DOES CREATIVITY CONTRIBUTE TOWARDS SUCCESS IN PERFORMANCE OF OPEN-ENDED SCIENCE INVESTIGATIONS?

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Abstract: The study explores the relationship between creative thinking ability and the performance of open-ended science laboratory investigations in secondary school female pupils aged 13 to 14 years old. Toh (1990) has found that open-ended science investigations consisted of six distinct components: preliminary trials, planning, performing, communicating, interpreting and feedback. The paper looks into the correlation of creative thinking ability and the six components as well as the performance of whole investigations. Analysis of results reveals a significant correlation between creative thinking ability and four of the six components: planning, performing, communicating and interpreting. The study, however, finds no significant correlation between creative thinking ability and the performance of whole investigations. These findings have important implications for teachers who planned on using open-ended laboratory investigations as a strategy to achieve creativity in the laboratory.

Introduction

The call for developing creative thinking ability in pupils has prompted educators, including those involved in science education, to seek new strategies that could involve this higher-order thinking skill. Science as a subject taught in schools in Singapore, as in many other parts of the world, has two major components. One component is classroom-based theory lessons and the other is laboratory-based. The strategies that are employed in the classrooms and the possible gains that can be derived from them are well-documented (Marzano et al. 1988; Swartz and Parks, 1994). On the other hand, when the laboratory-based component is examined, the number of studies that looked into how it involves creative thinking is far less in comparison. This despite many claims that one of the higher goals of laboratory work is the development of creative thinking ability (Hegarty-Hazel, 1990; Hofstein and Wahlberg, 1995; Gangoli, 1995). Not all laboratory work can enhance such thinking ability. Many laboratory activities are designed simply to demonstrate and verify some physical principle, or to determine the value of some constant. Such activities often require pupils to follow recipe-like instructions (Clackson and Wright, 1992).

From the review of literature on creativity, two important strategies are often mentioned in approaches to developing creativity, "problem-solving" and "open-endedness". Moravcsik (1981) has suggested using open-ended experimental-based problems to promote creative thinking in pupils.

Woolnough and Allsop (1985) concur with this view when they wrote:

> The quality of work done by students when their investigations are based on their own open-ended problems is significantly greater…Such investigations are to encourage and develop in the students different and often unexpected talents of originality, creativity, independence…
>
> (Page 53)

Creative Thinking Ability

Creativity can be defined by looking at four major aspects: creative personality traits, creative products, creative process, and the creative press or supporting environment (Soh, 1997). Davis and Rimm's (1982) definition of creativity is based on the characteristics or personality traits of individuals. It is used in this study because the instrument employed in this study, How Do You Think Inventory (Form E), designed by Davis (1975), is based on attitudes, motivation, interest, values, and other biological characteristics of an individual. The creative person is assumed to be of above average in spontaneity and willing to take risk and make mistakes. At the same time, they are playful and have a sense of humour. They are also open to new ideas and experiences, and have both artistic and aesthetic interest. The researchers also cited traits that are deemed as *not* being creative, for example, "neat", "well-ordered", "predictable" and "value others' opinion".

Open-ended Science Investigations

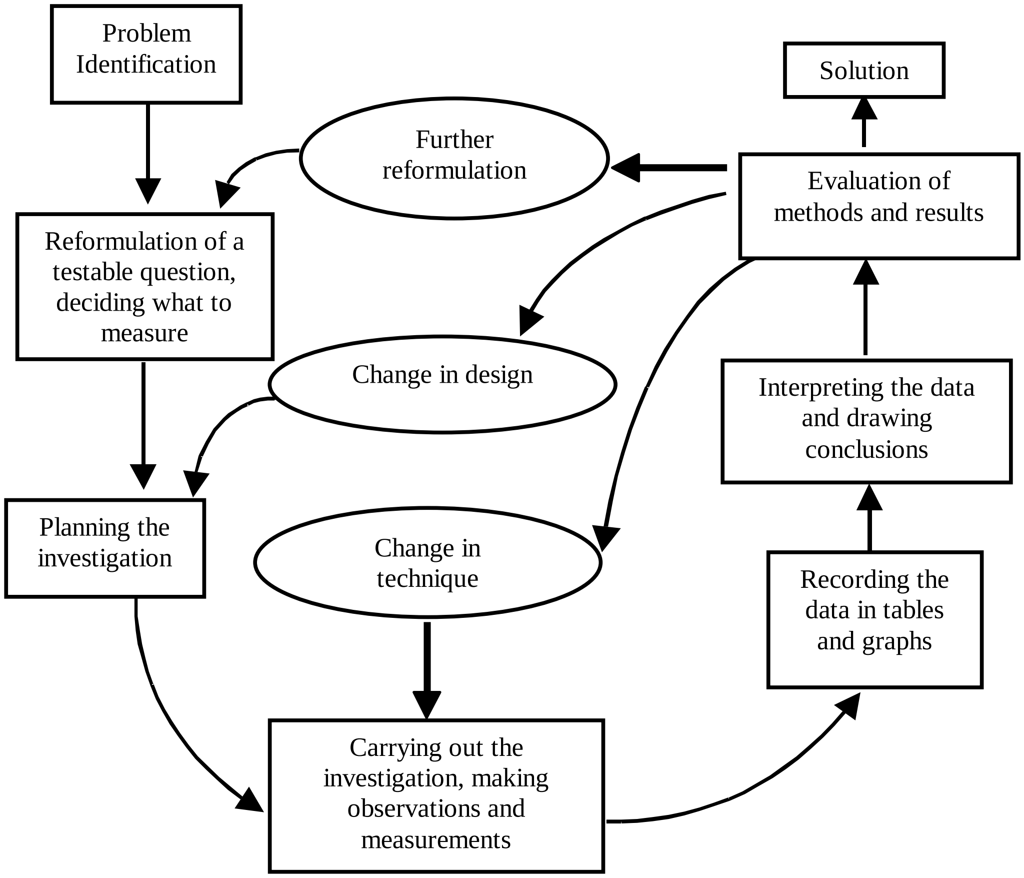
Distilling from numerous studies, Toh (1990) came to a conclusion that there are six components in any open-ended science investigation. The six components, and the skills identified with each of them, are summarised in Table 1. Lock (1989) and Toh (1990), in their separate investigations, found very low inter-correlation values between these components. So, they concluded that the components must be distinct.

Table 1: Components of Science Investigations and their Skills (Toh, 1990)

Processes	Skills Identified
Preliminary Trials	Problem formulation
Planning	Planning and designing procedures
	Controlling variable
	Quality of experimentation
Performing	Setting up
	Manipulating apparatus
	Carrying out
	Observing
	Measuring
	Repeating of measurements
Communicating	Reporting
	Recording of results
Interpreting	Interpreting
	Analysing
	Drawing conclusions
	Discussing results
Feedback	Further reformulation

The Assessment of Performance Unit (APU) in UK incorporates all six components in their model of investigative work (Figure 1). The important feature of the model is the "iterative approach" in reaching a final solution. This means the investigator can choose to go through various cycles or loops of evaluations, and modifications to the initial strategy, before the task is completed. Kimbell (1991) believes that by *not* imposing a degree of rigidity or order in the search of a solution, the model allows the creative process to be exercised.

Figure 1: The APU Problem-solving Model (DES, 1987)



Methodology

Sample

The sample comprises of 114 female pupils, aged 13 to 14 years old, and randomly selected from two schools. They were in secondary two at the time of the study. The pupils have been exposed to five years of formal science education, four years in primary school and a year in the lower secondary level. Very simple practical tasks are carried out at primary level but at lower secondary level, the pupils learned more substantially process skills like taking measurements and making observations. Most of their laboratory investigations are the traditional teacher-directed approach type that gives detailed instructions (Yeo, 1991; Yap 1994).

Instrumentation

Creative thinking ability of the pupils is measured using the How Do You Think (HDYT) Inventory (Revised Form E) designed by Davis (1975). This was originally a 100-item test with respondents providing feedback on a five-point Likert scale. Form E of the HDYT inventory is derived from a Form B, which was reported to have a relatively high reliability coefficient of 0.933. In a study, the HDYT scores of a sample were correlated with creativity ratings given to their project work. The correlation was found to be 0.42 ($p < 0.01$). According to Davis (1975), this is quite reasonable considering the large number of factors influencing test and criterion scores in measurements of creativity. The Revised Form E was re-validated by Teo and Quah (1997) for use in the Singapore context. It consisted of 96 items; four items not applicable to the Singapore context were discarded and another two were modified to suit the local culture.

Two open-ended investigations are used in this study: "Sticky-tape" and "Candle". The two selected tasks were devised and validated by the APU and Lock (1986) respectively. Toh (1990), for his own study, also validated the two tasks for use in the Singapore context. The coverage of the two investigative tasks is summarised in Table 2 shown below.

Table 2: Summary of Investigative Tasks

Task	Independent variable	Dependent variable	Nature of Problem
Sticky-tape	Type of tape	Force to pull tape off	To determine the minimum force required to pull the tape off the surface.
Candle	Size of container	Time candle burns	To time the duration a candle takes to burn in a confined space

The pupils' performance in each task is measured using the Self-Report Sheet (SRS) devised by Toh (1990). The SRS was reported to have a relatively high inter-rater reliability of 0.943 ($p < 0.01$). The instrument measures individually all six components and the composite score determines the performance of whole investigations. The SRS are marked using the scoring rubrics devised by Toh (1990) for both tasks.

Findings and Discussion

Performance of Open-ended Investigations

Table 3 gives a summary of the performance for the sample in both investigations. The most common score (mode) for the Candle task is 11, and 38.6% of the sample has this score. In fact, a total of 73.6% obtained scores between 10 and 12 (inclusive). For the Sticky-tape investigation, the mode is 9 and 24.6% has this score. A total of 80.7% has scores between 8 and 12 (inclusive).

Table 4 gives a summary of performance in the six components for both tasks. To compare the performance between different components, the relative performance value is used. This value is obtained by dividing the mean score for the particular component with its maximum achievable score.

Table 3: Performance of Candle and Sticky-tape tasks

Investigation:	Candle	Sticky-tape
Total number (N)	114	114
Mean	10.74	10.05
Standard Deviation	1.53	1.92
Variance	2.38	2.73
Mode	11	9
Minimum, Maximum marks	5, 14	6, 14
Range	9	8

Table 4: Summary of the Performance in the Components

Process skills	Mode	Mean (8) (N = 114)	Standard Deviation	Maximum score	Mean scores (8) Maximum score
Preliminary Trials	1	0.79	0.38	1	0.79
Planning	3	2.80	0.79	5	0.56
Performing	3	2.50	0.61	3	0.83
Communicating	2	1.79	0.63	3	0.59
Interpreting	2	1.62	0.64	2	0.81
Feedback	1	0.98	0.64	2	0.49

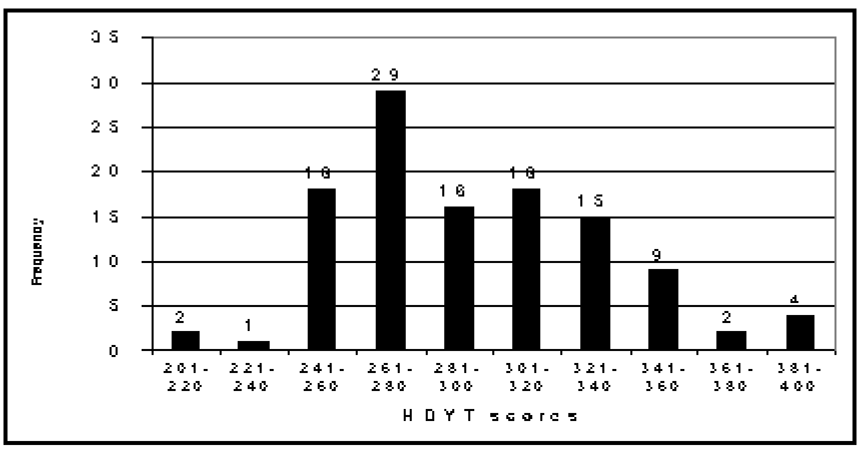
Comparing the six components, the pupils in the sample have done well in preliminary trials and are proficient in skills required in the interpreting and performing components. In the other three components, communicating, planning and feedback, the relative performance values are relatively lower, with the lowest value given by the feedback component.

Creative Thinking Ability

Figure 2 shows the distribution of the HDYT scores for the study sample.

The mean score obtained from the study sample is 294.1 with a standard deviation of 38.2. Most pupils (84.2%) scored between 241 and 340 with 53.5% of the study sample scoring above the mid-point of 288.

Figure 2: Distribution of the HDYT scores in the Study sample



Correlation between Creative Thinking Ability and the Performance of Open-ended Investigations

The Pearson product-moment correlation coefficient obtained is only 0.064, indicating that the two variables have very negligible correlation.

Correlation between Creative Thinking Ability and the Six Components

Table 5 summarises the correlation results of creative thinking ability with the six components.

Table 5: Creative Thinking Ability and the Six Components

Types of correlation	Component	Pearson's Correlation Coefficient
Positive	Planning	0.35*
	Communicating	0.23*
Negative	Performing	- 0.28*
	Interpreting	- 0.27*
Zero	Preliminary Trials	0.055
	Feedback	0.098

* significant at the 0.01 level (2-tailed)

The results of this study, which show performance of open-ended investigations is not significantly correlated with creative thinking ability, seem to be against the popular notion that open-ended questions involve creative thinking, thus creative individuals should show better performance in open-ended investigations.

On closer examination of the results, several observations can be drawn to account for these results. As stated earlier (see Table 4), the planning and communicating components have not been carried out as well as the performing and interpreting components. As shown in Table 5, both planning and communicating components are found to have correlated positively with creative thinking ability. Had the pupils performed *better* in them, compared to performing and interpreting, the whole investigation scores would have positively correlated with creative thinking ability. According to Hackling and Garnett (1992) the response to laboratory investigations shown by pupils is a reflection of the style of laboratory work to which the pupils have been exposed. Of the two components, planning is often missing in the traditional laboratory approach. Moreover, in most cases, pupils are often guided on how to communicate their results such as by providing ready-made tables that contained the investigated variables.

The pupils in the sample seemed to have done better in the performing and interpreting components because both are often heavily emphasised in the traditional laboratory approach. The fact that they are negatively correlated with creative thinking ability can be explained. The performing component calls for the individual to operate or use the apparatus and materials in a standard way, and at the same time, to take precautionary measures to ensure the accuracy of data. There is a need to stay focus and to be on task so that a complete set of readings can be obtained. Creative individuals are presumably more off-task because of their greater curiosity and tendency to take risk. As for the interpreting component, it requires cognitive skills that are convergent rather than divergent. The latter is often associated with the creative thinking process and has been identified as a strategy that creative individuals often used for problem solving (Sternberg and Lubart, 1993). The divergent thinking approach, however, may not lead to success in the interpreting component; on the other hand, it may actually lower its performance, as Toth and Baker (1990) have observed, "creative ability may impede convergent thinking through the excessive production of ideas".

Conclusion

Getting pupils to plan, perform and interpret their own experiments represents a substantial break from the more traditional teacher directed approach to practical work. The question of whether creativity can contribute towards success in the performance of open-ended science investigation really depends on the pupils' exposure to such laboratory work. This exploratory study implies that there is a need to move away from the teacher directed approach if open-ended investigations are to be used in encouraging creative thinking in the laboratory. If the open-ended investigation approach is to be employed, then competence in the skills used in two components, planning and communicating, should be taught and developed in pupils. This could involve the teaching of strategies in problem-identification and problem-formulation, as well as cognitive skills like mind mapping and brainstorming. As for the communicating component, the skills to be taught may include tabulation and graphical presentation of results. The conclusions drawn from the study are important considerations in the design and planning of learning experiences and teaching interventions, both by teachers and curriculum developers, as well as those who are responsible for the organisation of science education in schools.

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