the problem continuum and the CCC was noted by Alhusaini and Maker (2011) when they presented the DISCOVER assessments as a method that included the Problem Continuum and incorporated all five categories of the CCC. For example, students in the DISCOVER project participated in their facilitative classrooms, enjoyed their activities with a small group of peers, which followed creativity and environmental socialization in the CCC. Students developed some creative traits with their teacher or peers' encouragement, which met the CCC factor of Creativity as a Personality Trait. During the DISCOVER project, students were solving problems by responding to the activities, which fulfilled the CCC factor of Creativity as a Process and Creativity as Thinking Skills. Finally, students in the DISCOVER project created products that could be judged by other people, which satisfied the factor of Creativity as Products in the CCC. Alhusaini and Maker believed that an effective approach aimed at developing students' creativity should have included open-ended problem solving as well as all the CCC factors to improve students' creativity in a comprehensive way.

In the last three decades, much research has been conducted to examine the development of students' creativity, by studying its use in activities outside of the regular academic subjects and by integrating problem solving into regular academic subjects. Some researchers also have reviewed problem solving as an enrichment activity (Hunsaker, 2005; Ma, 2006; Scott, Leritz, & Mumford, 2004; Treffinger & Isaksen, 2005). However, no research reviews have been found in which researchers focused on investigating the uses of open-ended problem solving within regular academic subjects.

The purpose of this review was to investigate the uses of open-ended problem solving in developing students' creativity in three major areas: (a) to discover what participants were included (i.e. students' school levels, genders, ethnicities, and abilities); (b) to inspect the interventions' content by focusing on specific elements (i.e. problem types, academic subjects, and perspectives of creativity); and (c) to scrutinize the instruments that were used to measure open-ended problem solving. The question that guided the study was the following:

1. How has open-ended problem solving been used to develop students' creativity throughout educational research?

Method

Locating Studies

The ProQuest, ERIC, and EBSCO Databases were used to search for studies in which researchers examined the effectiveness of implementing open-ended problem solving in regular academic subjects to develop students' creativity. The terms used to search for studies were *open-ended problem solving to develop students' creativity*, *developing creative thinking in regular classrooms*, *open-ended activities*, *problem-based learning*, *PBL*, *creative problem solving with academic subjects*, *CPS*, *future problem solving with academic subjects*, *FPS*, and *the DISCOVER curriculum.* Hand searches were conducted in issues of well-known journals in the field of creativity from the last five years (2006-2011), including *Creativity Research Journal*, *Gifted Child Quarterly,* and *Journal of Creative Behavior*.

Procedure

The first step. The title and abstract from each article were reviewed to determine whether or not a study might be useful for this review. This basic search yielded a total of 208 studies. Those studies were evaluated with a focus on the purpose of this review. The criteria by which the studies were evaluated were the following: (a) the method of the study had to be experimental or qualitative, (b) the intervention had to include solving open-ended problems that were integrated with regular academic subjects, and (c) the study had to be conducted with students in a school setting. Additionally, one articles in the process of publication were included in which the DISCOVER curriculum was used as the intervention. After these criteria was applied, 23 of the original 208 studies remained.

The second step. In the journal *Exceptional Children*, Odom et al. (2005) published an article about evidence-based practices in Special Education research. In this article, they assisted researchers in the field of Special Education to become aware of certain quality indicators, because studies with indicators of high quality were more likely to result in observable evidence-based practices than studies without these indicators. In this study, some of the quality indicators were adapted as a way to critique the studies and to judge their quality.

Quality indicators developed by Gersten et al. (2005) were used to evaluate group experimental research, and those developed by Brantlinger, Jimenez, Klingner, Pugach, and Richardson (2005) were used to evaluate qualitative research. However, not all of their suggestions were used to critique the studies selected for this review. For example, one of the unused indicators from Gersten et al. was the comparability of intervention and comparison groups. In this review of research, we examined the uses of open-ended problem solving in school settings, so most of the studies were conducted in regular classrooms without randomized sampling. Moreover, some studies were conducted in one classroom with no comparison group. In this way, the quality indicators used in this review were selected based on the work of both Gersten et al. and Brantlinger et al.

The third step. A technique created by Montague and Dietz (2009) was adapted to evaluate the studies. Each article was read and critiqued by using the qualifiers *yes* or *no* for each subdivision. *Yes* implied that the indicator's subdivision was reported sufficiently in the study, and *no* implied that the indicator's subdivision was not reported sufficiently. The studies with a score of 75% or above were considered to have met the quality indicators (See Table 3, Table 4 Section A and B, and Table 5). After these quality indicators were applied, 20 of the original 23 studies remained. Table 2 includes summaries of each study arranged alphabetically by the researchers' surnames, and numbered from 1 to 20 for ease of identification in the other tables.

The fourth step. Based on the previous research reviews in the field of creativity, such as Ma (2006), who did a meta-analysis to examine the effect of some creativity training programs that were not integrated with regular academic subjects (e.g. the Creative Problem Solving [CPS] program and SCAMPER); Treffinger and Isaksen (2005), who examined the applications of CPS in school settings with a focus on gifted students; Hunsaker (2005), who studied the effectiveness of using creativity training programs in classrooms; and Scott, Leritz, and Mumford (2004), who examined the effectiveness of creativity training by doing a meta-analysis of 70 studies, a new approach was developed and adapted in this review to make the implications valuable and functional for both researchers and teachers. The studies were first analyzed by the content of their interventions, with emphasis on the subjects into which open-ended problem solving was integrated, and then by the grade levels in which they were implemented. After each group of studies was presented and synthesized, the findings were provided across all the studies in each particular group, focusing on which types of open-ended problem solving were used according to the problem continuum, as presented in Table 1 (Maker & Schiever, 2010). Also, the perspectives of creativity were inferred based on the five categories of the CCC (Figure 1). These kinds of analyses might help both teachers and researchers to implement open-ended problem solving effectively in the future.

The final step. Not all the researchers provided specific details about the elements that we focused on in this review (e.g. problem types and the perspectives of creativity). For example, most researchers presented similar or identical definitions of creativity and open-ended problem solving, while others did not define creativity and open-ended problem solving clearly. For these reasons, we relied on our interpretation of the researchers' statements to make judgments during the analysis. For instance, information and evidence about the researchers' practices during their interventions were gleaned from studies that did not have enough details based on inferences from their practices. For this reason, checklists were developed that contained all the examined elements (e.g. problem types and the perspectives of creativity). These checklists were revised and integrated in Table 7 to visualize the analysis procedure and to provide better understanding of the findings of this review. In studies about the DISCOVER project, all the examined elements were checked because this project was developed to include all the problem types.

Findings

Since Getzels and Csikszentmihalyi first published their article, titled "Scientific Creativity" (1967), an interest in the use of open-ended problem solving has developed. This increasing awareness was demonstrated with a simple chronological graph of the research included in this review from 1978 to 2011 (Figure 2). Also, other arrangements and organizations of data were included. Table 2 is the main table in this review with brief summaries (i.e. Purpose, Participants, Design, Intervention) of all studies arranged alphabetically by the researchers' surnames, and numbered from 1 to 20 to ease recognition in the other tables; Tables 3, 4, and 5 are critiques of each study based on the quality indicators; and the other tables include the revised checklists in which the descriptions of participants (Table 6), interventions (Table 7), and measurements (Table 8) were given. The information was provided for each study as well as the percentages across all the studies.

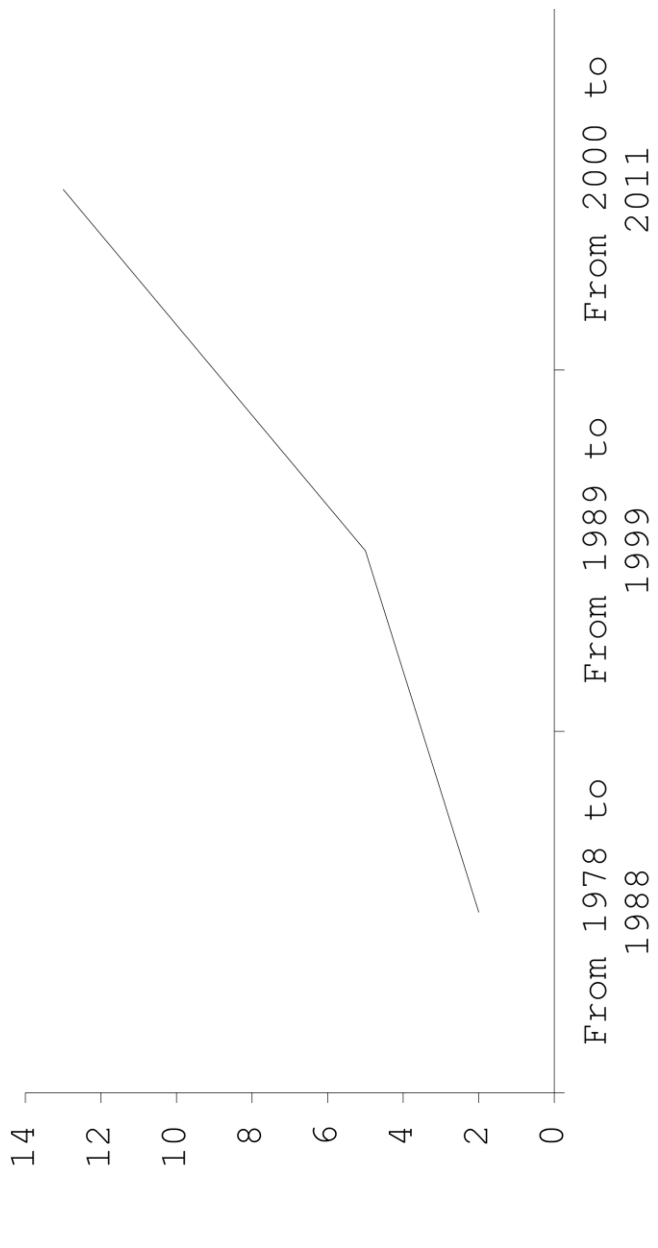


Figure 2. The number of studies of open-ended problem solving over time

Table 2. Studies of the Effectiveness of Open-Ended Problem Solving

Study	Purpose	Participants	Design	Intervention
1. Byrne et al. (2010)	To examine the effectiveness of a training program designed to develop the ability to evaluate new ideas and plan for idea implementation	141 undergraduates, including 55 males and 83 females	Experimental static-group one test design	One day of the training program in which the open-ended problem solving was integrated with the subject of advertisement
2. Cheng et al. (2010)	To investigate the effects of training programs in the Chinese language to develop students' writing creativity	64 fourth-graders in two classrooms	Experimental one test mixed design	Five weeks of implementing the Chinese free-writing training program in which open-ended problem solving was integrated with the subject of language
3. Cunningham and MacGregor (2008)	To investigate the effects of training programs in solving problems, such as realistic and puzzle-like, to develop creativity	45 undergraduates, including 26 males and 14 females	Experimental two by two factorial design	One day of the training program that was implemented to develop the ability of solving problems; The open-ended problem solving was integrated with the subject of math
4. Gallagher (1992)	To study the effectiveness of using a problem based curriculum at the high school level	120 gifted students	Experimental static-group pretest-posttest design	One semester, gifted students were given open-ended problem solving in science, society, and the future (SSF)
5. Hertzog (1998)	To explore curriculum differentiation for gifted students in grades 3 and 4 by examining learner responses to open-ended problem solving	11 students, including 4 males and 7 females	Qualitative naturalistic study	One academic year through which gifted students were given open-ended problem solving in different academic subjects

Table 2. Studies of the Effectiveness of Open-Ended Problem Solving(Continued)

Study	Purpose	Participants	Design	Intervention
6. Hicks (1980)	To examine whether or notcreative thinking could be enhanced in fourth grade students	23 students, including 8 males and 15 females	Experimental one-group pretest-posttest design	Eight weeks of treatment program in which open-ended problem solving was integrated with the subject of reading
7. Houtz et al. (1978)	To study the development of creative thinking in gifted and non-gifted students through all elementary school years	233 students from second through sixth grade	Experimental many-group (classes) adapted design	Ten weeks of implementing a problem solving program that included open-ended problem solving in all academic subjects
8. Jin and Moon (2006)	To examine whether academically talented students who attended a residential science high school in Korea had levels of school/life satisfaction different from their peers in regular high schools	299 gifted students, including 215 males and 84 females	Experimental adapted design	All years of high school was an implementation of advanced curricula in science, so the open-ended problems were integrated with various science subjects
9. Jo and Maker (2011)	To investigate the impact of the DISCOVER curriculum on first through fifth grade students' mathematical knowledge and mathematical creativity	835 students from different backgrounds	Experimental three-group adapted design	Three years of implementing the DISCOVER curriculum in which open-ended problem solving was integrated with all academic subjects
10. Kuang (2011)	To illustrate how professors could motivate pre-service early childhood teachers to be more creative using the DISCOVER model	50 undergraduates, all of whom were females	Qualitative analyses of art work	One semester was spent to implement the DISCOVER problem types to motivate pre-service early childhood teachers as a part of a children's literature course

Table 2. Studies of the Effectiveness of Open-Ended Problem Solving(Continued)

Study	Purpose	Participants	Design	Intervention
11. Kuo et al. (2010)	To determine the effectiveness of the PSMIGP program in which the DISCOVER curriculum was adapted to develop gifted children's multiple intelligences strengths	61 gifted students, in kindergarten, 11 of whom were twice exceptional	Mixed method with qualitative analysis	Three years of teaching gifted preschool children open-ended problem solving in their interest areas
12. Maker et al. (2008)	To study the relationship between creativity development and the implementation of the DISCOVER curriculum	1986 students from grades K to 6	Experimental three-group adapted design	Three years of implementing the DISCOVER curriculum in which open-ended problem solving was integrated with all academic subjects
13. Maker et al. (2006)	To determine the effectiveness of the DISCOVER curriculum in developing students' creativity	2983 students from grades K to 6	Experimental three-group adapted design	Three years of implementing the DISCOVER curriculum in which open-ended problem solving was integrated with all academic subjects
14. Maker et al. (1996)	To examine the effectiveness of implementing the DISCOVER curriculum on students' problem solving ability	46 students, including 27 males and 19 females	Experimental two groups pretest-posttest	One year of implementing the DISCOVER curriculum in which open-ended problem solving was integrated with all academic subjects

Table 2. Studies of the Effectiveness of Open-Ended Problem Solving(Continued)

Study	Purpose	Participants	Design	Intervention
15. Reid and Yang (2002)	To study the effectiveness of 14 open-ended problems designed for 14- to 17- year-old students in chemistry	63 students with an average age of 16	Qualitative analyses of students' worksheets	One year of implementing open-ended problem solving to develop students' ability in the subject of chemistry
16. Russo (2004)	To examine the differences in creativity between high IQ and average students in 5th and 6th grades	37 students, including 18 males and 19 females	Experimental one-group pretest-posttest design	Six months of teaching the students open-ended problem solving in FPS was integrated with all academic subjects
17. Schack (1993)	To investigate the effects of a crea-tive problem solving curriculum on students of varying ability, 6th to 8th grade	276 students, including some gifted students	Experimental static-group pretest-posttest design	Eighteen weeks of teaching the students different academic subjects with emphasis on FPS
18. Sierra-Fernandes and Perales-Palacios (2003)	To examine the effects of using instruction with computer simulation as a tool for open-ended problem solving in 16-year-old students	55 students, including 19 males and 36 females	Experimental Solomon four-group design	Two years of the training program in which open-ended problems were integrated with computer science content

Table 2. Studies of the Effectiveness of Open-Ended Problem Solving(Continued)

Study	Purpose	Participants	Design	Intervention
19. Tallent-Runnels and Yarbrough (1992)	To determent whether gifted students in grades 4 to 6 participating in the FPS program would feel that they had more control over their futures than other students	338 gifted and average students	Experimental one-group-posttest design	One year of implementing the FPS program in which open-ended problems were integrated with social science
20. Zimmerman et al. (2011)	To examine the use of concept maps as a tool to solve problems in earth science as a part of implementing the REAPS model with 3rd grade students	50 students, including 25 from each class	Experimental two groups pretest-posttest adapted design	One year of teaching the students earth science by using the REAPS model in which open-ended problems were integrated with science

Note. Studies were numbered from 1 to 20 alphabetically by the researchers' surnames; the purpose, participants, design, and intervention were provided as a summary about each study; SSF = Science, Society, and Future; DISCOVER = Discovering Intellectual Strengths and Capabilities while Observing Varied Ethnic Responses; FPS = Future Problem Solving; REAPS = Real Engagement in Active Problem Solving.

Table 3. Selected Quality Indicators for Experimental Studies

Quality Indicators	Study Numbers															
	1	2	3	4	6	7	8	9	12	13	14	16	17	18	19	20
Participants																
• Sufficient information	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
• Criteria for inclusion	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Intervention																
• Procedure described	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Dependent Variables:																
• Valid and reliable measures	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*Yes*	*Yes*	*Yes*
• The local reliability reported	*No*	*No*	*No*	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*No*	*No*	*No*
• Appropriate measures used	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Data Analysis																
• Appropriate design	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
• Appropriate analysis	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
• Effect size reported	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Total quality indicators found	8	8	8	8	8	7	9	8	9	9	9	8	7	8	8	8
	88%	88%	88%	88%	88%	77%	100%	88%	100%	100%	100%	88%	77%	88%	88%	88%

Note. Studies were numbered according to numeration in Table 2; *Yes* = Found; *No* = Not found.

Table 4. Selected Quality Indicators for the Qualitative Studies

Section A		
Observations or Settings Designs	Study Numbers	
	5	11
• The setting of the people who were selected for observation was appropriate	*Yes*	*Yes*
• Sufficient time was spent	*Yes*	*Yes*
• The researcher fitted into the site	*Yes*	*Yes*
• The research had minimal impact on the setting	*Yes*	*Yes*
• Field notes were collected systematically	*No*	*Yes*
• Sound measures were used to ensure confidentiality of participants and settings	*Yes*	*Yes*
Total quality indicators found	5	6
	83%	100%
Section B		
Analyses of Documents Designs	Study Numbers	
	10	15
• Meaningful documents were found and their relevance was established	*Yes*	*Yes*
• Documents were obtained and stored in a careful manner	*Yes*	*Yes*
• Documents were sufficiently described and cited	*Yes*	*No*
• Sound measures were used to ensure confidentiality of private documents.	*Yes*	*Yes*
Total quality indicators found	4	3
	100%	75%

Note. Studies were numbered according to numeration in Table 2; *Yes* = Found; *No* = Not Found.

Table 5. Selected Quality Indicators for Data Analysis in All Qualitative Designs

Quality Indicators for Data Analysis	Study Numbers			
	5	10	11	15
• Results were sorted and coded in a systematic and meaningful way	*Yes*	*Yes*	*Yes*	*Yes*
• Sufficient rationale was provided for what was included in the report	*Yes*	*Yes*	*Yes*	*Yes*
• Documentation of methods used to establish trustworthiness and credibility were clear	*Yes*	*Yes*	*Yes*	*No*
• Reflections about researchers' personal perspectives were provided	*No*	*Yes*	*Yes*	*Yes*
• Conclusions were substantiated by sufficient quotations from participants	*Yes*	*No*	*Yes*	*Yes*
• Connections were made with related research	*Yes*	*Yes*	*No*	*Yes*
Total quality indicators found	5	5	5	5
	83%	83%	83%	83%

Note: Studies were numbered according to numeration in Table 2; *Yes* = Found; *No* = Not Found.

Table 6. Participants in All Studies

Study	School levels					Abilities				Genders			Ethnicities			Total
	K	E	MS	HS	U	GT	AV	DS	UN	M	F	UN	O	T	UN	S
1.					√		√			√	√				√	141
2.		√					√			√	√		√			64
3.					√		√			√	√				√	45
4.				√		√	√					√			√	120
5.		√				√				√	√				√	11
6.		√					√			√	√				√	23
7.		√				√						√		√		233
8.				√		√				√	√		√			299
9.		√							√			√		√		835
10.					√				√		√				√	50
11.	√					√		√		√	√			√		61
12.	√	√							√			√		√		1986
13.	√	√							√			√		√		2983
14.		√				√	√				√			√		46
15.			√						√			√			√	63
16.		√				√	√			√	√			√		37
17.			√			√	√					√			√	267
18.			√	√					√	√	√				√	55
19.		√				√	√					√			√	338
20.		√							√			√			√	50
Total	3	11	3	3	3	9	9	1	7	9	11	9	2	7	11	7707
	15%	55%	15%	15%	15%	45%	45%	5%	35%	45%	55%	45%	10%	35%	55%	

Note. K = Kindergarten; E = Elementary; MS = Middle school; HS = High school; U = University; GT = Gifted Students; AV = Average Students; DS = Students with Disabilities; UN = Unreported; M = Males; F = Females; O = One ethnic group; T = Two ethnic groups or more; "√" = Found; Total S = Total Students.

Table 7. Descriptions of Interventions in All Studies

Study	Problem Types were included as presented in Table 1						Academic subjects			The perspectives of creativity were inclusive as presented in Figure 1					Time spent
	I	II	III	IV	V	VI	SS	HS	AC	ES	PT	CP	TS	P	
1.			√	√	√		√			√		√		√	1 Day
2.					√	√	√							√	5 Weeks
3.			√	√	√			√				√		√	1 Day
4.				√	√	√			√	√		√			1 Semester
5.					√	√			√			√		√	1 Year
6.			√	√	√		√			√			√		8 Weeks
7.			√	√					√			√			10 Weeks
8.				√	√	√		√		√	√	√			3 Years
9.	√	√	√	√	√	√			√	√	√	√	√	√	3 Years
10.	√	√	√	√	√	√	√			√	√	√	√	√	1 Semester
11.	√	√	√	√	√	√			√	√	√	√	√	√	3 Years
12.	√	√	√	√	√	√			√	√	√	√	√	√	3 Years
13.	√	√	√	√	√	√			√	√	√	√	√	√	3 Years
14.	√	√	√	√	√	√			√	√	√	√	√	√	1 Year
15.			√	√	√			√		√	√	√		√	1 Year
16.				√	√	√			√			√			6 Months
17.			√	√					√			√			18 Weeks
18.				√	√			√		√	√	√			2 Years
19.						√	√				√	√			1 Year
20.	√	√	√	√	√	√		√		√	√	√	√	√	1 Year
Total	7	7	13	17	17	13	5	5	10	13	11	18	8	12	Average: 15
	35%	35%	65%	85%	85%	65%	25%	25%	50%	65%	55%	90%	40%	60%	Months

Note. SS = Social Sciences; HS = Hard Sciences; AC = All academic subjects; ES = Creativity as Environmental Socialization; PT = Creativity as Personality Trait; CP = Creativity as Process; TS = Creativity as Thinking Skills; P = Creativity as Products; "√" = Found; Average = average time spent across all the interventions (approximately).

Table 8. Methods of Measuring Open-Ended Problem Solving in All Studies

Study	Qualitative Methods			Quantitative Methods								Total within study
				Traditional Measurements			Nontraditional Measurements					
	OB	AD	IN	TT	TC	QU	CA	DI	TM	CO	JU	
1.									√		√	2
2.							√					1
3.									√			1
4.									√			1
5.	√											1
6.				√								1
7.				√								1
8.						√						1
9.								√				1
10.	√	√										2
11.	√	√	√									3
12.					√							1
13.					√							1
14.								√				1
15.		√	√									2
16.				√								1
17.											√	1
18.						√			√			2
19.						√						1
20.										√		1
Total	3	3	2	3	2	3	1	2	4	1	2	
	8			8			10					
	40%			40%			50%					

Note. OB = Observations; AD = Analyses of Documents; IN = Interviews; TT = Torrance Test of Creative Thinking; TC = Test of Creativity Thinking-Drawing Production; QU = Questionnaires; CA = The Consensual Assessment Technique; DI = The DISCOVER Assessments; TM = Teacher/researcher-made tests; CO = Concept maps; JU = Judges; "√" = Used.

Open-Ended Problem Solving Integrated with the Social Sciences

The term *social sciences* was used to group five of the fields of study that were reviewed in the present research (i.e. advertisement, writing, reading, literature, and social science). One study was found in each of the listed fields. Three out of the five studies were conducted with young students in elementary schools (Cheng, Wang, Liu, & Chen, 2010; Hicks, 1998; Tallent-Runnels & Yarbrough, 1992); on the other hand, the others were conducted with university students (Byrne, Shipman, & Mumford, 2010; Kuang, 2011). While these studies occurred in different countries, at different times, at different school levels, including different perspectives of creativity, and using different types of open-ended problem solving, all of their findings seemed consistent in increasing students' creativity through open-ended problem solving.

At the elementary school level in the United States, Hicks (1980) conducted a study to determine whether creative thinking could be enhanced in fourth grade students by focusing on reading. Hicks used two different forms of the Torrance Tests of Creative Thinking-Verbal (TTCT-V) as a pretest and posttest to avoid repetition. Variables such as students' reading levels and IQs were tested for purposes of control before the intervention began. Hicks designed reading activities to develop students' creativity over the eight weeks of implementation. In our view, the major criticism of Hicks' study was that the number participants was 23 students, which may have affected the ability to generalize the results.

At the same grade level (i.e. fourth grade) but in Taiwan, Cheng, Wang, Liu, and Chen (2010) studied the effect of association instruction on students' poetic creativity. After five weeks of implementing the writing activities for 30 minutes a day during which students were given open-ended writing prompts, the researchers used the Consensual Assessment Technique (CAT) with nine judges as a posttest. Different from Hicks' (1980) study, Cheng et al. designed their activities to be open-ended. Also, they used a two group design, which was more effective than the design in Hicks' study. In addition, Cheng et al. reported an inter-judge agreement of .85 as a local reliability of the CAT; also, they reported the correlations between creativity and other dimensions: consistency of theme, pleasing flow of words, and grammar. Correlations, if low, showed the validity of the CAT's use in the study, OK-but the correlations ranged from .96 to .74. The high correlations showed that the judges had not distinguished between creativity and other domains when they were rating students' creativity (Amabile, 1996). In fact, these high correlations caused concern about the quality of the judgments and the validity of the final results. Even though the studies of Hicks and Cheng et al. were not comparable in many aspects (e.g. intervention, instruments, and the participants' cultural backgrounds), the results of both studies were consistent in that open-ended problem solving resulted in developing students' creativity in both writing (Cheng et al.) and reading (Hicks).

In a different type of study, Tallent-Runnels and Yarbrough (1992) examined whether gifted students who participated in the Future Problem Solving (FPS) program would believe that they had more control over their futures than those who did not participate. Researchers divided participants into three groups. Groups A and B included students who were identified as gifted, while Group C included average-ability students from fourth to sixth grade. In Group A, the students participated in the FPS activities. In Groups B and C, the students did not participate in the FPS activities. The students in Group A were asked to find problems that might happen in the future and then to solve them.

In contrast to the studies of Hicks (1980) and Cheng et al. (2010), Tallent-Runnels and Yarbrough (1992) used an adapted experimental design with three groups and one test, and included gifted students; this was the only study in this category in which gifted students were included. The main instrument in this study was a questionnaire developed to measure students' self-confidence. Additionally, the researchers did not report the way they developed the questionnaire or its local reliability, which would be helpful in determining the quality of the test in measuring students' emotional skills. Also, Tallent-Runnels and Yarbrough included students from different grade levels, so grade level was an uncontrolled variable, which might have affected the results of the study.

Similar to the studies of Hicks (1980) and Cheng et al. (2010), Tallent-Runnels and Yarbrough (1992) found that students who participated in the intervention, Group A, had the greatest feeling of control over their futures. Also, the differences between Groups B and C were not significant, even though group B included gifted students and group C included average-ability students. As a result of their findings, Tallent-Runnels and Yarbrough agreed that open-ended problem solving could be used not only to develop students' cognitive ability, as Hicks and Cheng et al. found, but also to assist students in developing their emotional skills.

With American university students, Byrne, Shipman, and Mumford (2010) examined the effects of a treatment program in forecasting on the development of creative problem solving and planning. In contrast to the studies of Hicks (1980), Cheng et al. (2010), and Tallent-Runnels and Yarbrough (1992), the intervention used by Byrne et al. consisted of students spending one day formulating advertisements for new products. Students then were asked to evaluate each other's work based on quality, originality, and elegance. After the evaluation, students brainstormed to improve the advertisements, then forecasted the implications of their ideas. At the end of the intervention, students were asked to respond to the researchers' email with a one- or two-paragraph forecast for up to six of their best ideas. Three judges were asked to evaluate the students' responses based on 27 criteria that were developed by the researchers.

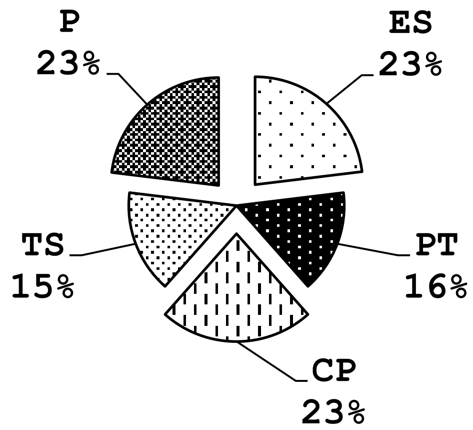
The major criticism of the Byrne et al. (2010) study was the small number of judges (i.e. three people), who rated students' products based on specific criteria, to test the effects of the interventions. An increase in the number of judges would increase reliability and validity, as would not giving criteria or a training program (Amabile, 1996). Byrne et al. reported an inter-judge agreement of 0.73 as local reliability of the measurement. Although the correlation between the three judges was positive, we considered it to be a low coefficient because the judges were given the criteria. Also, Byrne et al. did not use other dimensions as Cheng et al. (2010) did to find the validity of their measurements. These kinds of limitations in the study of Byrne et al. might have affected their final results. Nevertheless, Byrne et al. found that the intervention affected students' problem-solving skills, so their result was consistent with other studies, such as Tallent-Runnels and Yarbrough (1992), Hicks (1980), and Cheng et al.

Approaching creativity from a different direction, Kuang (2011) studied the effect of using the DISCOVER project in a children's literature course, with the intention of motivating Taiwanese pre-service early childhood teachers to use the DISCOVER curriculum in their own careers after graduation. The intervention included an explanation of the DISCOVER project and presentation of some related materials. Before the intervention was begun, the researcher used six activities to stimulate students' creativity. Based on the problem continuum (Maker & Shierver, 2010), the researcher developed the activities and gave the students the option of choosing closed problem solving from Types I to III or open-ended problem solving from Types IV to VI. Although the researcher did not report the exact duration of the activities, she said that the participants were not limited in the time given to finish the activities.

At the end of the experiment, Kuang (2011) found that the two problem types most commonly chosen by students were Type IV, with 35 students creating 76 products, followed by Type III problems, with 22 students creating 29 products. Students used drawings as representations of mathematical concepts (e.g. sun + rain + seeds = forest, and flower + bee = honey). Because Kuang studied documents (participants' drawings), her inclusion of many drawings to support her findings showed the appropriateness of her analysis. Both Kuang and Byrne et al. (2010) conducted their studies with undergraduate students and focused on the students' specific fields; however, Kuang conducted a qualitative study with a focus on open-ended problem solving, which was more comprehensive than Byrne et al. because the intervention took place over a longer period of time.

The uses of open-ended problem solving during the interventions in the social sciences. In the study of Hicks (1980), the intervention included activities similar to the TTCT-V tasks (i.e. fluency, flexibility, and originality), so these kinds of activities could have ranged from Types III to V because problems were specified. Cheng et al. (2010) included writing prompts as the intervention, so the problem types could have ranged from Types V to VI. Tallent-Runnels and Yarbrough (1992) focused on problem finding in their intervention, which was definitely open-ended problem solving (i.e. Type VI). Byrne et al. (2010) included activities such as evaluating and developing products, ranging from Types III to V. Finally, in the study of Kuang (2011) the intervention included the DISCOVER project with all Types from I to VI included. Even though she mentioned that participants usually selected problem Types III and IV, all problem types were included in her intervention. Problems from Types IV to VI were considered open-ended problem solving; the open-ended problems used most often within the social sciences category were problem Type V, with 27%, and Types IV and VI, with 20% each. Additionally, all the Types from I to VI within the social sciences category have been analyzed (Figure 3).

The Uses of the CCC



ES = Creativity as Environmental Socialization
CP = Creativity as Process
P = Creativity as Products
PT = Creativity as Personality Trait
TS = Creativity as Thinking Skills

The Uses of the Problem Continuum

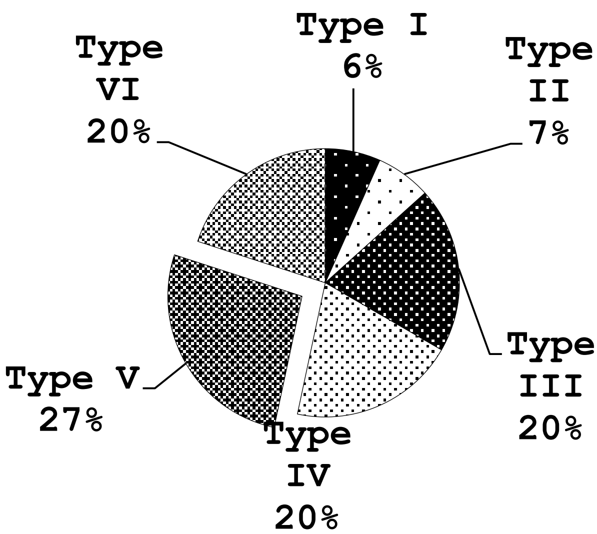


Figure 3. Uses of the problem continuum and the CCC within the social sciences interventions.

Open-Ended Problem Solving Integrated with the Hard Sciences

The term *hard sciences* was used to group five of the fields of study that were reviewed (i.e. mathematics, science, chemistry, computer science with physics, and elementary earth science). One study was reviewed from each of the five fields. Four of the five studies were conducted with young students from elementary and high school levels (Jin & Moon, 2006; Reid & Yang, 2002; Sierra-Fernandes & Perales-Palacios, 2003; Zimmerman, Maker, Gomez, & Pease, 2011), while the other was conducted with university students (Cunningham & MacGregor, 2008). Similar to the social sciences categories, the findings of the studies in the hard sciences were mostly consistent in improving students' creativity through the use of open-ended problem solving.

At the elementary school level, Zimmerman, Maker, Gomez, and Pease (2011) conducted a study to determine whether a teacher's use of the Real Engagement in Active Problem Solving (REAPS) model enhanced teachers' ability to teach effectively by measuring their students' integration of science concepts. The researchers used concept maps as both pretests and posttests to measure students' knowledge in earth science. Two third-grade classes were taught at different times, and two experts, one in the field of education of gifted students and one in the field of science supervised the teachers. The concept maps were scored separately using two methods of scoring. The researchers found significant increases between pretest and posttest scores in both classes. The sole criticism of Zimmerman et al.'s study was that only one person scored the students' concept maps. On the other hand, two methods were used, and the researcher found a high correlation between them.

At the high school level and with Spanish-speaking students, Sierra-Fernandes and Perales-Palacios (2003) examined instruction using computer simulation in a physics class to solve open-ended problems and its effects on students' knowledge and attitudes about science. Different from the study of Zimmerman et al. (2011), Sierra-Fernandes and Perales-Palacios developed a test including 15 open-ended questions to determine students' use of open-ended problem solving. In addition, Sierra-Fernandes and Perales-Palacios measured students' attitudes and achievement. Reflecting the results of Zimmerman et al., Sierra-Fernandes and Perales-Palacios found that the ability to solve open-ended problems and students' knowledge increased significantly. However, the researchers did not find significant differences in students' overall attitudes. One of the uncontrolled variables that might have affected the results of Sierra-Fernandes and Perales-Palacios' study was the students' familiarity with computers. Overall, Sierra-Fernandes and Perales-Palacios found that the use of open-ended problem solving assisted students in developing their knowledge successfully, which was the same conclusion that was made by Zimmerman et al. (2011).

In the studies of both Sierra-Fernandes and Perales-Palacios (2003) and Zimmerman et al. (2011), researchers did not use creativity as the main variable, but they mentioned creativity in their procedures. For instance, in the study of Zimmerman et al., the DISCOVER project was a part of the REAPS model; also, the term *creativity* was used several times in the text of the study. In this context, we believed that both studies developed students' creativity by teaching them a method and asking them to respond creatively. However, the absence of an instrument to measure students' creativity in a specific academic subject might prevent both researchers from considering creativity as one of the main variables. Also, we could argue that creativity in a specific academic subject has been tested through most of the previous literature in the field of creativity as knowledge-based ability, so we believed that mastering the knowledge as described in Bloom's Taxonomy would enhance students' creativity in that specific academic subject.

Jin and Moon (2006) also studied high school students, and examined whether academically talented students who were attending a residential science high school in Korea had levels of school-life satisfaction different from their peers of similar ability attending regular high schools. All participants had attended their high schools for at least two years. Jin and Moon tested school/life satisfaction as the main focus, while Sierra-Fernandes and Perales-Palacios (2003) evaluated student attitudes and other variables in students at the high school level. However, Jin and Moon found significant differences between the gifted students in a residential science high school. They had greater school/life satisfaction than gifted students in regular schools. In brief, the results of Jin and Moon's study were not consistent with the finding of Sierra-Fernandes and Perales-Palacios' study about students' attitudes, suggesting that students' familiarity with computers in Sierra-Fernandes and Perales-Palacios' study might have affected the results negatively. Additionally, Jin and Moon's study was different from both Zimmerman et al.'s (in press) and Sierra-Fernandes and Perales-Palacios' studies because gifted students were included. This study was the only one in the hard sciences category in which gifted students were studied.

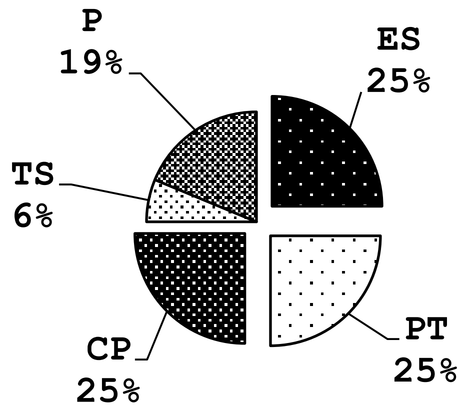
Also at the high-school level, Reid and Yang (2002) investigated the effects of integrating 14 open-ended problems into the subject of chemistry to determine how concepts and linkages influenced success in solving open-ended problems. Different from Sierra-Fernandes and Perales-Palacios (2003), Jin and Moon (2006), and Zimmerman et al. (2011), Reid and Yang used qualitative methods to conduct their study. The students had been taught 18 units for one year by using the eight problem types (i.e. Johnstone's theory). The students worked in groups of three, and were encouraged to talk and take notes. The researchers observed the students and collected all written materials. After analyzing 668 sheets and observation forms, the researchers drew a chart of the ways the students approached open-ended problems. Also, the researchers suggested that creating links between all academic subjects might help students to solve open-ended problems. The researchers in this study did not describe their documents, nor did they describe clearly the method of data analysis, which would have been useful to help other researchers know the effects of their intervention.

At the university level, Cunningham and MacGregor (2008) studied the effects of realistic and puzzle-like programs on creative insight in problem solving. In contrast from Sierra-Fernandes and Perales-Palacios (2003), Jin and Moon (2006), Zimmerman et al. (2011), and Reid and Yang (2002), the intervention in Cunningham and MacGregor's study was part of a university course, and took approximately one day, during which students were taught to work with words, numbers, and geometric shapes. The researchers developed a test with three different problem types to measure students' problem-solving abilities. After analyzing the data, the researchers found a significant increase in creative insight in problem solving in the experimental group when compared to the control group. However, Cunningham and MacGregor did not report the local reliability of the instruments used, which would be helpful in determining the quality of their measurement.

The uses of open-ended problem solving during the interventions in the hard sciences. In the study of Zimmerman et al. (2011), the intervention was the REAPS model, which included the DISCOVER project and two other models, so problem Types I to VI were included. However, in the study of Sierra-Fernandes and Perales-Palacios (2003), the intervention included activities that were open-ended, but because the researchers specified the problems, we inferred that the problem types ranged from Types IV to V. Jin and Moon (2006) included activities, such as research, problem solving, and hands-on activities that could range from Types IV to VI. Reid and Yang (2002) included definitions and scales of open-ended problem solving different from the problem continuum (Maker & Schiever, 2010). However, by investigating the framework of their definitions and their practices, one could infer that the problem types ranged from III to V. Similar to Reid and Yang and Sierra-Fernandes and Perales-Palacios, in the intervention of Cunningham and MacGregor (2008), the researcher specified the problem and used problems from Type III to V as well. In conclusion, the open-ended problem solving types used most frequently within the hard sciences category were problem Types IV and V, with 29% each, and Type VI, with 12%. Additionally, all the Problem Types used within the hard sciences category have been presented in Figure 4.

The perspectives of creativity used during the interventions in the hard sciences. In Zimmerman et al. (2011), the DISCOVER project was adapted, so researchers were implementing this project with all its requirements, which met all the CCC factors. Jin and Moon (2006) and Sierra-Fernandes and Perales-Palacios (2003) encouraged students to work together to solve problems using different processes, so Creativity as Environmental Socialization, Creativity as Process, and Creativity as Personal Traits were met. In the study of Reid and Yang (2002), the students were encouraged to work together in a facilitative environment, and were asked to create projects, so Creativity as Environmental Socialization, Creativity as Personal Traits, Creativity as Process, and Creativity as Product were met. However, in Cunningham and MacGregor's (2008) intervention, students usually solved problems independently, and they used many processes to create original solutions; as a result, Creativity as Process and Creativity as Products might have been met. In conclusion, the perspectives of creativity used most often during the interventions within the hard sciences category were Creativity as Environmental Socialization, Creativity as Personality Traits, and Creativity as Process, with 25% each. Additionally, all the CCC factors within the hard sciences category were analyzed (Figure 4).

The Uses of the CCC



ES = Creativity as Environmental Socialization
PT = Creativity as Personality Trait
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TS = Creativity as Thinking Skills
P = Creativity as Products

The Uses of the Problem Continuum

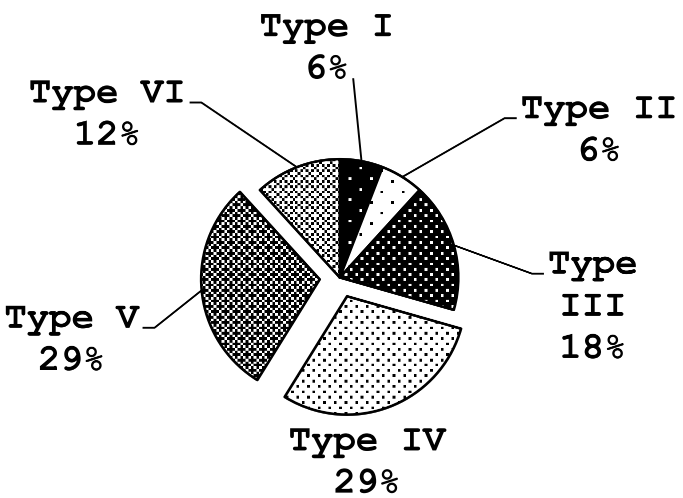


Figure 4. Uses of the problem continuum and the CCC within the hard sciences interventions.

Open-Ended Problem Solving Integrated across All Academic Subjects

The term *all academic subjects* was used in this review to describe 10 studies that had an intervention in two or more different academic subjects, except one study conducted by Jo and Maker (2011), in which the researchers focused on math using data collected during a comprehensive study of the DISCOVER curriculum. The intervention was in all academic subjects, but the analysis was of results in math. The study of Jo and Maker was included in this group because the intervention was in all subjects. The 10 studies (Gallagher, Stepien, & Rosenthal, 1992; Hertzog, 1998; Houtz, Rosenfield, & Tetenbaum, 1978; Jo & Maker, 2011; Kuo, Maker, Su, & Hu, 2010; Maker, Jo, & Muammar, 2008; Maker, Muammar, Serino, Kuang, Mohamed, & Sak, 2006; Maker, Rogers, Nielson, & Bauerle, 1996; Russo, 2004; Schack, 1993) were conducted with students from elementary through high school. Most of the studies were consistent in their development of students' creativity, similar to the findings in the social and hard sciences categories.

With preschool Taiwanese students, Kuo, Maker, Su, and Hu (2010) examined the effects of using a program developed based on the DISCOVER curriculum to improve students' problem solving abilities. The intervention was activities based on the students' interests and intelligences, with all problem types. In part of the program students were taught as a group, and in another part, individually. The intervention took three years, through which researchers found that the students used many approaches to solve problems, and that the students were delighted to challenge others and be challenged. Kuo et al. included 11 twice-exceptional children (i.e. gifted students with disabilities), who showed great improvement over time. The researchers did not make connections between their conclusions and related research. However, their study was the only one in which gifted students with disabilities were studied.

In the United States and at the elementary school level, Maker, Muammar, Serino, Kuang, Mohamed, and Sak (2006) assessed the impact of using the DISCOVER curriculum for three years on developing students' creativity. The Test of Creative Thinking-Drawing Production (TCT-DP) was used to measure students' creativity. Different from the study of Kuo et al. (2010), which was a mixed method with great focus on the qualitative analysis, the study of Maker et al. (2006) was quantitative. Also, the researchers used an adapted experimental design, as done with some other studies on the DISCOVER project, in which all teachers at each of four schools were included in the study. Teachers were observed and divided into three levels of implementation (high, middle, and low implementers), based on systematic criteria. The researchers compared the students' creativity across their teachers' levels of implementing the DISCOVER curriculum.

The researchers did not find overall differences between the students in the first and third years of implementing the DISCOVER curriculum; however, in the second year, they found significant differences between the students in classrooms of teachers who exercised different levels of implementation. The results of the second year were consistent with the study of Kuo et al. (2010): students' creativity was improved by using open-ended problem solving. However, the results of the first year, which were not consistent with the findings of Kuo et al., could be explained as an indication that students needed more time to show changes as a result of the new teaching method and that teachers needed more time to learn it. However, the results of the third year were unexpected. The reasons for this might be that the instrument was ineffective to measure students' creativity over time, especially when students reached the highest level of solving problems (i.e. Type VI); the students might be tired of repeating the test; or students did not respond seriously to the posttest assessment at the end of the project.

Jo and Maker (2011) examined the impact of implementing the DISCOVER curriculum on students' mathematical knowledge and mathematical creativity. Teachers were divided into three levels of implementation. However, they used the math section of the DISCOVER Assessment to measure students' mathematical knowledge and mathematical creativity instead of the TCT-DP. In contrast to the previous studies, the researchers did not find overall significant differences between students' mathematical creativity scores in classrooms of teachers at different levels of implementation. With further analysis, the researchers found differences in mathematical creativity in the second and third grades in classrooms of high-level implementers when compared with students who were in the middle-level implementers' classrooms. The researchers did not find significant differences between the mathematical knowledge and creativity of students in first, fourth, and fifth grades based on the implementation levels of the teachers. The researchers pointed out that very little evidence was found that teachers actually used the DISCOVER model when teaching math.

In one of the first studies of the DISCOVER curriculum, Maker, Rogers, Nielson, and Bauerle (1996) studied the effects of the DISCOVER curriculum at the elementary school level by using the level of implementation to select two teachers, one high and one middle implementer, based on systematic criteria. Consequently, the experimental design in this study was different from the studies of Maker et al.

(2006); Maker et al. (2008); and Jo and Maker (2011). However, similar to the study of Jo and Maker (2011), the DISCOVER assessments were used as pretests and posttests. Gifted students were included in this study as with the Kuo et al. (2010) study. Also, students had been taught all academic subjects in whole-group, small group, and individual-choice activities. The researchers found that the students who had been taught by a high implementer teacher increased significantly in the areas of spatial artistic, oral linguistic, and math problem solving ability from pretest to posttest compared to students with a middle implementer teacher. The researchers did not find differences between boys and girls in overall problem solving ability. Even though the experimental design in the study of Maker et al. (1996) was different from the previous studies in that two groups were pretested and posttested with multiple comparisons (i.e. each group by pretest and posttest separately, and both groups only by posttest), the researchers established the use of implementation levels to divide teachers into experimental groups. One of the major strengths in this study was providing results of each small group in the whole sample (i.e. ethnicities, genders).

Studying the same school level (i.e. elementary school), Hertzog (1998) explored the meaning of curricular differentiation for identified gifted students by examining students' responses to open-ended activities. Similar to the studies of Kuo et al. (2010) and Maker et al. (1996), gifted students were included in Hertzog's study. The students were taught 33 open-ended problems for one academic year, through which the researcher collected data during 100 hours of observations and interviews. Therefore, the study of Hertzog was conducted using a qualitative method different from the studies of Maker et al. (2008); Maker et al. (2006); Jo and Maker (2011); and Maker et al. (1996), which were conducted using quantitative methods.

Similarly to Kuo et al. (2010), Hertzog (1998) concluded that the students were able to solve open-ended problems in all academic subjects, and that they enjoyed it; also, the teachers were able to encourage the students and facilitate their learning processes. The main criticism of Hertzog's study was that the researcher did not systematically collect her field notes; also, the researcher did not reflect on her personal perspectives, which might affect her findings. Hertzog used the problem continuum (i.e. old version from Types I to V), so based on the new version of the problem continuum, she used problem Types IV to VI with a great focus on problem finding based on students' interests. The results of this study were consistent with other studies such as Maker et al. (2008); Kuo et al.; Maker et al. (1996), in which researchers found teaching by using open-ended problem solving to be effective in assisting students to develop their creativity in solving problems.

Similar to the studies of Maker et al. (2006), Maker et al. (2008), and Jo and Maker (2011), Houtz, Rosenfield, and Tetenbaum (1978) selected all students in one elementary school to examine the development of creative thinking. Gifted students were included as they were in the studies of Kuo et al. (2010), Maker et al. (1996), and Hertzog (1998). The intervention included seven conceptual stages of the Creative Problem Solving (CPS) process. Different from other studies, the study of Houtz et al. included an intensive ten weeks of treatment, and alternate forms of the tasks were scored. The median reliability was .63, while the median interscorer agreement was .96. The researchers found overall increases in the students' creativity, especially in grades four through six. However, Houtz et al. did not report the effect size, which would have been helpful in determining the level of effectiveness of the study's intervention.

At the middle school level, Schack (1993) investigated the effects of using creative problem solving on students' problem solving ability. Similar to the study of Maker et al. (1996), Schack divided students into two groups, experimental and control. Both groups were asked to respond to a hypothetical problem as a pretest and posttest; two judges then scored their responses independently with an inter-judge agreement of .76. Even though the correlation between the experts was positive, this was a low correlation based on Amabile's (1996) recommendations. In addition, the validity of the study would have been improved if other dimensions of the products were evaluated as a contrast. After 18 weeks of the intervention, students were given a final project of solving a real-life school problem. The intervention of Schack's study was intensive, as in the study by Houtz et al. (1978). Schack found significant differences between the pretest and the posttest in the experimental groups, similar to Houtz et al.

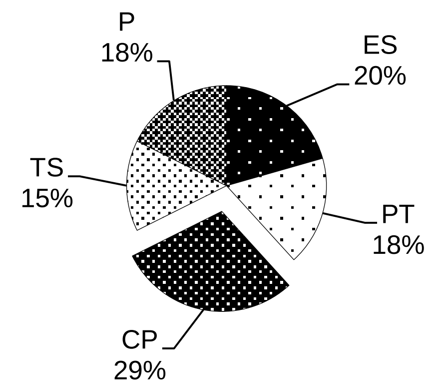
Studying the same school levels (i.e. middle school), Russo (2004) examined the effects of using a six-step creative problem-solving process on students' creativity. The TTCT-V (Forms A and B) and three Future Problem Solving tasks were used as pretests and posttests to measure the students' creativity and problem-solving ability. The experimental design was similar to the studies of Maker et al. (1996) and Schack (1993). After six months of teaching the students for 90 minutes per week, the researcher found that gifted students scored lower on their pretests than average students, but scored higher on the posttests. In contrast, average students scored high on their pretests, but low on the posttests. After analysis, the researcher found significant differences for gifted students between the pretest and post-test scores. The studies of Schack and Russo were conducted with middle school students, and they were not equivalent in many aspects (e.g. intervention, instruments, and the participants' ability). However, the results of both studies were consistent; open-ended problem solving was found to assist students in developing their creativity.

At the high school level, Gallagher, Stepien, and Rosenthal (1992) examined the use of a problem-based curriculum on students' ability to solve problems. Similarly to Maker et al. (1996), Schack (1993), and Russo (2004), Gallagher et al. divided the students into two groups, and both groups were asked to solve a real-life problem in the students' environments as a pretest and posttest. The intervention was designed to include science, society, and future (SSF). After one semester, the researchers found an increase in the students' abilities (e.g. problem finding, solution finding, and implementation). Gallagher et al. did not report the local reliability of their instruments, which would help to determine the quality of their measurement. Even though the study of Gallagher et al. was considered in the category of all subjects, the results of Gallagher et al. were consistent with other studies at the high school level, such as Sierra-Fernandes and Perales-Palacios (2003) in computer science and physics, Jin and Moon (2006) in science, and Reid and Yang (2002) in chemistry. Additionally, Gallagher et al. had results that were consistent with studies in the category of all academic subjects, such as Schack (1993), Russo (2004), Houtz et al. (1978), and Maker et al. (2008), in which the researchers found an improvement in students' creativity.

The uses of open-ended problem solving during the interventions in all academic subjects. In the studies of the DISCOVER project, such as Maker et al. (2008), Kuo et al. (2010), Maker et al. (2006), Maker et al. (1996), and Jo and Maker (2011), the intervention was the DISCOVER project, so problem Types I to VI were included. However, in the study of Hertzog (1998), the intervention included activities that were open-ended and ranged from Types IV to VI. In the studies of Schack (1993) and Houtz et al. (1978), the interventions included activities based on the problem continuum with processes or steps to solve problems, so the problem types in this study ranged from Types III to IV; on the other hand, Russo's (2004) included the same process as Schack's (1993), but without any help, so the problems ranged from Type IV to VI. Gallagher et al. (1992) included some advanced problem solving (e.g. problem finding [FPS]); however, the researchers sometimes mixed them with real-life problems, so the intervention included problem types ranging from

Types IV to VI. In summary, the open-ended problem solving types used most often within the all academic subjects category were Type IV with 23%, VI with 19%, and Type V with 18%. Additionally, all the problem continuum types, from I to VI, within the all academic subjects category were analyzed (Figure 5).

The Uses of the CCC



ES = Creativity as Environmental Socialization
PT = Creativity as Personality Trait
CP = Creativity as Process
TS = Creativity as Thinking Skills
P = Creativity as Products

The Uses of the Problem Continuum

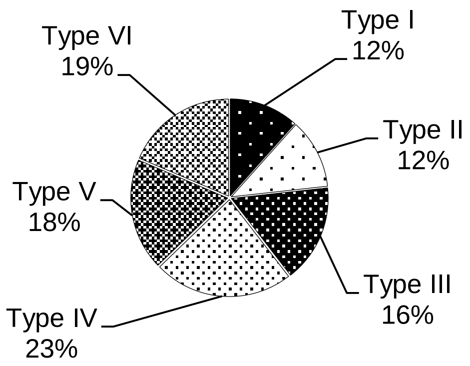


Figure 5. Uses of the problem continuum and the CCC within the all academic subjects interventions.

The perspectives of creativity used during the interventions in studies of all academic subjects. In the DISCOVER project's studies, such as Maker et al. (2008), Kuo et al. (2010), Maker et al. (2006), Maker et al. (1996), and Jo and Maker (2011), researchers used the DISCOVER curriculum model as an intervention, and implemented all its requirements; thus, they have met all the CCC criteria as explained earlier. In the study of Hertzog (1998), the students were encouraged to work independently and to solve problems using different processes. Consequently, the Creativity as Process and Creativity as Products might have been met. In the studies of Schack (1993), Houtz et al. (1978), and Russo (2004), the interventions included the CPS process, suggesting that Creativity as Process was used. In conclusion, the perspectives of creativity used most frequently during the interventions within the all academic subjects category were Creativity as Process with 29% and Creativity as Environmental Socialization with 20%. Additionally, all the CCC factors within the all academic subjects category were analyzed (Figure 5).

Overall Findings Across All Studies

To identify the gaps among the 20 studies from 1978 to 2011 and to give a clear image about the uses of open-ended problem solving in the fields of Creativity and Giftedness, the overall findings could be viewed in Table 6, in which we included the descriptions of participants; Table 7, in which we provided the descriptions of interventions; and Table 8, in which we gave the descriptions of the measurements. Overall, the studies included a total of 7707 students participating in the interventions with an average duration of 15 months to develop creativity by using open-ended problem solving.

First, participants were from diverse backgrounds. For example, they were studying at many different school levels (i.e. kindergarten in 15%, elementary school in 55%, middle school in 15%, high school in 15%, and university in 15%). Inferring from that, the highest percentage of studies were conducted at the elementary school level. Moreover, students' abilities were analyzed and the students most frequently included were gifted students (45%), average-ability students (45%), and students with disabilities (5%); on the other hand, 35% of the studies did not include information about students' ability levels. The researchers did not focus on students with disabilities or even twice-exceptional students. Another finding was that female students were included in 55% of the studies, while males participated in 45%, but in 45% of the studies information about students' gender was not provided. Students' ethnicities were not provided in 55% of the studies, and 35% of the studies included more than two ethnicities (Table 6).

Overall, during the interventions all the problem types were used (e.g. Type I in 35%, Type II in 35%, Type III in 65%, Type IV in 85%, Type V in 85%, and Type VI in 65%). Type VI, problem finding, was less integrated in the 20 studies than were the other open-ended types. Open-ended problem solving was used in 45% of the interventions with all academic subjects, in 25% of the interventions in the hard sciences, and in 25% of the interventions in the social sciences. The perspective of creativity most often used in the interventions was Creativity as Process in 90% of the studies (Table 7). Last, measuring open-ended problem solving was done in 50% of the studies by using nontraditional instruments, such as teacher-made tests, the CAT, and the DISCOVER assessments (Table 8).

Conclusion

The purpose of this review is to investigate the uses of open-ended problem solving over time through educational research to develop students' creativity by exploring three major areas: (a) to discover what participants have been included (i.e. students' school levels, genders, ethnicities, and abilities); (b) to inspect the content of the interventions by focusing on specific elements (i.e. problem types, academic subjects, and the perspectives of creativity); and (c) to scrutinize the instruments that have been used to measure open-ended problem solving.

The Participants

Among the 20 studies, 55% are conducted at the elementary school level (Cheng et al., 2010; Cunningham & MacGregor, 2008; Hertzog, 1998; Hicks, 1980; Houtz et al., 1978; Jo and Maker, 2011; Kuo et al., 2010; Maker et al., 2006; Maker et al., 2008; Maker et al., 1996; Russo, 2004; Tallent-Runnels & Yarbrough, 1992; Zimmerman et al., 2011). Two reasonable explanations may be given for that. First, because all subjects are taught by one teacher, re-designing the curriculum and integrating it with open-ended problem solving is easier than when multiple teachers are involved. Second, elementary teachers may be interested in participating in studies more often than teachers from upper school levels.

Another finding is that students with disabilities are included in only 5% of the studies (Kuo et al., 2010). As an explanation, some researchers may have a stereotype about the capability of students with disabilities to solve open-ended problems. On the other hand, in 55% of the studies, students' ethnicities are not provided or not considered in the analyses except in the study of Maker et al. (1996), in which the data are analyzed by giving some results about each ethnic group. A possible reason for not analyzing the data according to ethnic groups may be to avoid having to explain results if one group performs better than another.

Implications for future research and practice. The gap in conducting studies with upper school levels is clear. Studying those school levels will add to the literature valuable information about developing students' creativity at all school levels. On the other hand, teachers in upper school levels should participate and request researchers to conduct studies in their classrooms. Another implication is including students with disabilities in future research in which creativity may be developed. In fact, most of the students with disabilities can be facilitated with those interventions (Kuo et al., 2010), so teachers in the field of special education may try to adapt some activities or ask researchers to do studies with their students. Moreover, future researchers should report students' ethnicities and consider this variable in their data analysis, which will be helpful for future reviewers to generalize findings or draw useful conclusions about developing students' creativity across ethnic groups.

The Content of Interventions

During the interventions, the most often used open-ended problem solving type across the 20 studies is Type IV and V in 85% of the interventions (Byrne et al., 2010; Cheng et al., 2010; Cunningham & MacGregor, 2008; Gallagher et al., 1992; Hertzog, 1998; Hicks, 1980; Houtz et al., 1978; Jin & Moon, 2006; Jo & Maker, 2011; Kuang, 2011; Kuo et al., 2010; Maker et al., 2006; Maker et al., 2008; Maker et al., 1996; Reid & Yang, 2002; Russo, 2004; Schack, 1993; Sierra-Fernandez & Perales-Palacios, 2003; Zimmerman et al., 2011). However, the least frequently used open-ended problem solving type was Type VI (i.e. problem finding), in 65% of the studies (Cheng et al., 2010; Gallagher et al., 1992; Hertzog, 1998; Jin and Moon, 2006; Jo and Maker, 2011; Kuang, 2011; Kuo et al., 2010; Maker et al., 2006; Maker et al., 2008; Maker et al., 1996; Russo, 2004; Tallent-Runnels & Yarbrough, 1992; Zimmerman et al., 2011). The researchers who included this type in their interventions did not use it frequently. Most of the time Type VI is recognized during the interventions as final projects. The reason for not using problem Type VI might be the factor of time because the process of solving Type VI problems is much more complex than the others (e.g. finding a real problem and then solving it); for example, Gallagher et al. (1992) noted that the students take the whole semester to solve only four problems recognized as Type VI.

In 45% of the interventions, open-ended problem solving is integrated with all academic subjects. This kind of integration is much more effective than using open-ended problem solving with only one subject. In our point of view, students have to practice using open-ended problem solving in many different content areas and for a long period of time until they integrate creative problem solving into their behavior. The perspective of creativity through which open-ended problem solving is most frequently implemented is Creativity as Process, in 90% of the studies. This does not mean that other perspectives of creativity are less important, but does give an idea about a strong connection between Creativity as Process and open-ended problem solving.

Implications for future research and practice. We suggest that future researchers and teachers integrate problem finding (i.e. Type VI) into their interventions. Maker and Schiever (2010) described problem Type VI as the most open-ended problem. Another suggestion is to continue integrating open-ended problem solving with all academic subjects. Also, for future researchers and teachers, using all the perspectives of creativity as described in the CCC (Alhusaini & Maker, 2011) may help to achieve good results.

The Instruments

In most studies, the researchers used nontraditional instruments to measure open-ended problem solving, such as the CAT, DISCOVER assessments, teacher-and-researcher-made tests, and concept maps (Byrne et al., 2010; Cheng et al., 2010; Cunningham & MacGregor, 2008; Gallagher et al., 1992; Jo & Maker, 2011; Maker et al., 1996; Schack, 1993; Sierra-Fernandez & Perales-Palacios, 2003; Tallnet-Runnels & Yarbrough; 1992; Zimmerman et al., 2011). Of course, most traditional tests are not appropriate for measuring open-ended problem solving.

Implications for future research and practice. Future researchers and teachers should use nontraditional measurements in an objective way; for example, using the CAT to rate students' products requires providing validity and reliability based on experts' judgments that can be applied to all other adapted uses of expert ratings of students' work.

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