Can we make science teaching relevant for students?
¿Podemos hacer la enseñanza de las ciencias apropiada para los estudiantes?

MIIA RANNIKMÄE, ANNE LAIUS

University of Tartu, Estonia
miia@ut.ee, annelai@ut.ee

Abstract
The current research tries to evaluate the scientific and technological literacy (STL) teaching approach from the point of view of teaching/learning instruction and its influence on students' opinions about the relevance of science education. The constructivist instruction has wider meaning than a simple, activity-based recipe. It includes teacher-created teaching scenarios (STL scenarios), which need to be relevant for students and society and hence build on students' knowledge and interests. And in looking forward, it needs to help equip students with skills that society needs (demands) from its active members. Such instructions will be effective only for teachers, acting as facilitators, and hence will depend on teacher's ownership. 236 ninth grade students were taught by 18 teachers over an 8 week period. Student achievement in six domains (personal relevance, scientific uncertainty, critical voice, shared control, student negotiation and attitude) was compared against a control group formed from 211 students taught by 13 teachers.

Key words: *scientific literacy, STL teaching, learning environment, attitude.*

Resumen
El presente trabajo intenta evaluar el enfoque de alfabetización científica tecnológica desde el punto de vista de la enseñanza y aprendizaje y su influencia en las opiniones de los estudiantes sobre la relevancia de la educación en ciencias. La instrucción constructivista tiene el significado más amplio que una receta simple, basada en las actividades instructivas. Este enfoque incluye los escenarios educativos creados por los maestros, los cuales deben ser pertinentes para los estudiantes y la sociedad para construir su conocimiento y sus intereses correspondientes. También es esencial ayudar a los estudiantes a formar las habilidades que la sociedad necesita y requiere de sus miembros activos. En este trabajo 236 estudiantes de noveno grado fueron instruidos por 18 maestros durante 8 semanas. Los logros del estudiante en seis campos (la relevancia personal, incertidumbre científica, capacidades críticas, control compartido, compromisos y actitudes) se compararon con un grupo de control formado por 211 estudiantes y 13 maestros.

Palabras clave: alfabetización científica y tecnológica, ambiente de aprendizaje, actitudes.

INTRODUCTION

Research has shown the following gaps and tendencies in science education.

1. Science taught at school seems to be *irrelevant for students*. Students do not see science useful for their life and future developments (OSBORNE & COLLINS, 2001; HOLBROOK, 1998, 2001; YAGER, 1996).
2. *Science content is dominating* over students' everyday needs; remains unchanged, in the face of societal change, and overloaded with facts and theories taken from the past (KRAJCIK, MAMLOK & HUG, 2001).
3. Students' perceptions of their experience of school science have shown that school science has been, in the eyes of students, a subject dominated by content with too much repetition and *too little challenge* (OSBORNE & COLLINS, 2001).
4. Science education is isolated from the value components of education, and communication and collaborative behavioural (learning) skills are not appreciated as goals of science education. Science education has *become value free* in the eyes of students. At the same time, the community needs to address moral and ethical issues and related problems (ANDERSON, 1992, HOLBROOK, 1992, LAYTON, 1986).
5. Research over the last 10 years has shown that the *lack of higher order learning* among students has inhibited the development of problem-solving and decision-making skills among school graduates (RANNIKMÄE, 2001a; ANDERSON, ANDERSON & VARANKA-MARTIN, 1992; ZOLLER, 1993; TAL, DORI & KENY, 2001).

All the previous concerns are interrelated, but addressing/highlighting issues in different contexts of science education. In general, all can be discussed within two domains: teacher's inability to teach higher order thinking skills (problem-solving, decision-making, reasoning) to students (Rannikmäe, 2001b) and concerns for the context in which the science content is taught by teachers (HOLBROOK & RANNIKMÄE, 2002).

The World Conference on Science (UNESCO, 1999) drew attention to the need to raise public awareness of science and technology among the general public, if citizens are to play a full role in the economic and democratic development of the country. But an essential first step was recognised as the need to increase *the popularity of science subjects for students.*

This leads, it can be argued, to the need for a rethink of the goals put forward for science education and the need to modify the subject content, skills to be enhanced and values to be inculcated, making it more culturally relevant for learners. The need to view science, taught in schools, as much broader than just propagating the scientist's view, has given rise to the goal of teaching science as the promotion of *scientific and technological literacy (STL)* among all students (HOLBROOK, 1998). STL in this context is taken to mean the utilisation of sound science knowledge to solve problems and make decisions in everyday life and thus rise the quality of life (HOLBROOK and RANNIKMÄE, 1997). The rationale suggested is that students need to cope with an ever increasing pace of scientific and technological change and with the accompanying social change that is taking place in their lives. The students also need to be better prepared, in a democratic society, to become responsible citizens, making appropriate and informed decisions that affect their lives.

STL education goes further. Besides suggesting the need to cope with change, it recognises that it is essential to promote communication skills in a variety of forms, collaboration skills among students and recognition of skills to form and justify social values (UNESCO, 1999; HAND, 1999). All of the above were highlighted as essential components of science education during the International Science Education Conference (GOA, 2001, background paper). These were also highlighted in the final report of the CEFIC/ICASE conference on education-industry partnerships (York, 2000). STL has become an internationally recognised paradigm for an approach to the teaching of science subjects (MILLAR, 1996, HOLBROOK, 1998, WESTBY, 2000). Developments in cognitive and social psychology have led to new ways of understanding human learning and knowledge. Research has showed that when information is acquired through memorisation of discrete facts, the level and kind of understanding that results makes it difficult for students to access this information and apply it to new situations (BRANDSFORD *et al*., 1999). When students acquire new information in a meaningful context and relate it to what is already known, they connect new information to better, larger and more linked conceptual networks of understanding (KRAJCIK *et al*., 2001). Learning is social interaction and it involves shared experiences and understandings among students, teachers and community members (KLAHR *et al*., 1993).

In the teaching of science, it is important to develop higher order thinking skills and critical thinking in students, but without showing links between the teaching and society and technology, everything is in danger of being *irrelevant for students*.

There is much attention paid at qualitative research in science education, where social skills within subject knowledge have been the focus. Studied have been undertaken on how students made decisions in solving socially oriented problems within a science context (RATCLIFFE, 1998, 1999) and how to apply science knowledge in explanations of media information (PIEL, 1993; PHILLIPS, 1999). If problem solving is successful in utilising scientific evidence, then reasoning within decision making about socio-scientific issues demands scientific evidence, value judgements and student decision making strategies as important factors for teaching (RATCLIFFE, 1998). Decision-making skills are highlighted by Kortland (2000) where he pointed out students argumentative skills lead to decision making in socially related environmental situations.

Research carried out by Rannikmäe and Holbrook shows the importance of teaching in promoting higher order thinking skills among students (HOLBROOK and RANNIKMÄE, 1996; Rannikmäe, 1998, 2001a, 2001b, 2001c). The role of STL teaching materials (material that derives from a social issue and promotes science cognitive learning in that context to arrive at a decision making process involving the acquired science and other social science components) within science teaching was studied in 1997-98 using already existing teaching materials (Holbrook & Rannikmäe, 1996, 1997, 1999; Otsnik and Rannikmäe, 1997). It appeared that the teacher's approach was stereotypical - the teaching sequence was still from fundamental principles, leading to applications of science; social issues, as a major goal of the materials used, were pushed to the sidelines; and mainly subject knowledge was assessed. At the same time, students felt sympathy towards the new approach, but did not see any learning (Rannikmäe, 1998).

METHODOLOGY

Sample

The research was carried out during the 2001/2002 school-year among the teachers of science subjects and the students of the 9th grade of different Estonian schools. 330 teachers of biology, chemistry, physics and science, and 447 students were tested to get a comparative survey of the learning environment in science subject classes. To survey the influences and changes both of students, and teachers after they had enrolled on STL in-service courses, 18 teachers and their 236 students from 9 schools were investigated before the in-service courses in October 2001 and after an 8-week module geared to STL teaching in May 2002. The experimental group of teachers (and schools) were divided into three groups (3 schools per group): in Group 1 one teacher participated, in Group 2 two teachers participated and in Group 3 three teachers participated in the courses and taught the same students at the same time in different science classes. In addition, 13 teachers and their 211 students from 8 schools agreed to participate in the study as a control group and were tested at the same times before and after the treatment. These teachers were not involved in the STL in-service courses.

INTERVENTION

The experimental teachers enrolled in the 8-month STL teaching intervention study, participating in the in-service courses of collaborative teamwork in science classes and in the course of the in-service courses their students were exposed to an 8-week STL teaching module. The content of the 8-month STL teaching in-service courses was:

· The introduction of STL philosophy;

· Critical analysis and modification of STL teaching goals;

· Combining the teams of schools for collaborative work and discussing the possible integrative themes in science classes for STL module;

· The introduction of the structure of STL teaching materials;

· Discussion in collaborative groups and developing an integral scenario for 8-week STL module;

· Choosing the themes and scenarios for school teams of science teachers and enrolling the 8-week STL teaching module in science classes for the ninth grade students.

The science teachers of specified school teams created their STL teaching materials collaboratively in consideration of the following criteria (Holbrook, Rannikmäe, 1996):

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. Following the material is a learning exercise, i.e. it provides an intellectual challenge and utilizes constructivist principles — moving from the information and understanding already in the possession of students to the new;
4. The activity is student participatory, i.e. the student is involved either individually or groups for a considerable amount (>60 %) of the teaching time;
5. Consideration is given to enhancing a wide range of communication skills.

INSTRUMENTS

Students and teachers were tested before and after the intervention against six domains to describe STL learning environment and students' attitudes towards science. As STS and STL teaching approaches are considered to be quite similar and do not differ in the themes of this research, the instruments were selected from Instrument Package & User's Guide (1997) of the Iowa Chautauqua program. The used instruments are elaborated below:

1. Constructivist Learning environment Survey (CLES) - a 42 item, five-point Likert scale questionnaire for teachers and students used to assess the learning environment through 6 scales: personal relevance (PR), scientific uncertainty (SU), critical voice (CV), shared control (SC), student negotiation (SN) and attitude (AT) scale. This instrument consists of positive and negative statements which must be answered on a scale that ranges from "Almost always" to "Almost never". For positive item statements, the "Almost always" choice was recorded as 5, moving down to the "Almost never" choice which would receive a 1. For negative item statements, the number procedure is reversed. (Enger, Yager, 1998). All average results growing over three are assumed positive and below three, to tend to decrease in the negative direction.
2. Assessing Attitudes in Science - an 18 item, five-point Likert scale questionnaire for assessing student's attitudes towards science as a subject, towards science in general and toward a career as a scientist. The scale range and scoring is similar to the previous CLES test: the instrument consists of positive and negative statements which must be answered on a scale that ranges from "Always" to "Never". For positive item statements, the "Always" choice was recorded as 5, moving down to the "Never" choice which would receive a 1. For negative item statements, the number procedure is reversed. All average results growing over three are assumed positive and below three, to tend to decrease in the negative direction.

The instruments were translated into Estonian, adapted to the local school conditions and validated by the 45 Estonian chemistry teachers, participating various in-service courses during the school year of 1999/2000. The instruments were also piloted by 78 ninth grade students from Estonian basic schools. These instruments made available to investigate from STL teaching criteria (Holbrook & Rannikmäe, 1997) students opinions of promotion of social, personal and process skills through STL teaching module. Social skills were measured in terms of student negotiation and shared control, personal skills in terms of personal relevance, critical voice and attitude, process skills against scientific uncertainty and attitudes towards science.

Personal Relevance Scale (PR) is concerned with students' experience of the personal relevance of school science. The scale has been designed to measure the extent to which students perceive the relevance of school science to their out-of-school lives. From a constructivist perspective, the classroom environment should not promote a discontinuity between school science and students' out-of-school lives by evoking an abstract and decontextualized image of science. Rather, the classroom environment should engage students in opportunities to experience the relevance of school science to their everyday interests and activities.

Scientific Uncertainty Scale (SU) is concerned with students' perceptions of science as a fallible human activity. The scale has been designed to measure the extent to which students perceive science to be an uncertain and evolving activity embedded in a cultural context and embodying human values and interests. From a constructivist perspective, the classroom environment should be concerned with engaging students in opportunities to learn to sceptical and critical about the nature and value of science.

Critical Voice Scale (CV) is concerned with students' development as autonomous learners. In particular, the scale has been designed to measure students' perceptions of the extent to which they are able to exercise legitimately a critical voice about the quality of their learning activities. From a constructivist perspective, the teacher should be willing to demonstrate his/her accountability to class by fostering students' critical attitudes towards the teaching and learning activities. This can be achieved by creating a social climate in which students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and to express concerns about any impediments to their learning.

Shared Control Scale (SC) is concerned with students sharing with their teachers control of the classroom learning environment. In particular, the scale has been designed to measure students' perceptions of the extent to which the teacher involves them in the management of the classroom learning environment. From a constructivist perspective the teacher should invite students to share control of important aspects of their learning by providing opportunities for them to participate in the processes of designing their own learning activities.

Student Negotiation Scale (SN) is concerned with negotiation amongst students. This scale has been designed to measure students' perceptions of the extent to which they interact verbally with other students for the purpose of building their scientific knowledge within the consensual domain of the classroom. From a constructivist perspective, the classroom environment should be concerned with engaging students in opportunities to explain and justify their newly developing ideas to other students.

Attitude Scale (AT) has been included to provide a measure of the concurrent validity of the previously named scales. The scale measures student attitudes to important aspects of the classroom environment, including their anticipation to the activities; their sense of worthwhileness of the activities and the impact of the activities on student interest, enjoyment and understanding.

RESULTS AND DISCUSSION

The outcomes of the pre-test showed that there were no significant differences between experimental and control group teachers - both demonstrated high results in the scale of personal relevance (control group 3.62; experimental group 3.58) and attitudes (both 3.41). From the comparison of experimental and control group students no difference occurred with the scales of personal relevance, scientific uncertainty, and shared control. The other parts of the scale differed not significantly. At the same time teachers and students differed significantly within 5 domains (Table 1) and the difference did not disappear after 8-weeks STL intervention. Within the groups of control teachers and their students there were no significant changes on any scale of learning environment survey during the research period (Table 2).

Table 1
Comparison of the experimental group of teachers and their students changes on the learning environment survey
(Likert-style responses ranging from "never" to "always" ranked from 1 to 5 respectively)

Scale	Pre-test	Post-test	Mean change of experimental teachers N=18	T-test p	Pre-test	Post-test	Mean change of experimental students N=236	T-test p
Personal relevance	**3.58**	**3.90**	**0.32**	**<0.001****	**3.24**	**3.36**	**0.16**	**0.01***
Scientific uncertainty	3.12	3.30	0.18	0.06	3.29	3.35	0.06	0.08
Critical voice	**3.45**	**3.56**	**0.11**	**<0.001****	**3.25**	**3.36**	**0.11**	**0.01***
Shared control	**2.89**	**3.09**	**0.20**	**0.01***	**2.52**	**2.68**	**0.16**	**<0.001****
Student negotiation	3.16	3.53	0.37	0.01*	2.99	3.31	0.32	<0.001**
Attitude	**3.41**	**3.64**	**0.23**	**0.02***	**2.84**	**2.98**	**0.14**	**<0.001****

* Significant difference at the 0.05 level of confidence.
** Significant difference at the 0.01 level of confidence.

Table 2
Comparison of the control group of teachers and their students changes on the learning environment survey
(Likert-style responses ranging from "never" to "always" ranked from 1 to 5 respectively)

Scale	Pre-test	Post-test	Mean change of control teachers N=13	T-test p	Pre-test	Post-test	Mean change of control students N=211	T-test p
Personal relevance	3.62	3.78	0.16	0.43	3.23	3.24	0.01	0.86
Scientific uncertainty	3.14	3.29	0.15	0.37	3.27	3.29	0.02	0.59
Critical voice	3.32	3.45	0.13	0.24	3.36	3.33	-0.03	0.45
Shared control	2.79	2.96	0.17	0.32	2.51	2.54	0.03	0.50
Student negotiation	2.98	3.07	0.09	0.69	2.87	2.99	0.11	0.06
Attitude	3.41	3.68	0.27	0.17	2.76	2.83	0.07	0.13

During the intervention study, the teachers underwent a statistically significant change in the positive direction for personal and social domains on all scales of the learning environment in science classes. The same statistically significant influence of the STL teaching intervention study on the students' change occurred on all scales of learning environment within the personal and social domains. The increase of attitude have been registered towards science studies earlier, using STS teaching materials (Mamlok, 1998; Yager, Weld, 1999) and using STL materials (Rannikmäe, 2001), when the students' liking of STL teaching materials were under investigation. In current study the personal and social domains of the learning environment were investigated in detail within STL teaching.

According to the pre-tests, the personal relevance for science subjects turned out to be the most positive opinion about the learning environment survey among the science teachers. The students' opinions about the relevance of their science classes were not at the top of their list of preferences and it was significantly lower than the teachers' opinions on the same scale of learning environment. This gap between teachers' and students' opinions is related evidently to the unpopularity of science subjects among students, recorded frequently by international science education documents (UNESCO, 2000a; 200b; 2001). Obviously the teachers exaggerate the perception of the students about their personal preference before the STL teaching intervention. After the in-service courses and the 8-week STL teaching module, the gap between the results on the scale of personal relevance became even larger, as the teachers' change was more than twice as high as the student change. Therefore, it would seem that the influence of the 8-month in-service courses on the teachers was more substantial than the impact of the 8-week STL teaching module on the students. This suggests, that the relevance for science is related to the continuing unpopularity of science among the students (Sjøberg, 2002; Niwano, Y., Sclossler, S., Yager, R.E., 2000; Wheeler, 2000).

A change in teachers commonly influences a change in students and so it was assumed that if the teachers did not change significantly in the positive direction on a scale, the scale of scientific uncertainty, then the students' change on this scale would be even less.

This research revealed that the attitudes on the whole towards science were quite low among Estonian 9th grade students: the average on the pre-test were practically in the centre of the 5-point Likert scale, meaning an uncertainty of opinions. Only the attitude towards science as a subject was slightly larger, but the attitudes towards science in general and a career as a scientist remained both lower than the average. Such a low attitude towards science is usually quite common in countries where the science subjects are taught as different single subjects. (Table 3). On the whole, it can be concluded, that the STL teaching had the highest effect on the attitudes towards science as a subject. The lowest influence of STL teaching after the intervention occurred on the attitude towards a scientific career. Among the students of control group there were no significant changes in any scale of attitudes. (Table 4).

Table 3
Changes of students' attitudes in the experimental group
(Likert-style responses ranging from "never" to "always" ranked from 1 to 5 respectively)

Attitudes	Pre-test	Post-test	Mean change of experimental students N=236	T-test p
Towards science as a subject	**3.16**	**3.42**	**0.26**	**<0.001****
Towards science in general	**2.93**	**3.10**	**0.17**	**<0.001****
Towards career of a scientist	**2.85**	**3.00**	**0.15**	**0.01***

* Significant difference at the 0.05 level of confidence,
** Significant difference at the 0.01 level of confidence

The summary results of all tests, undertaken during the intervention study in the specified groups of experimental teachers, showed, that the lowest students' changes occurred with one teacher being involved in the 8-week STL teaching module, although the teacher could teach three subjects at the same time (Table 5). The lowest results in this case appeared on the scale of personal relevance and the biggest effect appeared on the scale of shared control. Two or three teachers working as a collaborative team affected the students more significantly. Among the students of Group 2 (two teachers) and Group 3 (three teachers) significant positive differences in changes did not occur obviously because of the fact, that the students of Group 3 had in pre-tests higher average results than the students of Group 2. For this reason the changes of the third group of students were not very significant, compared with the second group, but their final results on the post-test were still higher that the average results of the second group students. It can be claimed that the team-work of teachers had a greater impact on their students than the single teacher working alone. In addition, it is worth mentioning that the changes of the teachers themselves during the STL teaching intervention study between the groups were not statistically significant. This could lead to the supposition, that the teacher's influence on their students depended more on the variety of different teachers' personalities, participating in the STL teaching module, than the number of science subjects taught at the same time by the same approach of teaching.

Table 4
Changes of students' attitudes in the control group
(Likert-style responses ranging from "never" to "always" ranked from 1 to 5 respectively)

Attitudes	Pre-test	Post-test	Mean change of control students N=211	T-test p
towards science as a subject	3.00	3.12	0.12	0.08
towards science in general	2.82	2.89	0.07	0.22
towards career of a scientist	2.73	2.83	0.10	0.052

Table 5
Comparison of students' changes in the three specified groups of experimental teachers

Test	Students' mean change in Group 1 (one teachers) N=66	Students' mean change in Group 2 (two teachers) N=85	T-test p (Gr.1/2)	Students' mean change in Group 3 (three teachers) N=85	T-test p (Gr.2/3)
Learning environment					
Personal relevance	-0.03	0.23	0.01*	0.11	0.12
Scientific uncertainty	0.05	0.06	0.43	0.07	0.43
Critical voice	0.07	0.11	0.35	0.13	0.39
Shared control	0.23	0.10	0.12	0.20	0.18
Student negotiation	0.26	0.34	0.29	0.33	0.49
Attitude	0.01	0.22	0.02*	0.15	0.27
Average	*0.10*	*0.18*	*0.04**	*0.17*	*0.40*
Attitudes					
Attitudes towards science as a subject	0.17	0.41	0.03*	0.18	0.02*
Attitudes towards science as general	0.16	0.20	0.35	0.13	0.26
Attitudes towards career of a scientist	0.13	0.16	0.37	0.15	0.44
Average	*0.15*	*0.26*	*0.04**	*0.15*	*0.05*
Total average	***0.12***	***0.20***	***0.01****	***0.16***	***0.12***

* Significant difference at the 0.05 level of confidence

CONCLUSIONS

1. STL teaching will improve the personal and social domains of the learning environment within science classes for both teachers and students. The STL teaching in-service intervention was clearly an effective tool with significant impact. There was a consistent positive change of teacher's understanding and ownership of STL teaching philosophy. Only scientific uncertainty seemed unchanged by the intervention and this may have been due to the fact that the 8-month intervention study of STL teaching was not enough to understand science processes at a range wider than had been required during previous learning and teaching experiences. The positive change of teachers during the 8-month STL teaching intervention had a positive change effect on the student's opinions about the learning environment within personal and social domains.
2. The influence of team-work by several teachers will impact significantly on student change during STL teaching compared to that of a single teacher working individually. The students demonstrated greater changes if more than one teacher was involved in STL teaching module. This showed the role and importance of teacher's collaborative team-work on widening the student's understanding of science.
3. Exposure of students to an 8-week STL teaching module in their science classes will improve their opinions about the learning environment and their attitudes towards science. Enrolling on the 8-week STL teaching module resulted in a significant positive effect on student's attitudes towards science as a subject, science in general and scientific careers, for both male and female students. Positive attitude changes within the learning environment and classroom climate, and towards different scales of science showed that STL teaching was relevant for science studies at the students' point of view. The positive attitude towards science was shown to lead to development of process skills as a part of scientific activities and subsequent justified decision-making in daily life.
4. As there were no significant changes over the study period within the control groups of teachers and students, it proved that the used instruments were suitable for measuring STL teaching environment components.

ACKNOWLEDGEMENTS

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

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Received 29.07.2003, approved 05.03.2004