What could contribute to science learning that can make students think/perform more creatively

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Introduction

During the process of teaching Science, as science teachers, we are interested in two aspects, namely:

> how much scientific knowledge and skills students have learnt (quantitative aspect); and
>
> to what extent students are able to apply the knowledge and skills to solve scientific problems (qualitative aspect).

In this paper, we would like to focus only on the qualitative aspect of learning outcomes. In this instance one is particularly keen to know whether students can create their own problem-solving skills based on the scientific knowledge and skills learnt. This creation of one's own way, we believe, has something to do with the training of creativity in thinking/performing in science. Since creativity in thinking/performing is content related (Edwards, 1987), we also believe that a good knowledge in science content will lay the foundation for the development of such creativity. Based on the above arguments,

a small scale research comprising three case studies was conducted to find out what could contribute to the teaching and hence student's learning of science which make the latter think/perform more creatively.

Purpose of the Study

The study was aimed at:

developing instructions and teaching strategies by:

(a) focussing on creative methods of teaching science.

(b) placing emphasis on teaching science for creativity through group setting, project work and problem-solving process.

(c) incorporating learning strategies into the science curriculum.

examining the relative effects on students' performances in science for students who go through the treatment using the mentioned teaching units versus students who learn the same concepts and skills through traditional modes of lesson delivery.

Assumptions and Conditions

For the research considered here, the following assumptions and limitations apply:

There are different versions to define "creativity".

The one adopted for this study is that given by Torrance (1978), viz.:
"the process of sensing gaps or disturbing missing elements: forming ideas or hypotheses, and communicating the results, possibly modifying and restating the hypotheses".

The advantage of accepting this definition of creativity is that it becomes possible to recognise creative thinking abilities and creative potential both through test and non-test procedures.

Creativity is generally perceived in two ways: some view it as the production of a new entity or idea unknown to man. Others have a more inclusive definition comprising all creative abilities, such as flexibility, fluency, originality, elaboration and sensitivity.

Based on the context of Singapore, the following student characteristics are identified for this study as conforming to creative practices in science:

(a) alert during the process of learning.

(b) practising reflective thinking.

(c) searching for personal solutions(s) to problems.

(d) willing to share ideas with others.

* Learning strategies are behaviours and thoughts that a learner engages in during learning and that are intended to influence the learner's encoding process (Weinstein and Mayer, 1985).

* The experimental design is as follows:

(a) The study involves both experimental and control groups.

(b) The subjects for these studies are randomly selected.

(c) Pre and post tests are conducted before and after the treatment respectively.

(d) The duration for the study is 6 weeks. At the secondary level, there are 4 periods (4 x 30 minutes) of science per week (for case studies A and C). At the junior college level, there are 2 periods (2 x 45 minutes) of tutorial sessions and 3 hours practical work per week (for case study B).

(e) Since the study involves experimental and control groups, the measurement of the outcomes of the treatment is confined to the usual way of test setting in the classroom. In this instance, achievement tests are used. Other types of assessment modes are also implemented for other purposes, but will not be taken up in this paper.

Method

- Sample

Six groups of students from two secondary schools and one junior college were involved in the study. Some details of the sample are set out below:

Case Study	A	B	C
School	A	B	C
Instruction incorporated with	Creative Science teaching approach	Teaching science for creativity	Learning strategies in science
No. of students involved	33 (EG)* 40 (CG)*	44 (EG)* 40 (CG)*	40 (EG)* 39 (CG)*
Level of students	Secondary three	Pre-University one	Secondary four
Topics	° Measurement of length, area volume and time ° Mechanics: Newton's Laws of Motion, Moments of a Force, and Pressure	° Errors ° Vectors ° Kinematics	° Chemistry of nitrogen

EG : Experimental group
CG : Control group

- Instruction and Treatment

A brief summary of treatment provided to different groups of students is given below:

(A) Case study A : Instruction Based on Creative Teaching.

This study focuses on creative teaching in science. The teacher involved in the treatment group was expected to demonstrate the characteristics of a creative teacher such as:

- innovative and imaginative use of teaching materials and strategies.

- flexibility to adjusting herself to varied students' background and to maintain students' interest and enjoyment of the lessons.

- empathy with students' learning difficulty.

In order to ensure a high degree of student involvement in particpation and practice of creative thinking skills, the teacher was also expected to create a conducive climate and environment for learning science.

The design of the teaching package was based upon the basic process of planning, inducting, communicating, managing and evaluating. Except for the content which was pre-determined by the school, the selection of the materials, media and methodology was made so as to achieve a creative style of delivery.

(B) Case study B : Instruction Based on Teaching Science for Creativity.

In this study, the teacher stimulated students to develop their own creativity through group setting, project work and problem-solving process.

More importantly, the teacher established a creative environment to facilitate:

- free expression and exchange of ideas,
- learning through discovery and divergent thinking.

The design of this teaching package was also based upon the basic processes of planning, inducting, communicating, managing and evaluating as mentioned in case study A. In almost all the processes, students were placed in a student-centred learning environment. For example, in the process of evaluating, the encouragement of pupil self-evaluation (such as checking one's work and providing explanations to justify one's actions during the learning process) was employed.

Under group setting, pair work dominated about 50% of the time. Because of students' maturity they were allowed to choose their own partners, whom they felt comfortable to work with.

In the implementation stage, the teacher tried her best to ensure that her roles were in line with those characterised in the different phases of the creative process.

(C) Case study C : Use of Learning Strategies in Chemistry Teaching.

Learning strategies selected for use in this study were: identifying key concepts, concept mapping, visual aids, establishing learning goals and reflecting. Lessons were planned in such a way that these strategies were incorporated into the teaching procedure. Whenever possible during lesson presentation the teacher let her students know the particular strategy she uses. The students were also encouraged to learn to use the strategy to help them internalise. The lessons were structured in such a way that the students were trained in the use of learning strategies through:

- examples used and demonstrated by the teacher during lesson presentation.

- their active participation in using a particular strategy as encouraged by the teacher.

In other words, the teacher set the example for students to learn and use the strategies.

Results and Discussion

The data used to evaluate the effectiveness of the treatment in the different case studies were obtained from tests administered to students of the respective experimental and control groups.

(A) Case study A : Instruction Based on Creative Science Teaching.

Since pre test and post test scores of each student were obtained, analysis using matched-samples was carried out. Table 1 below shows the results for studentised t-test.

Table 1 **Comparison of pre and post test scores**

	$\overline{D}$	$S\{\overline{D}\}$	t
Experimental Group (N=33)	51.5	12.5	4.1 ($p < 0.001$)
Control Group (N=40)	36.7	16.9	2.2 ($p < 0.05$)

* Maximum mark for both tests = 100

D = Difference between mean score of pre test and that of post test for each pair.

$\overline{D}$ = Average of D values

$S\{\overline{D}\}$ = Standard deviation of the average difference (D) between each pair of scores.

Comparing the t-values for the experimental group with that of the control group in their pre and post test scores, it is found that both were statistically significant.

But the higher t-value for the experimental group seems to suggest that this group demonstrated a better improvement than the control group. This argument is further supported by the findings (Table 2) that:

- initially, the control group was already significantly better than the experimental group based on their performance in the pre test; and

- the post test results for both groups showed an insignificant difference in their performance.

Table 2 **Comparison of mean test scores of Experimental N=33) and Control (N=40) groups**

Group / Test	Experimental Group ($\overline{X}p$)	Control Group ($\overline{X}c$)	$S\{\overline{X}p-\overline{X}c\}$	t
Pre test	14.8	52.5	10.4	-3.6 ($p < 0.001$)
Post test	66.3	89.2	19.2	-1.2 ($p > 0.20$)

$\overline{X}p$ = Mean score (of pre/post test) of the experimental group

$\overline{X}c$ = Mean score (of pre/post test) of the control group

Hence one could conclude that this creative approach to teach science has a positive influence on the performance of the students.

In this study, a questionnaire (5-point Likert scale) was administered to the experimental group to evaluate the teacher's performance. The items listed in the questionnaire were closely related to the characteristics of a creative teacher. The results of this questionnaire showed that students were in general agreed that the teacher who conducted the study possess characteristics of a creative teacher. They also indicated favourably that such approach made learning science more fun.

(B) Case study B : Instruction Based on Teaching Science for Creativity.

The results for the pre and post tests of the experimental and control groups are shown in Table 3.

Table 3 **Comparison of mean test scores of Experimental (N=44) and Control (N=40) groups**

Group / Test	Experimental Group ($\bar{X}p$)	Control Group ($\bar{X}c$)	$S\{\bar{X}p-\bar{X}c\}$	t
Pre test	31.3	30.7	6.5	0.092 (p >>0.05)
Post test	35.3	34.3	15.8	0.068 (p >>0.05)

* Maximum mark for the test was 50

The t-value of the pre test indicates that the entry levels of both experimental and control groups were not significantly different.

Furthermore, the t-value of the post tests also shows that there was no significant difference between the achievements of the experimental and control groups. This would suggest that the effectiveness of this instruction is not conclusive.

This is further supported by the results shown in Table 4. It is because by comparing the t-values for the experimental group with that of the control group in their pre and posttest scores, it is clear that both are statistically significant.

Table 4 **Comparison of pre and post test scores**

	$\bar{D}$	$S\{\bar{D}\}$	t
Experimental Group (N=44)	4.0	1.1	3.6 ($p < 0.001$)
Control Group (N=40)	3.6	1.2	3.0 ($p < 0.01$)

The students' responses to the Perceptions Questionnaire indicated that most of them enjoyed working in pairs/groups and that they could learn more from each other through a mutual exchange of ideas. However, the interviews and observations with the control group revealed that there was more student frustration in an individualized environment.

(C) Case study C : Instruction Based on Learning Strategies in Science.

Again, the matched-samples method was used to examine the effectiveness of the treatment in this case study. Table 5 shows the results of the analysis.

Table 5 **Comparison of the mean scores of pre and post tests**

	$\overline{D}$	$S\{\overline{D}\}$	t
Experimental Group (N=40)	25.2	2.9	8.7 (p << 0.001)
Control Group (N=39)	14.2	10.1	1.4 (p >> 0.05)

* Maximum mark for the test = 100

From the t-values for both groups shown, one could say that there was a significant difference in the results of the pre and post tests for the experimental group but not for the control group.

This leads one to believe that instruction is instrumental in improving students' achievement. This is further supported by the results in Table 6.

Table 6 **Comparison of mean test scores of Experimental (N=40) and Control (N=39) groups**

Group / Test	Experimental Group ($\overline{X}p$)	Control Group ($\overline{X}c$)	$S\{\overline{X}p-\overline{X}c\}$	t
Pre test	38.0	39.2	4.0	0.3 (p >>0.05)
Post test	65.2	53.4	2.4	4.9 (p <<0.001)

Discussion and Implications

1. It is interesting to note that young students are in general flexible to change. They can easily adopt new ways of teaching. Hence the change of teaching approach used is not a crucial problem for these students. On the part of students, it is a matter of whether they perceive learning to be interesting and enjoyable and whether they are satisfied with their progress. This could imply that well-structured lesson and quality science teaching are necessary to foster effective learning and will provide the necessary impetus for students to think/perform more creatively.

The experimental findings of case studies A and C reinforce the important role played by science teachers during the science lessons. In each case study, students were motivated and inspired by what teacher had demonstrated to them. They showed willingness to share and discuss as how teacher had done. Teacher, set herself to be a model, seems to have a deep influence in their learning and thinking behaviours.

2. The insignificant result shown by the case study B, which fostered creativity in science teaching, may indicate that at the higher level, the training of students on "thinking/performing more creatively in science" will encounter much more problems. Although students become more mature with age, they may be not mature correspondingly in their understanding of scientific concepts and skills. This has accordingly led to further support for our belief that the acquisition of fundamental scientific concepts and skills is the basic requirement for making thinking/performing in science more creative. Examining closely the answers of the test papers for both the experimental and control groups, we discover that a handful of students from the experimental group did provide encouraging, and exceptional good alternative solutions. This has led us to believe the efficacy of the experimental design of this study, although the outcome of this study is not conclusive. And this may also suggest that the treatment duration at the higher level should be longer if modifying behaviours would really be expected.

3. The finding of the case study B seems to contradict the study conducted by Foster and Penick (1985). Their study on 111 fifth and sixth grade students shows that small co-operative groups can be more creative than individuals working indepedently. And they concluded that in elementary science classes where creativity is one of the instructional objectives, co-operative groups and individual groups should be used. Although the discrepancy of the outcomes of these two studies could be due to different levels of the schools, i.e. in terms of the complexity of science at the higher level, we are more concerned with the difficulty in changing students' alternative framework as well as their learning behaviour. Could it imply that the fostering and the facilitating of creativity in science should begin at a younger age? This would require further investigation.

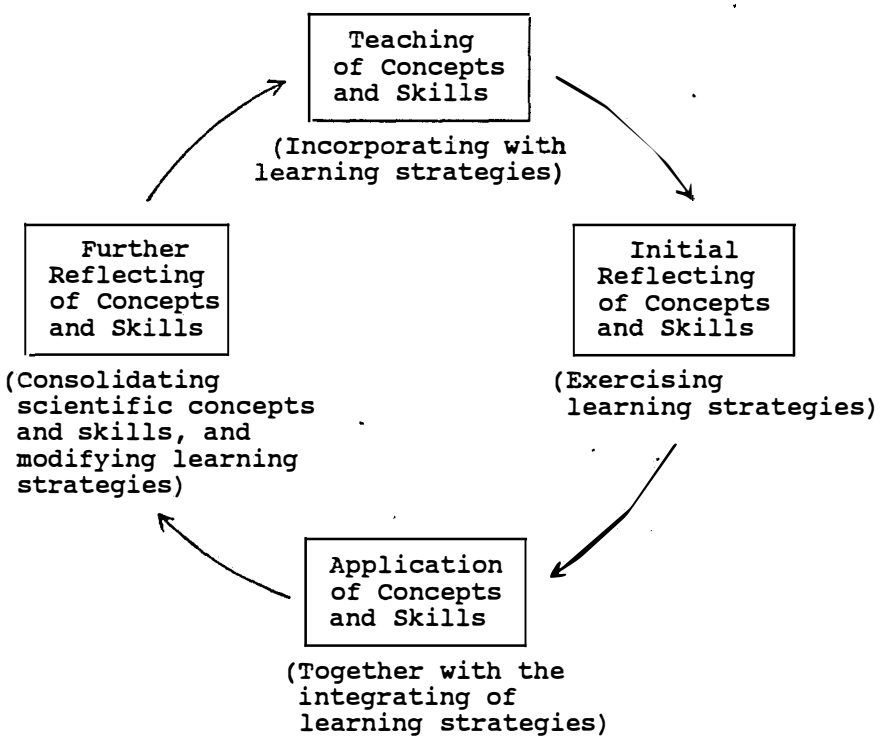
4. All the above observations collectively suggest the importance of the teacher role as a contributory factor for the success in training for creativity. This could have something to do with the uniqueness of the subject. Science for its nature is logical by itself. It embodies the knowledge and processes which are considered not ordinary common sense. At the lower level, science deals with the knowledge of matter and the skills of science processes, rather than philosophical

relationships. Furthermore, with the vast body of knowledge known as science, learning science will require a lot more effort if the knowledge needed to be learned has not been discriminately selected and well-structured. This distinct characteristic feature of science suggests that basically the learning of science relies very much on the teaching of science concepts and skills. And depending on how we teach, students will adjust themselves and learn accordingly.

Since reflective thinking is one of the components for creativity, specific skills on reflective thinking may need to be incorporated into the science curriculum if creative thinking/performing is to be promoted. These specific skills could be in the form of learning strategies. But it does not mean that such specific skills can be taught separately from the main body of knowledge and processes of science, and students can be expected to transfer such skills into learning science automatically and systematically. This view is well-supported by the research findings of Edwards (1987) that thinking skills have no direct correlation to the science achievement. It has to be integrated with the teaching of science. The teacher, as the role model, should constantly demonstrate and exercise all these skills during the process of teaching. And consequently students will directly or indirectly be affected by such

way of example and will see and be convinced that these specific skills are part of the knowledge and processes of science. If students are able to build upon such a foundation, their potential to think/perform creatively can be further developed and flourishing.

5. Based on the above three case studies, it is, of course, premature to make any conclusive generalization. However, arising from the above discussions, the instructional sequence to foster the creativity in science teaching and learning could be proposed as follows:



(a) The instructional sequence starts with teaching of concepts and skills by the teacher who will demonstrate how to acquire the scientific concepts and skills. The teacher will go through the process of demonstration/experimenting or questioning, etc., to stimulate students in recognizing the attributes of the scientific concepts. Certain learning strategies, such as concept mapping and process skills can also be incorporated into this process of teaching. At this stage, the teacher should dominate.

(b) After getting some knowledge and skills from the teacher, students should be provided with the opportunity to reflect the concepts and skills and to exercise the learning strategies. They will carry out certain simple tasks assigned by teacher, either as individual or group work (sharing experience). Tasks assigned could be in the form of experimenting, problem-solving or project work. We would expect that at this stage students are dominating in the process of learning.

(c) After this initial reflecting of concepts and skills, we have to place students at the new situation and show them how to apply the concepts and specific skills learnt to solve some new problems set. Here, the teacher should be more active.

(d) As students carry out the new tasks assigned through the use of experiments, problem-solving or project work, etc., they are in fact provided with opportunity for further reflecting of concepts and skills by re-examining the relationship of scientific knowledge and skills. This additional reflection on the concepts and skills would help improve learning strategies as well. Hence, on an overall basis, this will facilitate the learning of new concepts and skills.

The present model stresses very much on the role of teacher. We believe strongly that, especially at the stage of 'application of concepts and skills', teacher may need at times, to demonstrate her creative way of applying concepts and skills to solve problems. By doing so, the aim of making students think/perform more creatively could be enhanced.

6. The arguments we have put forward up-to-now might have given the impression that creative thinking/performing in science can definitely be trained and improved. However, teaching and learning of science is a complicated process. Other factors (e.g. school setting, students' learning ability, teacher's perceptions) will also affect the outcomes of learning. Hence, the extent of improvement in creative thinking/performing in science is likely to vary from student to student.

Conclusion

In this paper, three case studies and their findings have been briefly described and discussed. For the time being we may conclude that the essential ingredients for fostering the creative thinking/performing in science in schools are as follows:

- the teacher needs to demonstrate her mastery of scientific concepts and skills;

- specific skills, such as learning strategies and thinking skills, have to be integrated into the science curriculum;

- the instructional design should provide students with the opportunity to:
  - be more open-minded.
  - share ideas.
  - be more reflective.

In the process of fostering 'creativity' in learning science, individual difference should also be taken into account, and hence specific skills and instructional design must be adjusted accordingly.

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