Creativity Research Journal
2006, Vol. 18, No. 2, 213–227

RESEARCH NOTES

The Cognitive Processes of Pupils' Technological Creativity

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ABSTRACT: This study investigated pupils' self-awareness along with their self-evaluation of their cognitive processes when they were performing problem-solving tasks involving technological creativity. Thirty-six 4th to 6th graders participated in this study. A creativity test (Treasure Hunt on a Deserted Island) with 9 situation-based problems and 14 interview questions was employed, and both qualitative and quantitative methods were used to analyze the data. The findings suggest that (a) the creativity test is an effective tool for measuring pupils' technological creativity, for enhancing their motivation, and for providing data that enable us to better understand their cognitive processes involved in technological creativity; (b) having the internal motivation to solve problems and the attitude of welcoming challenges is crucial to pupils' technological creativity; (c) pupils have limited metacognitive ability and, on top of this, their problem-solving processes are not elaborate; (d) creative pupils are more adept at using cues to solve problems and their ideas concerning problem solving mainly stem from mindful learning; (e) most pupils have positive emotional traits and such emotions contribute to their technological creativity; and (f) the older pupils are, the less optimistic is their explanatory style.

Technological creativity, defined as the means by which individuals apply science to accomplish tasks in faster and better ways and, as a result, improve the overall quality of their lives, plays a crucial role in this ever-expanding age of knowledge. Undoubtedly, having a firmer grasp on how pupils use technological knowledge to solve authentic problems contributes to the effectiveness of enhancing their technological creativity. Dunbar (1997) claimed that it is possible to explore complex creative cognition in real-world contexts because, from such contexts, the fundamental mechanisms involved in creative cognition and the ways in which multiple cognitive processes interact to facilitate the generation of creative ideas or solutions can be identified. If this is indeed the case, then a question is raised: Can a situation-based problem-solving test with real-world contexts be an effective tool to investigate pupils' cognitive process concerning technological creativity?

Simonton (2003) has recently advanced the notion that, though scientific creativity is hard to envisage, it comprises certain basic elements that are nurtured through the accumulation of various life experiences. The nature of these experiences may very well be affected by personal characteristics, the family environment, school education, and even the social milieu

This research was supported in part by the National Science Council, Taiwan, Grant NSC92–2511-S-004-002. We thank graduate students Kai-Ming Huang, Chih-Che Lin, Chia-Ming Liu, and Yueh-Ying Peng for their help with the interviews and data analyses. We also thank William Lucas for his precious comments on this article.

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(Amabile, Conti, Lazenby, & Herron, 1996; S. K. Cheng, 1999; Michel & Dudek, 1991; Oldham & Cummings, 1996; Siau, 1995; Simonton, 2000, 2003; Sternberg & Lubart, 1999). Of these major influences, personal characteristics have been found to have the greatest impact on the development of technological creativity among adults (Yeh, 2004). Should this equally hold true among pupils, then the other question arises: Precisely which personal characteristics are crucial in the development of pupils' technological creativity?

Formation and Processes Involved in Technological Creativity

Three hypotheses concerning the incubation and formation of creative ideas have recently been proposed by Segal (2004). The first is *the autonomous-process hypothesis*, which theorizes that an unconscious integration of knowledge takes place either through the diffusion of the activated processes in the associative networks (Bowers, Regher, Balthazard, & Parker, 1990) or through the unconscious recombining of ideas that takes place during selective retention (Simonton, 1995). *The external-cues hypothesis* supposes that an initial unsuccessful attempt to solve a problem may virtually activate traces of stored memory and then an originally unrelated intervention may incite the critical traces and trigger their integration with the available information (Yaniv & Meyer, 1987). Finally, the third hypothesis—*the attention-withdrawal hypothesis*—propounds that people may encounter an impasse while solving a problem and that they may be likely to divert their attention away temporarily from the problem, which helps them to minimize the activation of false assumptions (Segal, 2004).

Amabile (1996) also identified five stages of creativity: (a) problem or task identification—task motivation determines whether the search for a solution will begin or continue; (b) preparation—domain-relevant skills determine which pathways will be available during the search for a response; (c) response generation—creativity-relevant procedures serve as an executive controller and influence how the search for a response will proceed; (d) response validation and communication—domain-relevant skills determine which criteria will be used to evaluate a response; and (e) outcome—an appropriate decision is made and the result of the outcome will, in turn, influence task motivation and further determine whether the process will continue or terminate. More recently, Ward, Smith, and Finke (1999) put forth the *creative cognition approach*, which focuses on the studies of insight, the extension of concepts, recently activated knowledge, conceptual combinations, and the study of creative imagery. They proposed five common types of generative processes: (a) the retrieval of existing structures from memory, (b) the formation of simple associations among the structures or combinations thereof, (c) the mental synthesis of new structures, (d) the mental transformation of existing structures into forms, and (e) the analogical transfer of information from one domain to another categorical reduction.

To sum up, the aforementioned hypotheses and theories of the creative processes largely comprise the retrieval, integration, and the retention of knowledge, the close connections between cues and the activation of knowledge, the crucial role of motivation, and the contribution of incubation to insight. Understanding how these factors or components and connections may actually interact in the process of pupils' technological problem solving, undoubtedly, is central to improving their technological creativity.

Personal Characteristics and Technological Creativity

The theories about creative processes (Segal, 2004) coupled with findings from earlier studies (Amabile et al., 1996; Oldham & Cummings, 1996; Siau, 1995) suggest that personal characteristics inherently have a strong influence on creativity. In this study, we centered our attention on how emotions, knowledge and experiences, motivation, and metacognitive ability influence pupils' cognitive processes that are involved in technological creativity.

By now, it has become widely accepted that positive affect leads to greater cognitive flexibility and facilitates creative problem solving (Aspinwall & Taylor, 1997; Estrada, Isen, & Young, 1997; George & Brief, 1996; Hirt, Melton, McDonald, & Harackiewicz, 1996; Isen, 1999, 2003). As Russ contended, emotions can contribute to creativity in two ways: First, the affective pleasure inherent in a challenge may be related to curiosity and the ability to successfully identify problems; second, openness to emotional states may be linked to transformation ability (as cited in Lubart & Getz, 1997). For these reasons, an individual who is in a positive emotional state is likely to be more capable of producing information, forming a wider variety of associations and, as a result, increasing her or his flexibility (Isen, 2002b; Murray, Sujan, Hirt, & Sujan, 1999). An alternative explanation provided by neuropsychologists is that dopamine pathways are activated during periods of positive affect and that dopamine may mediate the effects of this positive affect on cognition (Ashby, Isen, & Turken, 1999).

Moreover, Runco, Nemiro, and Walberg (1998) claimed that a sound knowledge base is essential for the development of creativity and that the ability to build new structures as well as the competence to fill gaps in knowledge is at the core of knowledge building. Along the same line, Feldhusen (1995) and Runco (1996) advocated that creative production mostly depends on a large and thorough knowledge base within a given domain and that such a knowledge base can be accumulated from academic learning, reading, and experience.

The importance of motivation, especially intrinsic motivation, is greatly emphasized in Amabile's (1997) component model. Runco et al. (1998) found that, among their 16 creative achievement composites, the motivation composite had the highest average rating. It has also been found that internal motivation, such as the desire to venture into new areas and do creative work, was vital to technological creativity among R&D workers in the technology industry (Yeh, 2004). Particularly noteworthy is that, based on her longitudinal study, Yeh (2003) has identified the following motivational components and claimed that they are important to pupils' attaining technological creativity: attempting to solve different problems, being curious, being willing to share ideas and brave enough to express oneself, being highly motivated to learn and achieve self-improvement and self-transcendence, and having a persistent urge to keep on trying.

Finally, it seems certain that, at the root of any successful technological creation are two abilities—the cognitive and the metacognitive. Donnelly (1994) defined creativity as the ability to see and transform materials and objects into new and original forms. Feldhusen (1995) regarded creative thinking as a metacognitive process for which planning, monitoring, and evaluating cognitive operations are required. As evidenced in the results of their studies, Berardi-Coletta, Dominowski, Buyer, and Rellinger (1995) claimed that such problem-solving skills as learning how to learn and heightening one's awareness as to what one is doing need to be emphasized when problem solving. This substantiates the earlier claim that, when problem solving, although stored knowledge is important, self-awareness and metacognition are essential because together they monitor and regulate the streams of activity involved in seeking solutions (Mokhtari & Reichard, 2002).

Purposes of This Study

Broadening the scope of a previous longitudinal study (Yeh, 2003) that focused on investigating the development of pupils' technological creativity with a large sample size, this study used a more qualitative approach via mostly exploratory personal interviews to achieve its two objectives. The first goal was to investigate whether using a narrative-style picture book with situation-based and problem-solving tasks was a preferable and an effective way to gain a better grasp on pupils' cognitive processes that are involved in technological creativity. The second aim of this research was to determine what kind of effects personal characteristics had on pupils' cognitive processes when they were undertaking creative problem-solving tasks in life-based technology. To have a better understanding of the interest in this study, we compared the performance of highly creative and less creative pupils as well as that of different grade levels.

Methods

Participants

In all, 36 fourth to sixth graders (18 girls and 18 boys) participated in this study. For each grade level, 6 (3 girls and 3 boys) had been classified in the highly creative group (HC) and 6 (3 girls and 3 boys) in the less creative group (LC). They had first been screened on the basis of their scores on the *Technological Creativity Test*, a divergent thinking creativity test, which had been previously used in Yeh's (2003) longitudinal study. The longitudinal study included 1,790 pupils in 2002 and 1,839 pupils in 2003, and the total number of individuals that participated throughout both sample periods was 1,051. The participants in this study were randomly sampled from the HC and the LC groups (about 200 pupils in each group) in both years. In other words, their creative performances were consistently high or low in the longitudinal study and their creativity scores were above *M* + 1 *SD* or below *M* – 1 *SD* in their grade levels.

Instruments

In this study, we employed a technological creativity test—*Treasure Hunt on a Deserted Island*—and a structured interview questionnaire with 14 items. The creativity test was a creative problem-solving test with three situations presented in a narrative style in a colorful, true-to-life picture book (Yeh, 2004). The story starts with a boy who dreams about a genie who takes him to a deserted island for a treasure hunt. The journey takes 2 days and 1 night, and the genie provides the boy with 10 instruments (see Figure 1) to help him solve the problems he encounters during the treasure hunt. The test emphasized the application of knowledge about technology in Nature and Life as well as the ability to creatively solve problems under restrictive conditions. Unlike traditionally used creativity tests, this treasure hunt test was administered via personal interviews for two reasons. First, it avoided potential limitations caused by pupils' different writing speeds. Second, from the answers to the research questions proposed in this study, the interviews could provide more in depth data when compared to paper-and-pencil tests. With no strict time limits imposed, the pupils were instructed first to define the problems they encountered, and second, to use the instruments and resources made available to them to solve the problems in creative ways.

Three creativity indexes, namely sensitivity, originality, and valuableness, were measured in the treasure hunt test. "Sensitivity" measured the pupils' ability to identify 9 major problems in 3 situations. The major task-related problems the participants encountered were as follows: Situation 1—(a) getting lost, (b) getting cold, and (c) getting hungry; Situation 2—(d) falling into a deep hole, (e) avoiding being attacked by wolves, and (f) safely taking an overnight rest; and Situation 3—(g) crossing a river; (h) unlocking an electrified lock; and (i) correctly identifying a real diamond. As for the second creativity index "valuableness," it measured the feasibility and appropriateness of each solution that the participants came up with. Turning to "originality," it assessed the novelty of each solution. Scores on sensitivity were not included in the final score of creativity; instead, they served as a weighting index of the score for originality and valuableness. More to the point, each solution was scored from 0 to 2 points on the three indexes of technological creativity

Figure 1. *Ten instruments provided in the Treasure Hunt on a Deserted Island.*

first, and then each score for "originality" and "valuableness" was multiplied by the score for "sensitivity." Finally, a total score for technological creativity was calculated as the averaged *T* score for "originality" and "valuableness" (F. Y. Cheng, 2004).

The treasure hunt test was first developed by Yeh (2003, 2004) and it has been tested empirically (F. Y. Cheng, 2004). The two indexes of originality and valuableness were significantly correlated, $r(416) = .70$, $p = .001$, and they had high correlations with the total score of creativity, *r*s(416) = .90 and .92, *p*s = .001, respectively. Moreover, the total score for creativity was significantly related to pupils' age, domain knowledge, and experience regarding creative performance, *r*s(416) = .44, .20., and .18, *p*s = .001, respectively (F. Y. Cheng, 2004). The treasure hunt test was developed and chosen here because it meets the requirements that a creativity test should contain "originality" and "valuableness" (Mayer, 1999) and that situation-based problem solving is an effective way to explore the cognitive processes of creativity (Dunbar, 1997).

By design, a checklist with 14 interview questions (see Appendix) was employed to understand the pupils' assessment of the treasure hunt test, the self-awareness and self-evaluation concerning their cognitive processes during problem solving. In answering each of the questions, the pupils could have multiple responses.

Process

Three graduate students were trained as interviewers and they administered the structured interviews on an individual basis. All interviews, completed within a 2-week period, were conducted in a quiet classroom at the participants' own school. During the interviews, the interviewers, first, tried to establish a warm and friendly atmosphere, and then, briefly explained the task. Once the participants were ready, the interviewer started to read each participant the story with both following the book *Treasure Hunt on a Deserted Island*. At the end of each presentation of a situation, the interviewer asked the participant to solve the related problems. All of the interviews were videotaped with a digital video camera and, at the end of the interview, a pencil box was given to each participant as a token of appreciation.

Data Analyses

After the videotaped contents were transcribed and encoded onto computer files, the contents were analyzed. Each response involving problem solving was numbered and tabulated on the basis of a checklist that was made for each of the 14 interview questions. To increase the reliability and validity of the analyses of the data, each response was separately analyzed by two graduate students who conducted the interviews. Whenever there was a discrepancy, a discussion between the interviewers followed and a consensus was reached. Along with the qualitative analyses, this study also conducted quantitative analyses to determine the differences among the pupils in the highly creative and those in the less creative groups in all samples as well as at each grade level.

Results

Preliminary Analysis

As might be expected, the highly creative group (HC) outperformed the less creative group (LC) on the two indexes of "valuableness" and "originality," *t*s(35) = –5.493, 6.286, *p*s = .000, and on the total score for technological creativity, $t(35) = 0.982$, $p = .000$ (see Table 1). Taking valuableness and originality as the dependent variables at the same time, no gender differences were found in the one-way multivariate analyses of variance, $\Lambda = .997$, $p = .945$, $\eta^2 = .003$.

Evaluation of *Treasure Hunt on a Deserted Island*

In the first set of questions on the treasure hunt test itself, the first three interview questions were asked (see Appendix). Among all 36 pupils, the majority (83.3%) stated that the test was interesting (Question 1), and this percentage was about the same for the HC and the LC group. The most important reasons for the test being interesting for both groups were "could think about problems" (36.1%), "could solve problems" (25.0%), and "the story was funny and interesting" (16.7%). The pupils in the HC group also mentioned "felt like I was experiencing the situations in person" (16.7%; see Table 2). Although most pupils at each grade level responded positively to the first question, the Grade 4 participants were by far the most positive

Table 1. *Original Scores and the T Scores on the Treasure Hunt Test*

	LC (n = 18)		HC (n = 18)			
	M	*SD*	*M*	*SD*	*t*	Significance
Valuableness	43.24 (15.56)	4.78 (5.81)	56.76 (32.00)	9.29 (11.29)	–5.493***	.000
Originality	42.77 (8.11)	4.67 (4.43)	57.23 (21.83)	8.57 (8.13)	–6.286***	.000
Total score	43.01	3.66	57.00	7.67	–6.982***	.000

Note. The numbers outside the parentheses are *T* scores whereas those in the parentheses are original scores. LC = less creative group; HC = highly creative group.
***$p < .001$.

(they had the highest percentage at 91.7%). Comparing the HC and the LC groups, no significant difference between the two groups was found. Nevertheless, we found that the sixth graders in the HC group tended to reason from more of a multiperspective and higher level of thinking, as shown in their higher agreement to "could make judgements by myself" and "could increase wisdom."

In assessing the appropriateness of the treasure hunt test (Question2), 58.3% of the total sample stated that they felt the tasks had an "average" level of difficulty, but the percentage of those feeling the tasks were "not difficult" in the HC group was about double that in the LC group (see Table 3). The most commonly mentioned reasons for considering the tasks not difficult were "questions were easy" (22.2%) and "had instruments available" (13.9%). On the other hand, the reasons for considering them difficult were "didn't know how to solve the problems" (11.1%) and "didn't know how to use the instruments" (5.6%). Among the grade levels, there was no consistency in the answers for either the HC or the LC groups. However, most participants in both the HC and the LC groups responded that the tasks had an "average" level of difficulty.

As concerns the format of the test (Question 3), Table 4 shows that 75.0% of the total sample expressed a preference for problem-solving tasks based on a picture book, such as this. Only 8.3% of all pupils expressed a preference for traditional paper-and-pencil tests. In the HC group, the main reasons for preferring the type of test in this study were "the story was interesting" (22.2%), "gave cues" (22.2%), and "provoked thinking in problem solving" (16.7%). It is worth noting that there was a sharply different response among

Table 2. *Frequency and Percentage of Responses to Question 1*

	LC (n = 18)		HC (n = 18)		Total (N = 36)	
Response	Count	%	Count	%	Count	%
Q1.1: Do you think the problem-solving tasks in the "Treasure Hunt" were interesting?						
1. Not interesting	1	5.6	0	0	1	2.8
2. Average	4	22.2	1	5.6	5	13.9
3. Interesting	13	72.2	17	94.4	30	83.3
Q1.2: Why? Why not?						
Provoked thinking and problem solving						
1. Could think about problems	4	22.2	9	50.0	13	36.1
2. Could solve problems	3	16.7	6	33.3	9	25.0
3. Could increase wisdom	1	5.6	1	5.6	2	5.6
4. Could make judgments by myself	1	5.6	0	0	1	2.8
5. Could use my imagination	0	0	2	11.1	2	5.6
Test content was appropriate and interesting						
6. Story was funny and interesting	4	22.2	2	11.1	6	16.7
7. Story provoked my curiosity	1	5.6	1	5.6	2	5.6
8. Felt like I was experiencing the situations	0	0	3	16.7	3	8.3

Note. LC = less creative group; HC = highly creative group.

Table 3. *Frequency and Percentage of Responses to Question 2*

	LC (*n* = 18)		HC (*n* = 18)		Total (*N* = 36)	
Response	**Count**	**%**	**Count**	**%**	**Count**	**%**
Q2.1: Do you think the problem–solving tasks in the "treasure hunt" were difficult?						
1. Very difficult	2	11.1	0	0	2	5.6
2. A little bit difficult	0	0	3	16.7	3	8.3
3. Average	13	72.2	8	44.4	21	58.3
4. Not difficult	3	16.7	7	38.9	10	27.8
Q2.2: Why? Why not?						
Learning						
1. Learned from extra curricular activities	0	0	1	5.6	1	2.8
2. Learned in class	0	0	2	11.1	2	5.6
3. Worried about giving wrong answers[a]	0	0	1	5.6	1	2.8
Application of resources						
4. Had instruments available	2	11.1	3	16.7	5	13.9
5. Didn't know how to use the instruments[a]	0	0	2	11.1	2	5.6
Thinking and problem solving						
6. Thought hard	0	0	3	16.7	3	8.3
7. Used imagination	0	0	1	5.6	1	2.8
8. Frequently encountered similar problems	1	5.6	0	0	1	2.8
9. Never encountered similar problems[a]	0	0	1	5.6	1	2.8
10. Didn't know how to solve the problems[a]	3	16.7	1	5.6	4	11.1
Appropriateness of content						
11. Questions were presented in a story	1	5.6	0	0	1	2.8
12. Questions were easy	5	27.8	3	16.7	8	22.2
13. Questions had an average level of difficulty	2	11.1	0	0	2	5.6
14. No standardized answers[a]	0	0	1	5.6	1	2.8
15. Questions were too difficult[a]	1	5.6	0	0	1	2.8

Note. LC = less creative group; HC = highly creative group.
[a]Represents pupils' reasons for considering the "treasure hunt" difficult

the LC group for preferring this type of test: "the questions were easy" (27.8%). By grade level, support in favor of this type of test was based on "the story was funny and interesting" among the fourth graders; on "was not as serious as school tests," "gave cues," and "didn't need to memorize" among the fifth graders; and on "the questions were easy" and "gave cues" among the sixth graders for both the HC and the LC groups.

Self-Awareness and Self-Evaluation of Cognitive Processes

This part of the results, covering Questions 4 to 14 (see Appendix), concluded the interview. In terms of emotional traits (Question 4), no large differences were observed between the HC and the LC groups, or among the grade levels. Most pupils described their general emotional trait as "glad or pleasant" (52.8%) or "happy" (33.3%). Very few of the fifth- and sixth-grade pupils in the LC groups (16.7%) were unable to identify their emotions. For those who could identify their emotions, most of the fifth- and sixth-grade pupils, and an overwhelming 100% of the fourth graders, claimed to have positive emotional traits.

Further, we found that the emotional state of all pupils in the total sample was either "glad" (33.3%) or "happy" (19.4%) combined with a little "nervous" when answering the questions in the test (Question 5). Only 16.7% of the LC group was unable to identify their emotional state. Among the three grade levels, only Grade 6 pupils showed larger differences between the HC and the LC group; the LC group generally had a more positive emotional state, whereas half of the HC group had a more negative emotional state (felt "unstable" and "confused").

Table 4. *Frequency and Percentage of Responses to Question 3*

	LC (*n* = 18)		HC (*n* = 18)		Total (*N* = 36)	
Response	**Count**	**%**	**Count**	**%**	**Count**	**%**
Q3.1: Would you like to to have your school tests to be like the "Treasure Hunt"?						
1. Don't like	1	5.6	2	11.1	3	8.3
2. Somewhat like	2	11.1	0	0	2	5.6
3. Average	2	11.1	2	11.1	4	11.1
4. Like	13	72.2	14	77.8	27	75.0
Q3.2: Why? Why not?						
Appropriateness of content						
1. The story was funny and interesting	3	16.7	4	22.2	7	19.4
2. The questions were easy	5	27.8	2	11.1	7	19.4
3. Liked this story	1	5.6	2	11.1	3	8.3
4. The questions were difficult[a]	1	5.6	0	0	1	2.8
5. The story was illogical[a]	1	5.6	0	0	1	2.8
Type of test						
6. Was not as serious as school tests	1	5.6	1	5.6	2	5.6
7. Didn't need math	0	0	1	5.6	1	2.8
8. Gave cues	2	11.1	4	22.2	6	16.7
9. Didn't need to memorize	1	5.6	1	5.6	2	5.6
10. Like traditional school tests[a]	2	11.1	1	5.6	3	8.3
Thinking and problem solving						
11. Provoked thinking in problem solving	0	0	3	16.7	3	8.3
12. Learned something	0	0	1	5.6	1	2.8

Note. LC = less creative group; HC = highly creative group.
[a]Represents pupils' reasons for not liking the "treasure hunt" as a school test model.

When asked whether they were answering the questions seriously (Question 6), most pupils responded in the affirmative (77.8%) and, in all, the percentage in the HC group was dramatically higher than that in the LC group (100.0% vs. 55.6%). By grade level, with the exclusion of the Grade 6 pupils, the results echoed those of the total; in the LC group, just under one third said they had answered the questions seriously.

On the aspect of how they did when answering the questions (Question 7), whereas 50.0% of the total sample stated that they had an average level of performance, 41.7% thought they did very well. Their good performance was reportedly due to "knew how to make use of the instrument" and "got the answers." On the other hand, their perceived bad performance seemed to have normally resulted from "unsure about the effectiveness of the solutions" and "couldn't answer some of the questions." There were no notable differences between the HC and the LC group other than two findings: 22.2% of the LC group reported a poor performance because they "couldn't answer some of the questions" and 16.7% of the HC group reported a good performance because they "knew how to make use of the instruments" (see Table 5). As for the differences by grade level, half of the Grade 4 pupils, two thirds of the Grade 5 pupils, and only one third of the Grade 6 pupils thought they did well when answering the questions. No consistent reasons for a good or bad performance, in particular, were found across all three grade levels.

In distinguishing between the levels of difficulty of the treasure hunt test (Question 8), in all grades and groups, about 50.0% of the pupils regarded Situation 3 as the hardest. Regarding the processes involved in their problem solving (Question 9), 83.3% of the total sample could not concretely describe their problem-solving process, and among the three grade levels, the percentage was particularly high (91.7%) for the Grade 4 pupils. Although 16.7% of all pupils did attempt to give some form of description, they could only give a vague response, such as "thought about the problems first, and then used the instruments to solve them." No obvious differences were found between the HC and the LC groups.

Table 5. *Frequency and Percentage of Responses to Question 7*

Response	LC (*n* = 18)		HC (*n* = 18)		Total (*N* = 36)	
	Count	%	Count	%	Count	%
Q 7.1: Do you think you answered the questions well?						
1. Don't know	1	5.6	0	0	1	2.8
2. Not well	1	5.6	1	5.6	2	5.6
3. Average	9	50.0	9	50.0	18	50.0
4. Very well	7	38.9	8	44.4	15	41.7
Q 7.2: Why? Why not?						
Application of resources						
1. Knew how to make use of the instruments	1	5.6	3	16.7	4	11.1
2. Knew how to apply related knowledge	0	0	1	5.6	1	2.8
3. Didn't know how to use the instruments[a]	0	0	1	5.6	1	2.8
4. No standardized answers[a]	1	5.6	0	0	1	2.8
Thinking and problem solving						
5. Got the answers	2	11.1	2	11.1	4	11.1
6. Thought hard	2	11.1	1	5.6	3	8.3
7. Didn't take too long to get the answers	0	0	1	5.6	1	2.8
8. Could complete the tasks	1	5.6	0	0	1	2.8
9. Couldn't answer some of the questions[a]	4	22.2	1	5.6	5	13.9
10. Took too long to get the answers[a]	0	0	2	11.1	2	5.6
11. Unsure about the effectiveness of the solutions[a]	3	16.7	3	16.7	6	16.7
Emotions						
12. Felt nervous[a]	1	5.6	0	0	1	2.8
No answer						
13. Didn't know why	1	5.6	1	5.6	2	5.6

Note. LC = less creative group; HC = highly creative group.
[a]Represents pupils' reasons for not doing well.

Concerning the main sources of their solutions (Question 10), they were "thought by myself" (72.2%), "clues in the pictures or instruments" (58.3%), and "thought hard" (41.7%). Worth noting is that, in the LC group, "learned from TV" and "heard from others" had higher percentages; against this, in the HC group, "learned from books" and "learned from class" had higher percentages (see Table 6). More specifically, among the fourth graders, the HC group more often mentioned "learned from life experiences" and "learned from past experiences." Among the fifth graders, the HC group most frequently mentioned "learned from books"; contrast this with those in the LC group who most often mentioned "learned from TV." Finally, among the sixth graders, the HC group most commonly mentioned "learned from books" and "from class," whereas those in the LC group most frequently mentioned "heard from others."

It was anticipated that personal camping experiences could have had some influence on how pupils came up with solutions; with this in mind, we asked Question 11. We found that, for the total sample, 72.2% did not have any camping experience and the percentages in the HC and the LC group were 66.7% and 77.8%, respectively. Among the three grade levels, no large differences in terms of having had camping experiences were found.

On the whole, most pupils (75.0%) reported that they frequently had some novel ideas, but the percentage in the LC group (66.7%) was lower than that in the HC group (88.3%) (Question 12). Over half of the pupils at each grade level remembered frequently having some novel ideas. The percentage among the fourth graders in the HC group was higher than that in the LC group; no obvious differences were found among the fifth or sixth graders. When asked to score their performance as far as coming up with novel ideas goes (ranging from 1 to 5 points), most of the Grade 4 pupils gave themselves 4 points, whereas most of the Grade 5 and 6 pupils gave themselves slightly lower scores of roughly 3 points.

Table 6. *Frequency and Percentage of Responses to Question 10*

Response	LC (*n* = 18)		HC (*n* = 18)		Total (*N* = 36)	
	Count	%	Count	%	Count	%
Q 10: Where did you get the ideas for the solutions?						
Imagination and thinking						
1. Used imagination	2	11.1	1	5.6	3	8.3
2. Ideas occurred suddenly	3	16.7	3	16.7	6	16.7
3. Thought hard	7	38.9	8	44.4	15	41.7
4. Thought by myself	14	77.8	12	66.7	26	72.2
Clues in the test						
5. Clues in the pictures or instruments	9	50	12	66.7	21	58.3
Personal experiences						
6. Life experiences	2	11.1	3	16.7	5	13.9
7. Past experiences	2	11.1	3	16.7	5	13.9
Learning						
8. Learned from books	1	5.6	6	33.3	7	19.4
9. Learned from TV	4	22.2	2	11.1	6	16.7
10. Learned in class	3	16.7	5	27.8	8	22.2
11. Heard from others	4	22.2	0	0	4	11.1
Mixed experiences						
12. Learned from books, TV, class …	0	0	1	5.6	1	2.8

Note. LC = less creative group; HC = highly creative group.

Finally, 44.4% of all pupils stated they would like to try to turn their novel ideas into products, but the percentage in the HC group was higher than that in the LC group (55.6% vs. 33.3%; Question 14). On average, about half of the pupils gave themselves 4 points (HC = 55.6%; LC = 44.4%), but overall, more pupils in the HC group gave themselves 5 points compared with those that did so in the LC group (33.3% vs. 22.2%). Most of the fourth- and fifth-grade pupils in both the HC and the LC groups gave themselves 4 points. Whereas most of the sixth-grade pupils in the HC group gave themselves quite high values of 4 or 5 points, most pupils in the LC group merely gave themselves a somewhat disturbing 2 points.

Discussion

Two questions were proposed in this study. The first concerned the effectiveness of the *Treasure Hunt on a Deserted Island* in understanding pupils' cognitive processes, and the second concerned the identification of important personal characteristics via personal expressions of their sense of self-awareness and self-evaluation when performing problem-solving tasks in life-based technology. Both questions are fully answered by the findings in this study. Though the findings are based on a small sample, the participants are sampled from a longitudinal study with reliable screening criteria. Therefore, it is expected that the findings will provide instructors with invaluable information with which to help pupils enhance their technological creativity.

Evaluation of the *Treasure Hunt on a Deserted Island*

Most participants held rather positive attitudes toward the test, responding that it was interesting, could provoke thinking and problem solving, and had a medium level of difficulty. Compared with more traditional school tests, the participants also preferred this test format—situation-based problem solving tasks presented in a picture book medium. The majority also agreed that the availability of instruments and cues during the problem-solving activities did contribute to their problem-solving abilities. This finding supports *the external-cues hypothesis* (Yaniv & Meyer, 1987), which postulates that it should be the case that external cues, in this case the instruments and the situational resources, activate stored memory pathways and allow individuals to integrate the information available to have it ready for easy access whenever they need to solve a problem.

Another point worth noting here refers to Torrance's (1967) claim that the processes of becoming sensitive to problems, identifying the difficulty, searching for solutions, and of formatting hypotheses are important during the creative process. Our treasure hunt test in conjunction with the interview procedures was, in essence, consistent with this style of problem-solving process. To explain, we asked the pupils to identify the problems in each situation before they proposed solutions; we also asked them to identify the most difficult problems.

On pupils' scores of technological creativity, this study also found a significant difference between pupils in the highly creative and those in the less creative groups (p = .000), highly indicative that, on the capability side, the treasure hunt test successfully discriminated between the two groups. Furthermore, the grouping in this study was based on the results of a divergent creativity thinking test employed in a longitudinal study (Yeh, 2003); therefore, it is reasonable to claim that divergent creative thinking test and the situation-based problem-solving test introduced here are likely complimentary to each other when it comes to measuring pupils' technological creativity.

Briefly speaking, the findings in this study demonstrate that the treasure hunt test is an effective tool for measuring pupils' technological creativity as well as for enhancing their motivation and ability to perform problem-solving tasks; furthermore, its effectiveness lies in the characteristics of consisting of situation-based, problem-solving tasks within the framework of a colorful, challenging story, especially with clues in the situations.

Identification of Personal Traits From Self-Awareness and Self-evaluation

By means of the treasure hunt test and the interviews, we were able to identify emotions, motivation, metacognitive ability, knowledge and mindful learning, as well as imagination as the important personal characteristics during pupils' cognitive processes involved in the development of technological creativity. This clearly suggests that the treasure hunt test is an effective tool in understanding pupils' cognitive processes. A more detailed discussion of this follows.

Emotions and creativity. Most pupils reported having not only positive emotional traits during their interviews but also positive emotional states in general at the time they were solving the problems during the interview. This provides evidence that positive affect enhances the sought-after abilities underlying innovation, creativity, and creative problem-solving processes (Isen, 1999; Kaugars & Russ, 2000; Lee & Sternthal, 1999). It is important to bear in mind that Lubart and Getz (1997) suggested that emotions can serve as a motivating force and that they can elicit specific concepts that may very well contribute to creative thinking. Beyond this, neuropsychologists have also advocated that positive affect is mediated by the dopamine system in the brain and then carries the effects on cognition (Ashby et al., 1999; Isen, 2002a). It was found here, however, that half of the highly creative pupils in Grade 6 had negative emotional states while they were solving problems, supporting the view that negative mood states may contribute to creativity (George & Zhou, 2002; Kaufmann & Vosburg, 1997). In this sense, George and Zhou (2002) found that negative moods were positively related to creative performance when the perceived recognition and rewards for creative performance and clarity of feelings were high. Kaufmann and Vosburg (1997) also found that negative mood states produced better creative problem solving than did positive moods. Negative moods may be a sign that there are problems or that things need to be improved, which may prompt people to make changes and thus stimulate their creativity (Frijda, 1988; Martin & Stoner, 1996). Accordingly, though positive emotional traits generally contribute to pupils' development of technology creativity, negative emotional states may be more critical in pupils' performance of technological creativity, especially for older pupils.

Motivation and creative performance. We found that the highly creative groups were more highly motivated to take the problem-solving tasks seriously and to make use of the instruments provided than were their LC counterparts. We also found that a higher percentage in the HC groups would like to try to turn their novel ideas into products than those in the LC groups. That the HC groups outperformed the LC groups in these two aspects should not be surprising in light of the findings of Amabile (1996), who claimed that task motivation plays a crucial role during the five stages of creativity and that people are most creative when they are driven by an "intrinsic motivation." Along the same lines, other researchers (Csikszentmihalyi, 1996; Nakamura & Csikszentmihalyi, 2003) have argued that the creative process is, in large part, a function of a specific kind of motivation. Yeh (2003) has also found evidence in favor of the argument that pupils with high technological creativity have a higher degree of motivation to solve different problems and to enhance self-improvement. Thus, the findings in this study cement the notion that internal motivation geared toward seeking challenges and problem solving is crucial to improving pupils' performance vis-à-vis technological creativity.

Metacognitive ability and creative problem solving. Metacognition involves an individual's self-monitoring, self-evaluating, and self-regulating when performing her or his ongoing tasks (Mokhtari & Reichard, 2002). In this study, we found that most pupils could not specifically describe their problem-solving process, and that they could only mention a two-step problem-solving process—thinking about the problems first, and then using the instruments available to solve them. Several implications emerge from these findings. First of all, it is implied here that the pupils have limited metacognitive ability and that their problem-solving processes are not elaborate. For the most part, however, researchers (for example, Mokhtari & Reichard, 2002) have shown a tendency to agree that metacognition includes cognitive abilities as well as the affective and motivational characteristics of thinking. On these grounds, the findings in this study may, second, suggest that the pupils, especially those in Grades 5 and 6, may possess the metacognitive ability but lack either the motivation or the awareness as to how to use that ability in the process of problem solving. The third implication from our results is that the pupils in the HC groups do, indeed, have appropriate cognition of their own creative performance but, as individuals get older, their explanatory style tends to be less optimistic (F. Y. Cheng, 2004; Nolen-Hoeksema & Girgus, 1995). This is evidenced by the finding that the fifth and sixth graders' self-evaluation scores on "having creative ideas" were lower than those of the fourth graders although the fifth and sixth graders' scores on the actual treasure hunt test were higher. This raises another issue: whether there is a link between explanatory style and technological creativity; this therefore is an area well worthy of further study.

Knowledge, mindful learning, and creative ideas. The results from this study demonstrate that the highly creative pupils obtained their creative ideas mainly from books, classroom learning, and personal experiences, suggesting that meaningful learning may greatly contribute to creative problem solving in technology. At the same time, this confirms the importance of a base of knowledge in creativity (Runco et al., 1998; Ward et al., 1999) and the significant contribution that reading makes to pupils' technological creativity (Yeh, 2003). For technological creativity to manifest itself well, practical knowledge, which indicates that one knows how theories actually function in various kinds of actual settings, may play a very important role. In this sense, the important role that previous experiences seem to play among our participants supports Runco's (1996) claims that direct experience can supply useful knowledge and that a developmental definition of creativity should focus on the everyday interpretation of experience rather than simply on major intellectual breakthroughs.

Imagination, TV, and creative solutions. It was found in this study that thinking and imagination had an influence on pupils' technological creativity, which replicates the finding in our previous longitudinal study (Yeh, 2003). Max Planck claimed that creative scientists "must have a vivid, intuitive imagination, for new ideas are not generated by deduction, but by an artistically creative imagination" (as cited in Simonton, 2003, p. 475). Here we found that TV programs were the most important source of creative ideas for pupils in the LC groups. Two hypotheses pertaining to the relationship between TV and a creative imagination have been proposed: *the stimulation hypothesis* and *the reduction hypothesis* (Valkenbugr & Voort, 1994). The stimulation hypothesis postulates that TV inspires a creative imagination by virtue of its content (Rubenstein, 2000). The reduction hypothesis, on the other hand, suggests that TV hinders the development of a creative imagination. The latter effect may stem from several factors: (a) TV presents viewers with ready-made visual images and thus leaves the viewer little room to form her or his own images; (b) TV allows viewers little time to reflect on a program's contents, thereby encouraging a nonreflective thinking style; (c) TV requires little need to fantasize, thus leading to an attitude that weakens an individual's desire to exert any mental effort to develop a creative imagination; and (d) TV takes the place of other experiences, such as reading, that are thought to stimulate the creative imagination (Greenfield & Beagles-Roos, 1988; Harrison & Willams, 1986). The fact that the pupils in the LC groups evidently obtained their ideas mainly from TV programs seems to support the TV stimulation hypothesis. On the other hand, their overall performance was inferior to that of their HC counterparts, the sources of whose ideas were mainly books and classroom learning; this tends to lend credence to the TV reduction hypothesis. Therefore, to decide whether TV programming stimulates or reduces one's imagination, the core of the issue obviously lies in the quality of the contents (Rubenstein, 2000). Therefore, improving the contents, types, and quality of certain TV programs can be one effective way to improve pupils' technological creativity, especially for those who are not interested in reading.

Conclusions

With a view to exploring pupils' cognitive processes of technological creativity during creative problem solving, this study employed personal interviews based on three problem-based situations presented in a narrative-style picture book, entitled *Treasure Hunt on a Deserted Island*. The findings suggest that the treasure hunt test is an effective tool for measuring pupils' technological creativity, for enhancing their motivation and ability to perform problem-solving tasks, and for understanding their cognitive processes of technological creativity. Moreover, the results from this study partly confirm past findings and partly open up a brand-new window for studying pupils' cognitive processes and the factors that influence problem solving in life-like situations involving technological creativity.

Creativity is jointly influenced by imagination, emotional traits and states, internal motivations, self-awareness, metacognition, insight, and domain knowledge; under no circumstances can any single factor be responsible for pupils' creative thoughts during the development of technological creativity. As creative ideas come to the forefront through a series of changes and associations that involve many different cognitive mechanisms, what seems certain is that it is difficult to discover and truly predict the underpinnings of the development of technological creativity.

References

Amabile, T. M. (1996). *Creativity in context*. Boulder, CO: Westview.

Amabile, T. M. (1997). Entrepreneurial creativity through motivational synergy. *Journal of Creativity Behavior, 31,* 18–26.

Amabile, T. M., Conti, R., Lazenby, J., & Herron, M. (1996). Assessing the work environment for creativity. *Academy of Management Journal, 39,* 1154–1184.

Ashby, E. G., Isen, A. M., & Turken, A. U. (1999). A neuropsychological theory of a positive affect and its influence on cognition. *Psychological Review, 106,* 529–550.

Aspinwall, L. G.., & Taylor, S. E. (1997). A stitch in time: Self-regulation and proactive coping. *Psychological Bulletin, 121,* 417–436.

Berardi-Coletta, B., Dominowski, R. L., Buyer, L. S., & Rellinger, E. R. (1995). Metacognition and problem-solving: A process-oriented approach. *Journal of Educational Psychology, 21,* 205–203.

Bowers, K. S., Regher, G., Balthazard, C., & Parker, K. (1990). Intuition in the content of discovery. *Cognitive Psychology, 22,* 72–110.

Cheng, F. Y. (2004). *The relationships among pupils' explanatory style, domain knowledge, creative life experience and their technological creativity.* Unpublished thesis, National Sun-yat Sen University, Kaohsiung, Taiwan.

Cheng, S. K. (1999). East-west difference in views on creativity: Is Howard Gardner correct? Yes and no. *Journal of Creative Behavior, 33,* 112–125.

Csikszentmihalyi, M. (1996). *Creativity.* New York: Harper Collins.

Donnelly, B. (1994). Creativity in the workplace. *The Journal of Technology Studies, 20*(2), 4–8.

Dunbar, K. (1997). How scientists think: On-line creativity and conceptual change in science. In T. B. Ward, S. M. Smith, & J. Vaid (Eds.), *Creative thought: An investigation of conceptual structures and processes* (pp. 461–493). Washington, DC: American Psychological Association.

Estrada, C., Isen, A. M., & Young, M. (1997). Positive affect facilitates the integration of information and decreases anchoring in reasoning among physicians. *Organizational Behavior and Human Decision Processes, 72,* 117–135.

Feldhusen, J. F. (1995). Creativity: A knowledge base, metacognitive skill, and personality factors. *Journal of Creative Behavior, 29,* 255–268.

Frijda, N. H. (1988). The laws of emotion. *American Psychologist, 43,* 349–358.

George, J. M., & Brief, A. P. (1996). Motivational agendas in the workplace: The effects of feelings on focus of attention and work motivation. *Research in Organizational Behavior, 18,* 75–109.

George, J. M., & Zhou, J. (2002). When bad moods foster creativity and good ones don't: The role of context and clarity of feelings. *Journal of Applied Psychology, 87,* 687–697.

Greenfield, P. M., & Beagles-Roos, J. (1988). Radio vs. television: Their cognitive impact on children of different socioeconomic and ethic groups. *Journal of Communication, 38,* 71–92.

Harrison, L. F., & Williams, T. M. (1986). Television and cognitive development. In T. M. Williams (Ed.), *The impact of television: A natural experiment in three communities* (pp. 87–142). San Diego, CA: Academic Press.

Hirt, E. R., Melton, R. J., McDonald, H. E., & Harackiewicz, J. M. (1996). Processing goals, task interest, and the mood–performance relationship: A mediational analysis. *Journal of Personality and Social Psychology, 71,* 245–261.

Isen, A. M. (1999). On the relationship between affect and creative problem-solving. In S. Russ (Ed.), *Affect, creative experience, and psychological adjustment* (pp. 3–17). Philadelphia: Taylor & Francis.

Isen, A. M. (2002a). A role for neuropsychology in understanding the facilitating influence of positive affect on social behavior and cognitive processes. In C. R. Snyder & S. J. Lopez (Eds.), *Handbook of positive psychology* (pp. 528–540). New York: Oxford University Press.

Isen, A. M. (2002b). Missing in action in the AIM: Positive affect's facilitation of cognitive flexibility, innovation, and problem-solving. *Psychological Inquiry, 13,* 57–65.

Isen, A. M. (2003). Positive affect as a source of human strength. In L. G. Aspinwall & U. M. Staudinger (Eds.), *A psychology of human strengths: Fundamental questions and future directions for a positive psychology* (pp. 179–195). Washington, DC: American Psychological Association.

Kaufmann, G., & Vosburg, S. K. (1997). "Paradoxical" mood effects on creative problem-solving. *Cognition & Emotion, 11,* 151–170.

Kaugars, A. S., & Russ, S. W. (2000). Emotion in children's play and creative problem-solving. *Creativity Research Journal, 13,* 211–219.

Lee, A., & Sternthal, B. (1999). The effects of positive mood on memory. *Journal of Consumer Research, 26,* 115–127.

Lubart, T. I., & Getz, I. (1997). Emotion, metaphor, and the creative process. *Creativity Research Journal, 10,* 285–301.

Martin, L. L., & Stoner, P. (1996). Mood as input: What we think about how we feel determined how we think. In L. L. Martin & A. Tesser (Eds.), *Striving and feeling: Interactions among goals, affect, and self-regulation* (pp. 279–301). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Mayer, R. E.(1999). Fifty years of creativity research. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 449–460). New York: Cambridge University Press.

Mellou, E. (1996). The two-conditions view of creativity. *Journal of Creative Behavior, 30,* 126–149.

Michel, M., & Dudek, S. Z. (1991). Mother-child relationship and creativity. *Creativity Research Journal, 4,* 281–286.

Mokhtari, K., & Reichard, C. A. (2002). Assessing students' metacognitive awareness of reading strategies. *Journal of Educational Psychology, 94,* 249–259.

Murray, N., Sujan, H., Hirt, E. R., & Sujan, M. (1999). The influence of mood on categorization: a cognitive flexibility interpretation. *Journal of Personality and Social Psychology, 59,* 411–425.

Nakamura, J., & Csikszentmihalyi, M. (2003). The motivational sources of creativity as viewed from the paradigm of positive psychology. In L. Aspinwall & U. M. Staudinger (Eds), *A psychology of human strengths: Fundamental questions and future directions for a positive psychology* (pp. 257–269). Washington, DC: American Psychological Association.

Nolen-Hoeksema, S., & Girgus, J. S. (1995). Explanatory style and achievement, depression, and gender difference in childhood and early adolescence. In G. M. Buchanan & M. E. P. Seligman (Eds.), *Explanatory style* (pp. 57–70). Hillsdale, NJ: Lawrence Erlbaum associates, Inc.

Oldham, G. R., & Cummings, A. (1996). Employee creativity: Personal and contextual factors at work. *Academy of Management Journal, 39,* 607–634.

Rubenstein, R. J. (2000). Stimulating children's creativity and curiosity: Does /??Do??content and medium matter? *Journal of Creative Behavior, 34,* 1–17.

Runco, M. A. (1996). Personal creativity: Definition and developmental issues. *New Directions for Child Development, 72,* 3–30.

Runco, M. A., Nemiro, J., & Walberg, H. J. (1998). Personal explicit theories of creativity. *Journal of Creative Behavior, 32,* 1–17.

Segal, E. (2004). Incubation in insight problem-solving. *Creativity Research Journal, 16,* 141–148.

Siau, K. L. (1995). Group creativity and technology. *Journal of Creative Behavior, 29,* 201–216.

Simonton, D. K. (1995). Foresight in insight? A Darwinan answer. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 465–494). Cambridge, MA: MIT.

Simonton, D. K. (2000). Creativity: Cognition, personal, developmental, and social aspects. *American Psychologist, 55,* 151–158.

Simonton, D. K. (2003). Scientific creativity as constrained stochastic behavior: The integration of product, person, and process perspectives. *Psychological Bulletin, 129,* 475–494.

Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 3–15). New York: Cambridge University Press.

Torrance, E. P. (1967). Scientific view of creativity and factors affecting its growth. In J. Kagan (Ed.), *Creativity and learning* (pp. 73–91). Boston: Houghton Mifflin.

Valkenburg, P. M., & Voort, T. H. A. (1994). Influence of TV on daydreaming and creative imagination: A review of research. *Psychological Bulletin, 116,* 316–339.

Ward, T. B., Smith, R. A., & Finke, R. A. (1999). Creative Cognition. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 189–212). New York: Cambridge University Press.

Yaniv, I., & Meyer, D. E. (1987). Activation and metacognition of inaccessible stored information: Potential bases of incubation effects in problem-solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 187–205.

Yeh, Y. C. (2003). *The development of pupils' technological creativity and the dynamic relationships among its influential ecological systems.* Project report of the National Science Council, Taiwan (NSC 91–2522-S-110-004).

Yeh, Y. C. (2004). The interactive influences of three ecological systems on R & D personnel's technological creativity. *Creativity Research Journal, 16,* 11–25.

Appendix
Interview Questions

1. Do you think the problem-solving tasks in the "Treasure Hunt" were interesting? Why? Why not?
2. Do you think the problem-solving tasks in the "Treasure Hunt" were difficult? Why? Why not?
3. Would you like to to have your school tests to be like the "Treasure Hunt"? Why? Why not?
4. How would you describe your emotions most of the time—for example, glad, angry, sad, or happy?
5. What was your emotional state when you were answering the questions? Were there any special feelings? Were you nervous?
6. Would you say you were answering the questions seriously?
7. Do you think you answered the questions well? Why? Why not?
8. Which part of the test do you think was the most difficult?
9. Do you know how you solved the problems? Can you describe your problem-solving processes?
10. Where did you get the ideas for the solutions? Did you hear or learn the ideas from somewhere, or did you invent them by yourself?
11. Do you frequently come up with some exciting ideas in your Nature class? Where did these ideas come from?
12. Have you ever been on a camping trip?
13. Do you frequently come up with some novel ideas? How would you score yourself on such an ability from 1 point to 5 points?
14. Would you like to try to turn these novel ideas into some useful products? How would you score yourself from 1 point to 5 points on such an ability?