Journal of Youth and Adolescence, Vol. 17, No. 3, 1988

Problem Discovery, Divergent Thinking, and the Creative Process

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Received April 3, 1987; accepted December 2, 1987

Previous empirical research suggests that problem discovery is an important step in the creative process. The present investigation was conducted to examine the role of problem discovery in the divergent thinking and creative performance of adolescents. Three divergent thinking tests were administered to a group of adolescents. Each test contained three presented *problems and one* discovered *problem. The discovered problem allowed the adolescents to think of a problem and then to provide solutions. Comparisons indicated that the adolescents generated significantly more responses to the discovered problems than the presented problems. Most important was that the unique variance of the discovered problems (controlling the variance shared with scores from the presented problems) was reliable and significantly related to five indices of creative performance. These results support the componential theory of divergent thinking and creativity, and are consistent with the developmental view of problem finding.*

INTRODUCTION

In recent years, many theorists have rejected the notion that creativity is a unitary trait, and have taken the position that creative performance is the result of an interaction of several abilities and skills. Runco (1986a), for example, suggested that both metacognitive strategy and cognitive ability per

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0047-2891/88/0600-0211$06.00/0

se are necessary "components" of the creative process. He demonstrated that gifted and nongifted children approach open-ended problems differently, with the former utilizing components that facilitate originality. Further empirical support for this view is given by Davidson and Sternberg (1984).

Although Runco (1986a) and Davidson and Sternberg (1984) have isolated several components, a comprehensive definition of creativity should incorporate the identification and definition of a problem or worthwhile task, and the generation, evaluation, application, and modification of solutions and ideas. Problem discovery is a particularly important component in the creative process because it occurs first, and because the quality of a problem may in part determine the quality of solutions. In Getzels's (1975) words, "a creative solution is the response to a creative problem" (p. 168). Additionally, although art, science, and other areas differ in some respects (e.g., prerequisite knowledge bases), the identification of a problem or task is probably crucial in all creative endeavors.

Csikszentmihalyi and Getzels (1970, 1971) were among the first to investigate creative problem finding. They presented 31 art students with a set of objects, and asked the students to arrange the objects and compose a drawing. The students were observed while they worked, and their discovery-oriented behaviors were recorded. Discovery-oriented behavior was defined as the number of objects used before drawing, the amount of time spent exploring the objects before drawing, the uniqueness of the stimuli used, and changes in media or perspective. The drawings were rated for their originality, aesthetic value, and craftsmanship. Correlational analyses indicated that ratings of problem-discovery behaviors were significantly related to the originality, aesthetic value, and craftsmanship of the completed drawings ($.42 < rs < .58$).

Moore (1985) took a similar approach with the verbal creativity of children. He allowed "middle school" children to choose an object, and then asked them to write an essay about it. Moore reported that students who wrote creative essays (judged by teachers) explored more objects than the students who wrote noncreative essays. These exploratory behaviors ostensibly were indicative of problem discovery. Moore (1985) also reported that the creative essays contained more changes in "object reality" and more words (an estimate of fluency) than the noncreative essays.

Wakefield (1985) examined the relationship of problem finding and divergent thinking by administering a series of visual (figural) divergent thinking tests to 23 fifth-grade children. The children were asked to describe all of the things that each figure could be, and these descriptions were scored for ideational fluency (i.e., the number of responses). One card in the series was completely blank, and the children were asked to first draw a figure (problem finding) and then provide ideas about it. Results indicated that the number of ideas given by the children to their own drawings was significantly correlated with the number of ideas given to the standard divergent thinking items ($r = .75$). Additionally, the scores from discovered problems had slightly better predictive validity than standard divergent thinking scores ($r = .46$ vs. .33). Similar findings were reported by Owen and Baum (1985).

Wakefield's (1985) investigation of problem finding and divergent thinking is particularly intriguing because divergent thinking is predictive of teachers' judgments of students' creativity (Runco, 1984), and children's writing, artistic, and crafts achievements (Runco, 1986b). Divergent thinking is also included in several definitions of giftedness (Albert and Runco, 1986; Renzulli, 1978). Still, problem-finding skills may in part depend upon mature cognitive structures (Arlin, 1975), and thus the results of Wakefield's (1985) study of fifth graders may not generalize to other age groups. The primary objective of the present investigation is to examine the relationship between problem discovery and divergent thinking in adolescents.

The second objective of the present investigation is to isolate the problem-discovery component of divergent thinking. Previous research has focused on the overlap of presented and discovered problems, and most analyses have been correlational. The present study is unique in its evaluation of differences between presented and discovered problems. The premise is that divergent thinking tasks that present problems require primarily ideational productivity, but divergent thinking tasks with discovered problems require both ideational productivity *and* the ability to define a workable task. There is an overlap between the two tasks, but the discovered tasks presumably involve a distinct problem-finding component. This can be determined by examining the unique variance of discovered problems. In this light, the present investigation is an empirical test of the componential view of the creative process.

The specific predictions tested in this investigation are concerned with the psychometric integrity and distinctiveness of the problem-finding component of adolescents' divergent thinking. The first prediction is that the unique variance of the scores elicited by a discovered divergent thinking task will be reliable and correlated with other indices of creative ability. This addresses the predictive validity of the scores (Anastasi, 1983). The second prediction is that scores on presented problems will be moderately but not highly correlated with scores on the discovered problems, and the last prediction is that the scores from the discovered problems will be unrelated or negatively correlated with scores from measures of academic ability. These final predictions are aimed at the discriminant validity of the problem-discovery scores (Anastasi, 1983).

METHOD

Subjects

Twenty-nine students (19 males and 10 females) from a mathematics and science summer program participated in the study. This program involves seven weeks of intensive study in calculus and physics, and for many students, research experience under the supervision of an academic scientist. The program has a relatively selective admissions policy using four criteria: Preliminary Scholastic Aptitude Test (PSAT) mathematics scores, grade point average from mathematics and science courses, two letters of recommendation, and a personal essay. Most students were considered to be scientifically and mathematically talented, and many were considered to be gifted. The median mathematics PSAT percentile was 65 (with a range of 66–99), and the median verbal PSAT percentile was 52 (with a range of 31–99). The ages of the students ranged from 15 years 11 months to 17 years 7 months.

Measures and Procedures

The Instances, Uses, and Similarities divergent thinking tests were used in this investigation. These are verbal tests. Each contained three standard "presented-problem" items and one "discovered-problem" item. The stimuli and instructions for the presented problems were adapted from Wallach and Kogan (1965). Each of these presents a task (e.g., "Name all of the things you can think of that move on wheels") and examinees are asked to give as many ideas as possible. They are also informed that there are no incorrect answers and that no grades are assigned.

The discovered problems were adapted from Wakefield (1985). Only instructions were presented on the discovered items. These instructions asked the examinees to define a task (i.e., find a problem), and then to provide solutions to it. For example, the following instructions were provided for the discovered problem of the Instances test:

> On the previous pages, you were asked to give "instances" of something (i.e., things that are square, strong, or move on wheels). Here we would like *you* to choose a category, and *then* list instances of it. Now you can choose something to make thinking of ideas easy! Be certain to choose a category that will allow you to give many responses. Keep in mind that the more ideas, the better!

Analogous instructions were provided for the discovered problems of Uses ("...choose an object and *then* list uses for it...") and Similarities ("...choose two objects that are alike, and *then* list your ideas of how the objects are similar..."). Each of the presented and discovered items was scored for the number of distinct ideas (ideational fluency). This scoring system is described in Runco (1986b).

A Creative Activities Check List was administered and used as the criterion measure. This particular checklist was adapted from Hocevar (1980), and is similar in format to those used by Runco (1987) and Wallach and Wing (1969). It lists 55 creative activities in five different areas: mathematics (e.g., "How many times have you applied math in an original way to solve a practical problem?"), science (e.g., "How many times have you set up your own experimental laboratory or experimental conditions"), art (e.g., "How many times have you painted an original picture?"), literature (e.g., "How many times have you had a poem, short story, or the like published in a school publication?"), and crafts (e.g., "How many times have you designed and constructed a craft out of wood?"). All tests were administered in a classroom during the summer program, with all examinees receiving the tests in the same order. Testing required two hours each day for three days.

RESULTS

A multivariate analysis of variance with gender as a between-subjects factor and age (in months) as a covariate indicated that there were no gender or age effects in the divergent thinking scores. All 29 cases were therefore used in subsequent analyses. Means and standard deviations for each item of the divergent thinking tests are presented in Table I.

Order effects were examined by comparing the first and second items of each test, and comparing the second and third items of each test. Correlated t tests revealed that the differences among the items of the Instances and Similarities tests were not significant. Scores on the third item of the Uses test were significantly higher than those on the second [t (28) = 7.54, $p < .001$, $r = .65$].

Table I. Means and Standard Deviations for the Divergent Thinking Test Scores[a]

	Instances		Uses		Similarities		Average	
Item 1	15.2	(9.1)	9.4	(2.7)	10.3	(3.9)	11.6	(4.1)
Item 2	15.6	(7.4)	9.3	(3.2)	9.5	(3.8)	11.5	(3.6)
Item 3	17.2	(6.3)	14.0	(4.4)	10.0	(4.9)	13.8	(3.8)
Average	15.9	(6.0)	10.9	(2.9)	9.9	(3.4)	11.5	(3.1)
Item 4	25.3	(13.6)	17.9	(9.9)	13.9	(6.4)	19.1	(7.3)

[a]Items 1–3 represent the presented problems and Item 4 represents the discovered problem.

Differences Between Presented and Discovered Problems

Differences between presented and discovered problems were tested by comparing the average of the three presented items with the last item (the discovered problem) within each test (the bottom two rows of Table I). Correlated t tests were again used. Results indicated that the discovered item elicited significantly more ideas on the Instances test [t (28) = 3.55, $p <$ .001, r = .13], the Uses test [t (28) = 3.90, $p <$ .001, r = .26], and the Similarities test [t (28) = 3.93, $p <$ .001, r = .52]. The mean correlation between the presented and discovered problems (using an r-to-z transformation) was .32. A comparison of the average of the nine presented problems and the average of the three discovered problems also revealed a significant difference [t (28) = 5.71, $p <$ .001, r = .28].

Unique Variance of the Discovered Problems

The unique variance of the discovered problems was examined in several ways. First, a canonical correlation was conducted to determine predictive validity. Canonical procedures calculate optimized composite scores, or "variates," for a set of predictors and a set of criteria. The canonical coefficient is the correlation between the two variates. The predictors were the mean scores (across tests) from the first, second, and third items of the three presented problems and the mean score of the three discovered problems. The criteria were the five area scores from the Activities Check List.

Results indicated that the predictor variate was significantly correlated with the criterion variate [R_c = .78, F(20, 67) = 2.22, $p <$ .01]. More importantly, a hierarchical regression analysis indicated that the discovered-problem scores were significantly correlated with the criterion variate (defined in the canonical analysis) after the variance shared with the presented problems was controlled [R^2−change = .09, F(4, 24) = 5.41, $p <$ .05]. In other words, 9% of the variance of the criteria was accounted for specifically by the scores from the discovered problems.

Two additional analyses were conducted to further examine the unique variance of the discovered problems. A regression analysis using the averages of the discovered and presented problems indicated that PSAT scores (a total of the verbal and mathematics scores after each was transformed into a z score) accounted for only 2.5% of the unique variance of the discovered problems (for a description of this regression procedure, see Cohen and Cohen, 1975, chap. 6). Finally, a correlational analysis was conducted to evaluate the interitem reliability of the scores from the discovered problems. Results indicated that the scores from the three discovered problems were fairly reliable, with alpha coefficients of .53 before and .48 after controlling the scores from the presented problems.

Discriminant Validity

Discriminant validity was evaluated by correlating the divergent thinking test scores and the Creative Activity Check List scores with PSAT scores. Results supported the discriminant validity of the creativity scores, for in general the divergent thinking test scores and the Creative Activity Check List scores were unrelated or negatively correlated with the PSAT scores. More specifically, the coefficients between the separate divergent thinking test scores and the PSAT scores ranged from .03 to .19. Similarly, only literature scores from the Check List were related to PSAT scores ($r = .39$, $p < .05$). Mathematics, science, art, and crafts scores were unrelated to PSAT scores ($-.23 < rs < .18$).

DISCUSSION

These results suggest that problem discovery is associated with creative performance in adolescents. As predicted, the scores from the presented problems and the scores from the discovered problems were moderately correlated, but the discovered problems elicited significantly more ideas than the presented problems. Importantly, the correlation between discovered and presented problem scores was much smaller (mean $r = .32$) than the coefficient reported by Wakefield (1985) in his work with fifth-grade children. This result is consistent with Arlin's (1975) position that problem finding is a developed skill and only becomes distinct from problem-solving skill during adolescence.

The moderate association between presented and discovered problems is also consistent with the componential view of the creative process because both tasks involve the ability to generate ideas. The significant difference between the scores from the two types of problems was expected because the scores on the discovered problems reflect the problem-finding component of creativity in addition to ideational productivity. The most important findings for the componential theory of divergent thinking were those involving the unique variance of the discovered problems (controlling the variance shared with the presented problems). This presumably reflects problem-finding skill and is by definition statistically independent of problem-solving skill (or ideational productivity). The unique variance of the scores from the discovered problems was reliable and contributed to the prediction of creative activity. The distinctiveness of the problem discovery is also supported by the discriminant validity of the discovered problem scores. Hence, three types of psychometric evidence support the distinctiveness and importance of the problem discovery component of divergent thinking.

The difference between the two types of problems may have resulted from the discovered problems allowing examinees to select personally meaningful tasks. In this sense, the difference between the presented and the discovered problems may partly reflect an attitudinal component of divergent thinking. Csikszentmihalyi and Getzels (1970) demonstrated that artists' creativity is related to "an attitude for discovery," and the same may apply to adolescents. An alternative explanation is that the difference between the tests resulted from practice. Although all of the examinees received the tests in the same order, with the discovered problem of each test administered after three presented problems, there was no indication of a systematic order effect. The scores on the second item in both Uses and Similarities were below those from the first item, and only the third item of Uses had a significant increase. Further, the average scores from Instances, Uses, and Similarities (Table I) do not reflect a practice effect. Finally, the magnitude of the difference between the presented and discovered problems is difficult to account for in terms of practice alone.

Csikszentmihalyi and Getzels (1971) suggested that there is a continuum with "presented problem situations" on one extreme and "discovered problem situations" on the other. The two types of problems differ in the amount of initial information, the degree to which the method is initially apparent, and how much agreement there is concerning correct solutions. In these terms, the discovered problems in the present investigation were not entirely discovered because guidelines were given in the instructions for each test. Bransford and Stein (1984) distinguished between the identification of a problem – simply recognizing that a problem exists – and the definition or operationalization of the problem. In these terms, the discovery tasks in the present investigation can be viewed as problems of definition rather than identification.

This distinction is a very important one, for real-world creativity probably requires both problem identification *and* problem definition. Additionally, this distinction and the continuum described by Csikszentmihalyi and Getzels (1971) might be useful in the educational setting. An educator could, for example, use various types of discovered and identification problems in the classroom to practice realistic problem-finding skills. Along the same lines, the results of the present investigation suggest that students' creativity and ideational fluency would be best exercised by assigning tasks that are extremely open-ended and allow students' own discovery.

Note that the individualized nature of the discovery problems required that only fluency scores were used in this investigation. Originality and flexibility are also important facets of divergent thinking (Runco, 1985, 1986c), but they are typically related to fluency (Runco, 1986d). Other components of divergent thinking and creativity should be examined in future research. Perhaps the critical and evaluative components of divergent thinking can be operationalized.

Also note that the criterion of creative performance used in this project only measures the quantity of creative activity. It tells us little about the quality of the examinees' accomplishments. Further, it was a self-report, and therefore potentially influenced by the examinees' memory and honesty. This particular measure has demonstrated its reliability many times in the past (for a review, see Runco, 1987), but future research should test the predictive validity of the problem-finding scores with other criteria of creative accomplishment.

The small sample of subjects in this project and the potentially restricted range of scores also suggest that additional research is needed. Given Arlin's (1975) argument that mature cognitive structures are necessary for problem finding, a comparison of the problem discovery of preoperational, concrete operational, and formal operational individuals would be extremely interesting. The present findings suggest that divergent thinking tests can be used to investigate problem finding, and they support the componential theory of problem discovery; but additional empirical research is needed to test the generality and applicability of this theory of the creative process.

ACKNOWLEDGMENTS

The data for this investigation were collected while Dr. Runco was in the Psychology Department at the University of Hawaii, Hilo. The authors would like to thank Suk Hwang and Becky J. Thurston, both of the University of Hawaii, Hilo, for their assistance with this investigation.

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