Science Education International
Vol. 16, No. 4, December 2005, pp. 281-289

International Council of Associations in Science Education

The Influence of Social Issue-Based Science Teaching on Students' Creative Thinking

ANNE LAIUS (anne.laius@ut.ee) and MIIA RANNIKMÄE (miia@ut.ee)
University of Tartu, Estonia

ABSTRACT *The goal of the current research was to investigate how STL (Scientific and Technological Literacy) teaching in science classes influences ninth-grade students' creative thinking and to identify any hierarchical levels for a qualitative description of students' creative thinking development. STL is taken to mean developing the ability to creatively utilise sound science knowledge (and ways of working) in everyday life, to solve problems, make decisions and hence improve the quality of life. It recognizes four essential components of science education teaching – learning outcomes geared to cognitive development, utilising science method attributes, personal development, and social values. Eight teachers, one from each of 8 different Estonian schools involved in the study, were enrolled in an 8-month STL teaching in-service course and gained ownership of STL teaching approaches, measured in terms of their ability to create social-issue based teaching materials. During this course, the teachers developed collaboratively the teaching materials, based on STL scenarios, and their 80 students (ten average students – 5 male and 5 females, from a class of each of the eight teachers) were exposed to an 8-week STL teaching module that was scheduled by the end of the teachers' training course. For assessing students' creative thinking abilities, a discrepant event test was used before and after an 8-week STL teaching module, using three scales: asking questions, suggesting causes, and predicting consequences. Hierarchical cluster analysis was conducted across all pre- and post-test data of creative thinking, and led to the identification of three groups of students in terms of the quality of their creative thinking. The current study showed that although students' quantitative creative thinking abilities (fluency) increased significantly within the STL teaching environment, it was difficult to modify the quality of students' creative thinking abilities (flexibility, originality). Almost two thirds of the students did not upgrade their hierarchical level within any scale of creative thinking, but STL teaching intervention was still considered as an effective approach with significant impact on students' creative thinking.*

KEY WORDS: *Creative thinking, STL (Scientific and Technological Literacy), STL teaching.*

Introduction

Scientific and technological literacy has become increasingly a major goal for science education and the term expresses major purposes of general education, such as, achieving society's aspirations and developing individual understanding about science and technology (Fourez, 1997; Yager & Weld, 1999). The overlap between the aims of context-based and application-led courses with scientific and technological literacy courses, together with the approaches they advocate, makes it highly desirable to establish the strength and the nature of claims for evidence-based approaches. Most studies reported outcomes related to students' attitudes, understanding, skills and gender (EPPI review, 2003), but the current study focused on STL (scientific and technological literacy) that has been less common.

In the current study, STL is taken to mean developing the ability to creatively utilise sound science knowledge in everyday life to solve problems, make decisions, and hence improve the quality of life (Holbrook & Rannikmäe, 2002). The STL philosophy is based on three main tenets for science education: 1) science education is a part of general education; 2) science education should be approached from a societal perspective, and 3) science education needs to be based on constructivistic principles (Holbrook & Rannikmäe, 2001). STL within formal schooling can be defined as "that science education, which is intended, within the school curriculum, to maximize the role of science education in aiding students to acquire the goals of general education, as stipulated by the society within a country" (Holbrook, 2003).

The STL teaching materials that support these goals should meet the following criteria: 1) Education goals are stipulated and form the major focus of the material, i.e., students are participating in the process of educational learning appropriate for the goals of the country and their intellectual development; 2) material is societally related, i.e., students are familiar with the situation and can thus appreciate its relevance; 3) the material is a learning exercise, i.e., it provides an intellectual challenge and utilizes constructivist principles — moving from the existing information and understanding to new information and understanding among students; 4) the activity is student participatory, i.e., the student is actively involved either individually or in groups for a considerable amount of the teaching time; and 5) consideration is given to enhancing a wide range of communication skills (Holbrook & Rannikmäe, 1996). Based on STL philosophy, and in an attempt to maximise relevance for students, any teaching in STL begins from an issue or concern in society, usually in the form of an attractive scenario. In order to understand the issue or scenario from the scientific point of view, the students learn the relevant conceptual science. Utilising this acquired conceptual science, the issue can be revisited and socio-scientific decision-making can be justified. (Rannikmäe, 2001a). The difference between STL philosophy and quite similar STS (Science/Technology/Society) teaching approaches relates to the starting point of teaching science. STL begins with a societal issue and conceptual science is driven by society. In the case of STS, the societal interest is considered, when the scientific concept has been already acquired (Aikenhead, 1994). The methodology for STL teaching has been suggested by Holbrook and Rannikmäe (1997), and its effectiveness has been shown in problem-solving and decision-making areas (Rannikmäe, 2001b), but there is no evidence reflecting the influence of STL teaching on students' creative thinking.

The contemporary world of knowledge is characterized by an explosion of information and ways of communication that require creativity for handling the accumulated scientific knowledge. Thus, science education must encourage the development of creative thinking. But, as creativity is not something that can simply be taught, we must create the conditions for its development (Erez, 2004). Creative thinking is considered as an integral part of science and the scientific process as it is used in identifying problems and hypotheses, and in developing plans of actions (Hodson & Reid, 1988). Sternberg (1999) defined creative thinking as the kind of thinking that is novel and produces interesting and valuable ideas. Of the many different thinking skills required by students following a science and technology curriculum, creative-thinking skills are considered valuable and essential (Howard-Jones, 2002), and any teaching that encourages and rewards creative thinking can improve school performance (Sternberg, 2003).

As creative thinking is considered worthy of attention in education, it becomes useful to have an instrument for assessing levels of creativity that can be employed in science lessons (Hu & Adey, 2002) for measuring students' creativity. Torrance (1990) considered fluency, flexibility and original thinking as central features of creativity and the best-known test of general creativity is the Torrance Test of Creative Thinking. This is a paper-and-pencil test, which taps divergent thinking abilities. Items are scored for fluency, flexibility and original thinking. Fluency means the number of appropriate responses, flexibility is the ability to shift thinking rapidly and produce different types of responses. Originality is the departure from commonplace responses, and is interpreted as an answer that is rare, and occurs only occasionally in a given population.

The present study was designed to provide answers to the question: Does STL teaching support the development of students' creative thinking? More specifically, the current research attempted 1) to investigate how the STL teaching in science classes influences the quality of ninth-grade students' creative thinking; 2) to develop hierarchical levels for describing the qualitative aspects of the students' creative thinking abilities, and 3) to find out the main parameters that describe the change of students' creative thinking.

Methodology

The sample of the study consisted of 80 ninth-grade students in eight different Estonian schools. Eighty students were chosen for comparative analysis, ten average students from each class of every school (5 male and 5 female students according to their average achievement in the science disciplines). Teachers involved in the study (N=8) enrolled in an 8-month STL teaching in-service course and gained ownership of STL teaching approaches, measured in terms of the ability to create social issue-based teaching materials, accompanied with consequence maps, that highlight key factors and learning activities' consequences in the modified form of concept maps (Rannikmäe, 2001a).

During the 8-month (from October to May) in-service course, the teachers developed the STL teaching materials, and in March and April their students enrolled in an 8-week STL teaching module that differed from their regular classes by societal teaching approach and student-centered methologies (Rannikmäe & Laius, 2004). A discrepant event test was used before and after the 8-week STL teaching module to assess the students' creative-thinking skills, based on information presented in the Instrument's Package and User's Guide (1997). An event was proposed and was considered as a kind of discrepant event for all students: "*Imagine the situation on the Earth, if Mankind had not invented paper.*" The discrepant event test consists of three scales: asking questions, suggesting causes, and predicting consequences (Yager, 1999). Initially, the students were allowed 5 minutes and were instructed to raise as many questions as possible about the specific discrepant situation. In the second and third activities, students were also allowed 5 minutes for each activity, and were asked to suggest causes and predict consequences resulting from the discrepant situation.

Every student was evaluated by quantitative measures geared to creative-thinking fluency (the ability to produce a large number of ideas, scored by the different relevant responses generated about the discrepant event) on all three scales. The total number of pertinent questions, causes and consequences related to the discrepant situation were counted (Enger & Yager, 1998). For determining statistically significant differences between pre- and post-test and between male and female students, the t-test controlled by the Wilcoxon signed rank test was used (Gall *et al.*, 1996). Standard deviations were given to indicate the distribution of mean results. The qualitative measure was geared according to creative-thinking flexibility (the ability to produce a wide variety of ideas), scored for each task by counting the number of different types or shifts used in the responses, and originality (the ability to produce unusual ideas), scored by the frequency of creative and imaginative ideas.

Results

Table 1 shows the changes in students' quantitative creative thinking abilities during the 8-week STL teaching module, measured as creative-thinking fluency on all three scales of creativity test: asking questions, suggesting causes and predicting consequences.

Table 1
Change of Students' Creative Fluency

Scale of creative thinking	Male students (n=40) Mean (*SD*)		Difference in means	*t*-test *p.*	Female students (n=40) Mean (*SD*)		Difference in means	*t*-test *p.*	Students (n=80) Mean (*SD*)		Differen in mea
	Pre-test	Post-test			Pre-test	Post-test			Pre-test	Post-test	
Asking questions	7.5 (3.8)	8.6 (3.9)	1.1	0.01*	9.0 (3.5)	11.4 (4.1)	2.4	0.001**	8.3 (3.7)	10.0 (4.2)	1.7
Suggesting causes	5.3 (3.7)	6.7 (3.5)	1.4	0.04*	5.9 (3.6)	7.1 (4.0)	1.2	0.09	5.9 (3.6)	7.2 (3.7)	1.3
Predicting consequences	7.9 (5.8)	8.9 (5.7)	1.0	0.01*	7.7 (4.5)	8.9 (4.6)	1.2	0.01*	7.8 (5.0)	8.9 (5.1)	1.1
Average	*6.9 (4.6)*	*8.1 (4.6)*	*1.2*	*0.001***	*7.7 (4.0)*	*9.3 (4.5)*	*1.6*	*0.001***	*7.3 (4.4)*	*8.7 (4.6)*	*1.4*

* $p.<0.05$,

** $p.<0.01$

Pre-test

The average results were highest on the scale of asking questions and the lowest on the scale of suggesting causes. Remarkable differences occurred in the creative thinking pre-test results of male and female students. The average results of female students were significantly higher on two scales of creative thinking, asking questions ($p. < 0.01$) and suggesting causes ($p. < 0.05$), but male students had higher results in predicting consequences ($p. < 0.01$).

Post-test

The difference in creative fluency (a quantitative indicator) results between pre- and post-test revealed that, during the 8-week STL teaching module, significant positive changes occurred in the mean creative thinking skills of students on all scales. The most significant increase in students' creative thinking abilities appeared on the scale of asking questions ($p. < 0.001$). This supported the notion that STL teaching was effective in encouraging students to ask different questions about the discrepant situations and to also predict the consequences. During the 8-week STL teaching module, male students significantly improved their performance on all three scales of creative thinking ($p. < 0.001$, $p. < 0.05$, $p. < 0.01$), but the female students' ability did not increase substantially on the scale of suggesting causes, and their mean difference in asking questions was twice higher than that of male students. A high proportion of students (65.0 %) had positive changes in the creative-thinking fluency scores, 31.2 % of students had not increased their creativity scores, and 3.8 % of students had a little decrease of their scores on creative fluency.

For more detailed investigation of the influence of STL teaching on students' creative thinking, the qualitative measure was formed on the basis of K-Means Cluster analysis and the scores of creative-thinking flexibility and originality on all three scales of creativity test (asking questions, suggesting causes and predicting consequences). According to the scores of creative thinking flexibility (the counted number of different types of questions, suggested causes, or predicted consequences) and originality (the uniqueness of questions, causes and consequences), scored from 0 to 3 points: if a response was unique (it was mentioned less than 5 % among the total number of students' answers), it was assigned a score of three points. If the response was partly unique (it was mentioned from 5 to 10 % among the total number of students' answers), it was assigned a score of 2 points; any response with less uniqueness (it was mentioned from 10 to 15 % among the total number of students' answers), it was assigned a score of 1 point, and if not unique, it was assigned a 0 score). Three levels on each creativity scale were identified. These three hierarchical levels of creative thinking were labelled, in ascending order, as A, B, and C: level A (2 – 7 points); level B (8 – 12 points); and level C (13 – 24 points). Hierarchical cluster analysis was then conducted across all pre- and post-test results, and the number of changes in the creative thinking levels was identified in order to describe the main parameters of STL teaching that influence students' creative thinking.

The results of students' pre-tests revealed that the majority of students (82.5 %) were categorized at all three scales of creative thinking on the lowest two levels (A, B), and only two students (2.5 %) were categorized at all three scales of creative thinking on the highest level C. During the STL teaching module, positive improvements of the levels of students' creative thinking occurred, but only with less than one third of students (32.5 %). The results in Table 2 indicate that the highest and significant positive change of creative thinking levels occurred within the scale of asking questions ($t = -4.135$, $p. > 0.001$), and the smallest and not significant positive change took place within the scale of suggesting causes (t = -1.423, $p.$ = 0.159). The positive change within the scale of predicting consequences was a bit lower, and occurred to be significant (t = -5.587, $p.$ = 0.012). This pattern followed the increases of the quantitative changes of creative thinking abilities.

Table 2
Change of Students' Creative Thinking Levels

	No of Creative Thinking Level A	No of Creative Thinking Level B	No of Creative Thinking Level C	Total No of Changes	*t*-test $p.$
Asking Questions	11	3	11	25	0.001**
Suggesting Causes	4	2	2	8	0.15
Predicting Consequences	7	5	4	16	0.01*

* $p.<0.05$, ** $p.<0.01$

Table 3 presents differences between male and female students. The results in Table 3 indicate that female students had increased their ability to ask questions more than male students, but male students, after the STL teaching, improved their abilities on the scales of suggesting causes and predicting consequences more than female students. At the same time, female students had more improvements on their higher levels of creative thinking than male students, but these differences were not statistically significant.

Table 3
Change of Male and Female Students' Creative Thinking Levels

	Asking Questions		**Suggesting Causes**		**Predicting Consequences**	
Level of Creativity	**Male students' changes**	**Female students' changes**	**Male students' changes**	**Female students' changes**	**Male students' changes**	**Female students' changes**
A	-5	-6	-3	-1	-4	-3
B	+2	-1	+2	0	+5	0
C	+3	+7	+1	+1	-1	+3

According to the hierarchical cluster analysis of the changes in creative thinking levels, the students were grouped into three different categories. The largest (I) group of 54 students (67.5 %) included those students who had no positive increase on any level of creative thinking. The second (II) group included 14 students who had one or two positive changes in creative thinking levels (17.5 %). The third (III) group included the 12 students who had 3 or 4 (1 student) positive changes in creative thinking levels (15.0 %). The number of changes in creative thinking level in terms of asking questions was the most obvious within the criteria of clustering.

Table 4 presents the differences between the quantitative and qualitative changes of students' creative thinking. The increase of quantitative part of creative thinking (fluency) is practically twice as high as the change of qualitative part of creative thinking (flexibility and originality).

Table 4
Comparison of Quantitative and Qualitative Changes in Students' Creative Thinking

	Positive change	No change	Negative change
Creative fluency (quantitative)	65.0 %	31.2 %	3.8 %
Creative flexibility and originality (qualitative)	32.5 %	67.5 %	0 %

Discussion and Conclusions

The current study showed that student's mean creative-thinking fluency abilities increased after the STL teaching intervention. The essential changes appeared to be related to the issue of asking more questions and to the issue of predicting consequences. The least increase was found in the ability to suggest causes. Therefore, the results assure that the STL approach of teaching was most effective in encouraging the students to ask different questions about the discrepant situation and in predicting consequences. On the contrary, the least increase was related to the ability to suggest causes. This result is quite similar to the process of problem solving where the difficult issue appears to be students' ability to recognise a problem (Laius & Rannikmäe, 2003; Park-Gates, 2001).

Earlier studies that employed science-technology-society (STS) in-service programs also reported positive effects on students' creative thinking abilities (Cho, 2002; Penick, 1996; Liu, 1996), but the assessment system did not separate the quantitative and qualitative part of creative thinking and the relationship between them.

The current study found that it is more difficult to increase the quality of students' creative thinking abilities. More than two thirds of students (67.5 %) did not improve their qualitative creativity level within any scale of creative thinking, while the positive quantitative changes of creativity scores occurred only for 65.0 % of students. Therefore, the STL teaching in-service intervention was considered as an effective approach that can have an impact on students' creative thinking abilities. The study indicated that student's creative abilities were in general better after the intervention. Estonian female students demonstrated larger increases in quantitative creative thinking abilities, especially on the scale of asking questions. Conversely to our results, the literature reports that male students had higher creativity scores (Hill, 2000; Simpson, 1999), but the qualitative increase of male students' creative thinking abilities exceeded that of the results of female students.

Limitations of the Study

The teachers involved in this study were motivated volunteers and did not represent all science teachers in Estonia. The students involved in the study were taught by the target teachers and thus were not representative of the total student population in Estonian schools.

Acknowledegements

This research has been supported by the Estonian Science Foundation (grant No. GBGMR 5663 and TBGMR 2529).

REFERENCES

AIKENHEAD, G. (1994). *What is STS Science Teaching?* In J. Solomon and G. Aikenhead (Eds.), *STS Education. International Perspectives on Reform,* (pp. 47–59). New York: Teachers College Press.

CHO, J. (2002). The development of an alternative in-service programme for Korean science teachers with an emphasis on science-technology-society. *International Journal of Science Education, 24,* 1021–1035.

FOUREZ, G. (1997). Scientific and Technological Literacy as a Social Practice. *Social Studies of Sciences, 27,* 903–936.

ENGER, S. K., & YAGER, R.E. (Eds.) (1998). *The Iowa Assessment Handbook.* USA: University of Iowa.

EPPI REVIEW. (2003). *A systematic review of the effects of context-based and Science-Technology-Society (STS) approaches in the teaching of secondary science.* UK: University of London.

EREZ, R. (2004). Freedom and Creativity: An Approach to Science Education for Excellent Students and Its Realization in the Israel Arts and Science Academy's Curriculum. *The Journal of Secondary Gifted Education, XV,* 133–140.

GALL, M.D., BORG, W.R., & GALL, J.P. (1996). *Educational Research: An Introduction, (6th ed).* USA: Longman Publishers.

HILL, G.T. (2000). *Sex and gender differences in humor, creativity, and their correlations.* Unpublished doctoral dissertation of The University of Texas at Austin. USA: Texas.

HODSON, D., & REID, D.J. (1988). Science for all: Motives, meanings and implications. *The School Science Review, 69,* 653–661.

HOLBROOK, J. (2003). Increasing the Relevance of Science Education: The Way Forward. *Science Education International, 14,* 5–13.

HOLBROOK, J., & RANNIKMÄE, M. (1996). Creating Exemplary Teaching Materials to Enhance Scientific and Technological Literacy. *Science Education International, 7,* 3–7.

HOLBROOK, J., & RANNIKMÄE, M. (1997). *Supplementary Teaching Materials: Promoting Scientific and Technological Literacy.* Estonia: University of Tartu.

HOLBROOK, J., & RANNIKMÄE, M. (2002). Scientific and Technological Literacy for All – an Important Philosophy for the Teaching of Science Subjects. In K. Niinistö, H. Kukemelk and L. Kemppinen (eds.), *Developing Teacher Education in Estonia,* (205–214). Turku: Painosalama Oy.

HOLBROOK, J., & RANNIKMÄE, M. (2001). *Introducing STL: A Philosophy and Teaching Approach for Science Education.* Estonia: University of Tartu.

HOWARD-JONES, P.A. (2002). A Dual-state Model of Creative Cognition for Supporting Strategies that Foster Creativity in the Classroom. *International Journal of Technology and Design Education, 12,* 215–226.

Hu, W., & Adey, P. (2002). A scientific creativity test for secondary school students. *International Journal of Science Education, 24,* 389–403.

Instrument's Package and User's Guide (1997). *Secondary Science and Mathematics Teacher Preparation Programs: Influences on New Teachers and Their Students.* USA: University of Iowa.

Laius, A., & Rannikmäe, M. (2003). The Influence of STL Teaching on Students' Creativity. *Science Education International, 14,* 21–28.

Liu, C. (1996). *A longitudinal study of the impact of a national science reform programme endorsed by the National Diffusion Network on Teaching and Learning: The Iowa Scope, Sequence, and Coordination Project.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, 2 April, St Louis, Missouri.

Park-Gates, S.L. (2001). *Effects of group interactive brainstorming on creativity.* Unpublished doctoral dissertation of Virginia Polytechnic Institute and State University. USA: Virginia.

Penick, J.E. (1996). Creativity and the value of questions in STS. In R.E. Yager (Ed.), *Science/Technology/Society as Reform in Science Education,* (pp. 84–94). Albany: State University of New York Press.

Rannikmäe, M. (2001a). *Operationalisation of Scientific and Technological Literacy in the Teaching of Science.* Dissertationes Pedagogicae Scientarum Universitatis Tartuensis. Estonia: University of Tartu.

Rannikmäe, M. (2001b). Effectiveness of Teacher-Developed Scientific and Technological Literacy Materials. In O. Jong, E. Savelsbergh and A. Albas (Eds.), *Teaching for Scientific Literacy: Content, Competency, and Curriculum,* CD-B series Vol.38, Utrecht, The Netherlands: CD-B Press.

Rannikmäe, M., & Laius, A. (2004). Can we make science teaching relevant for students? *Journal of Science Education, 5,* 73–77.

Simpson, N.D. (1999). *Relationships between the academic achievement and the intelligence, creativity, motivation, and gender role identity of gifted children.* Unpublished doctoral dissertation of University of Houston, USA: Houston.

Sternberg, R. J. (1999). *Handbook of creativity.* New York: Cambridge University Press.

Sternberg, R. J. (2003). Creative Thinking in the Classroom. *Scandinavian Journal of Educational Research, 47,* 325–338.

Torrance, E. P. (1990). *Torrance Tests of Creative Thinking.* Beaconville, IL: Scholastic Testing Services.

Yager, R. E. (1999). *The Iowa Chautauqua Project: Student Growth in A Variety of domains.* Iowa: Science Education Center, The University of Iowa.

Yager, R.E., & Weld, J. D. (1999). Scope, sequence and coordination: The Iowa Project, a national reform effort in the USA. *International Journal of Science Education, 21,* 169–194.