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ABSTRACT

This paper illustrates the effectiveness of two models of STL teaching in the classroom. The teaching of scientific and technological literacy for all (STL) involves increasing the relevance of teaching through relating it to local issues or concerns and incorporating values education. STL supplementary teaching materials were defined as materials which were social issue based, student centered, decision- making, and/or problem-solving units, within curriculum topics. Altogether, 45 teachers and 1,163 students were involved in different studies over the period 1997-2001. It was found that the major factor illustrating teachers' ownership of teaching STL was their involvement in the process of creating supplementary teaching materials, described through the longitudinal classroom observation study. (Contains 13 references.) (Author/YDS)

# STL Teaching – Immediate and Longitudinal Influence on Students' Learning.

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## ABSTRACT

This paper illustrates the effectiveness of two models of STL teaching in the classroom. The teaching of scientific and technological literacy for all (STL) involves increasing the relevance of teaching through relating it to local issues or concerns and incorporating values education. STL supplementary teaching materials were defined as materials which were social issue based, student centred, decision–making, and/or problem–solving units, within curriculum topics (Holbrook & Rannikmäe, 1997).

Altogether, forty five teachers and 1163 students were involved in different studies over the period 1997–2001. It was found that the major factor illustrating teachers ownership of teaching STL was their involvement in the process of creating supplementary teaching materials, described through the longitudinal classroom observation study.

## INTRODUCTION

Promoting STL among students has become a major target of science teaching over the last decade. Different countries have been approaching this process from their own viewpoint, but it has been obvious that teaching facts, or even guiding students to acquire isolated scientific concepts, was not enough. The focus of school programmes has been to move beyond acquisition of knowledge and focus more on the development of learning skills, values and ideas. The target of science teaching has been to help students gain the total range of educational objectives put forward for schooling at a certain age level. Bybee (1993) divided these educational objectives and by modifying his ideas slightly four major areas can be put forward – empirical knowledge, scientific method, personal development of students including career awareness and social development, or achieving the aspiration of society.

Achieving these objectives is not easy task for teachers. Research has shown, that there are big gaps between students' wishes and traditional teaching, heavily influenced by teachers' attitudes (Rannikmäe, 1998, Hofstein & Malmok, 2000), lack of teaching skills to assess against wider goals of science education and the need for in–service guidance for better understanding about the socially oriented goals for teaching science (Holbrook, 1999).

Teachers are afraid of change – teacher try to avoid change especially change where their expertise may be undermined) and therefore they must be guided through the various teaching stages (Aikenhead, 1997). Teachers in research projects had concerns about doing something different in the classroom (Bell & Gilbert, 1994). These concerns include fear of losing control in the classroom, covering the curriculum, meeting assessment requirements, etc. At the same time, we know that teachers are excellent learners who are interested in enhancing their teaching methods. But after attending in–service courses they still feel unable to use the new teaching activities, curriculum materials or content knowledge to improve the learning of their students (Bell, 1998).

Teacher change is linked with teacher beliefs. Previous studies have showed that perceptions and beliefs of teachers are strongly connected with their practice and behaviour. Teachers and their beliefs play a major role in science education reform, since teacher beliefs lead to actions, and these actions ultimately impact on students (Lumpe et.al, 1998). These beliefs and perceptions are part of teachers' professional ownership of, and greater control over, their own work. Teachers assimilate new content better and use varied teaching methods when they are actively participating in the development of teaching or evaluation methods (Sabar & Shafriri, 1982), or when they cooperate in the framework of a teacher team in planning their work (Oakland, 1995). So far there is little literature, which describes models, and case studies that can help in building an educationally effective framework for the professional development of teachers.

Based on the above issues, the goal for this study was to determine criteria for the evaluation of the effectiveness of STL teaching among students and to find factors, which most strongly influence teachers skills to promote STL among students. For teaching STL (Holbrook, 1998), it is obvious that teachers should be equipped with new types of teaching materials (Holbrook & Rannikmäe, 1997) that will motivate students' learning and take school science away from purely subject oriented textbook based teaching.

## RESEARCH DESIGN AND METHOD.

This research was focused on two models of STL teaching (Model as such was defined against the amount of instruction teachers were equipped to teach):

1. STL teaching based on STL supplementary teaching material given to the teacher (Holbrook & Rannikmäe, 1997).
2. STL teaching based on supplementary teaching materials created by teachers during the workshops.

The following hypotheses were put forward:

1. Simply using new types of teaching materials (which include also a teaching strategy) is insufficient to change teachers' attitudes towards teaching science in an STL manner.
2. The process of developing STL materials by teachers is the major factor changing teachers towards STL teaching.

3. Through STL teaching, students gain problem–solving and decision–making skills.
4. Teachers' longitudinal change towards STL is linked with the creation of socially derived ideas for teaching science and the practicing of students centred strategies in teaching.

Twenty teachers, participating in the model 1 study, were asked to try out STL supplementary teaching materials without additional instructions and guidance. None of them had previous exposure to the STL philosophy. All information needed was gained from the teaching materials. Data were collected from teachers by interview. In addition, the teachers obtained 470 students opinions and written records collected immediately after the lessons. Data were validated by triangulation using the student written records, student opinions and teacher interviews. All data were qualitatively analysed, based on three domains: implementation domain (what students were learning and teachers teaching), attitudinal domain (opinions related to personal and social development), teaching intention domain (understanding the goals of teaching–learning).

Twenty five teachers, involved in the model 2 study were encouraged to develop their own teaching material meeting the STL criteria (see previous symposium paper) and to try it out in the classroom. During the six month intervention period, teachers attended three writing workshops (a total of 24 hours face to face contact), where STL supplementary teaching materials were created and modified and the draft versions of students pre– and post–tests created. All teachers were asked also to use already existing STL materials (Holbrook & Rannikmäe, 1997) and develop these, by themselves, into teaching material suitable for grade ten students. At the same time, the teachers were trained to recognise the need for wider goals for science teaching, to use student centred teaching approaches, develop problem–solving and decision–making skills and assess students on the skills gained.

Qualitative data were gathered to describe the process of teacher change. The data collection included the use of semi–structured pre– and post– intervention interviews with teachers, observations and student written records from all stages of the process of the development of scripts. Quantitative data were collected from 693 students. Test results were assessed by the teachers and later, separately, by the principal investigator against STL criteria (Holbrook, 1998). Teachers collected student opinions after they had been using the material created by teachers.

The post–intervention interview concentrated on outcomes and values of the intervention study i.e.

- Students achievements.
- Teachers gains and constraints during the intervention.
- Concerns which may influence the continuance of STL teaching.

The interview data were validated by triangulation against the workshop records. Students pre– and post–tests were created by the participants during the workshops. The structure of the tests was designed against STL criteria and was expected to assess, besides science knowledge, problem solving, decision–making and communication skills. The four test questions were sequenced, in a hierarchical order, accordingly the domain emphasised: factual recall and understanding, then problem–solving, then decision–making, and finally organisation and presentation of ideas. The marking scheme summarised all elements belonging to the same domain across the whole test. Outcomes were validated after the research by teachers participating in study.

The actual number of students taken part in the pre– and post–test was not equal. However the mean altered little by the addition or removal of these students. As no data was available on the number of occasions each student was physically present in the class (and hence the amount of actual instruction received), no attempt was made to undertake data reduction, matching students taking both pre– and post–test. The longitudinal influence of the intervention was studied 10 months after the end of the intervention by means of classroom observation.

## RESEARCH FINDINGS

### Teachers readiness to teach STL

STL teaching demands the stating of wider educational goals for the lesson, developing higher order thinking skills among the students and, definitely teaching in a student centred way (Holbrook & Rannikmae, 1997). In the teacher interviews in both studies (table 1), teachers separated subject knowledge from skills. Skills were linked with students involvement in the learning process, whereas knowledge was given by the teacher's talk, or the textbook. (i.e. 'to teach general properties of metals', or 'skill to write ionic equations using the table of solubilities'). Teachers' answers were not organised – most of their answers included fragments from the curriculum content and there was no balance between the subject oriented goals and more general goals. ('to teach logical thinking', or 'to understand the world around us').

**Table 1. Number of Teachers stating one or more goals in each domain**

| Focus of goals | Model 1 Interview after STL lesson (teachers = 20) | Model 2 Pre-intervention interview (teachers = 25) | Model 2 Post-intervention interview (teachers = 23) |
|---|---|---|---|
| Subject knowledge oriented goals | 18 | 25 | 23 |
| Subject skills oriented goals | 12 | 18 | 23 |
| General Education goals | 4 | 7 | 20 |

Table 1 illustrates that using STL supplementary teaching materials (which includes the list of goals and teaching strategies) is not enough to get teachers to recognise and value wider goals for teaching. The fact teachers do not pick up the emphasis of the materials they use, indicates how teachers were adopting new ideas into their common teaching. Teachers' change towards STL teaching took place through the intervention period where teachers began to acknowledge similar components of STL lessons as their students did.

## STUDENTS OPINIONS ABOUT STL LESSONS

Students written responses, collected immediately after one single STL lesson, emphasised their recognisation of the possibility to think by themselves without subject centred guidance (27%). They noted they could apply science knowledge in solving everyday problems and communicate between each other (31%). Also 14% of students mentioned the STL lesson as something new and interesting in their eyes– something unusual.

Students open–ended answers were highly positive, but still influenced by the final examination demands ('these activities do not help us to pass the exam'). The same appeared within the long term study, where, in addition, the following domains were brought up by students (some students mentioned more than one domain)

1. Interested in the new activities (35,4%)
   '.....at the beginning we did not take seriously what the teacher suggested we do, it was not what we were used to doing .....new activities that we never use in chemistry lesson – we were drawing pictures. It was interesting, but we should learn the textbook too.....'
2. Communication and collaboration (55%)
   '.... I liked the groupwork, but there was a lack of additional material. My knowledge was not so good. It is good when strong students belong to the group; they can help the others. I am afraid I did not learn much knowledge for the exam, but I could discuss about interesting problems and analyse the graph showing the cleanliness of the school swimming pool water.....'
3. Problem–solving and decision–making in social context (72%)
   '..... it was easy to solve these tasks; they were taken from everyday life. I recognised problems that I never thought were linked with school chemistry......'

## STUDENT ACHIEVEMENT

Science learning is always linked with conceptual development. New approaches to the teaching process should lead to gains in areas of focus, but conceptual development should not suffer. The Iowa SS&C project (Yager & Weld, 1999) showed that students achieved significantly better than in typical textbook dominated courses in each of the assessed domains: concept, process, application, creativity, attitude and world view. The current research outcomes (table 2) show the biggest improvement in problem–solving and decision–making domains. The slightly lower mean values in conceptual development were not significant and could well be explained by the different curriculum materials (metals, non–metals) assessed in the pre– and post–tests.

**Table 2. Student Achievement and STL Teaching**

| | Pre-Test (N = 682) | | Post-test (N = 623) | |
|---|---|---|---|---|
| Domain | Mean value | % students reaching score 0 1 2 3 | Mean value | % students reaching score 0 1 2 3 |
| Problem Solving skill (max. value = 2) | 0.80 | 20 58 12 - | 1.16 | 12 52 26 - |
| Decision making skill (max value = 3) | 0.55 | 76 20 4 - | 1.21 | 51 15 29 5 |
| Skill to recognize Vales (max value = 1) | 0.10 | 90 10 - - | 0.42 | 58 42 - - |

| Domain | Mean value | Standard Deviation | Mean value | Standard Deviation |
|---|---|---|---|---|
| Science conceptual development (max. value = 9) | 5.75 | 1.45 | 5.31 | 1.40 |
| Communication skill development (max. value = 11) | 5.40 | 2.30 | 7.22 | 2.12 |

In scoring student achievements in each of the domains, it was considered that:

- science concepts, factual recall, understanding and application is included in all test items (scores awarded in all 4 questions);
- communication skill was part of every open–ended answer (scores awarded in 3 of the 4 questions);
- problem–solving and decision–making were part of two questions (2 questions from 4);
- skill to recognise values appeared mainly in writing the essay (one question)

The marking of the test showed:

Following STL teaching, an additional 24% students succeeded in achieving a decision–making score; close to maximum scores were achieved by 25 % more students than before the intervention.

Students' change was similar across all the schools and classes, indicating there was very little (not significant) influence by the teacher.

## TEACHERS' OPINIONS

Teachers who were using the ready made written STL material (model 1) continued to give the major thrust to concepts and skills related to science areas. Only very few teachers (4 from 20) saw the development of communication skill, creativity or co–operative learning as a learning component for students.

During the 6 month intervention (model 2), most of the teachers developed a more advanced perception regarding their role as facilitators of learning. The teachers increase their confidence to teach science (chemistry) in a student centred manner. They appreciated the students' motivational feedback, collected through the essay type answers after lessons where the material, developed by the teacher, was used.

Teachers did not recognise their growth in curriculum related knowledge and skills, as their marking scheme (even though it had changed) still gave a high emphasis to the role of subject knowledge. The fact that students' essays were more developed than in the pre–test was not noticed by teachers. Teachers were not familiar with strategies for assessing essays. Essays were marked against subject knowledge. On the other hand, teachers had a deep interest in the marking scheme used by the principal investigator and showed their interest in wishing to analyse their students' responses again. All teachers agreed with the increased students' achievement in the problem–solving and decision–making areas and, through that, recognised their change:

> '.....I did not think that I was teaching so differently. I just did my usual work and used STL materials and ideas. Maybe I really have changed. Maybe I was using approaches without acknowledging that I was using more problem–solving examples in my teaching. ... But I agree with that when I looked again at the test, and if I had marked the test against these criteria – I see many students did better. But a lot of that is not in the final examination....'

Besides the "hidden" change, teachers acknowledged their achievements in non–subject areas. Most teachers saw the greatest contribution of the intervention in the domains of teamwork, wider pedagogical knowledge and interdisciplinary knowledge. As all teachers involved in the study were teaching chemistry only, the need for wider interdisciplinary knowledge in solving daily life related situations become crucial. Many teachers promised to collect additional information during the summer to make the teaching material they had developed more justified. The process of developing teaching materials raised the teachers interest in publishing them. Here again the value of team work was highlighted and the need for looking through and discussing together all developed materials. The idea of the teacher as a researcher was acknowledged.

## DISCUSSION AND CONCLUSIONS

These two studies showed the need for teachers in–service guidance for better understanding of the intentions of STL teaching. The STL modules helped teachers broaden their teaching goals, but did not clarify the STL philosophy of teaching. Using socially oriented, students centred teaching materials enhanced positive motivation of the students in learning science. Students appreciated the opportunities to think and develop co–operative learning skills, as well to apply science knowledge in new situations– relevant to students.

During the 6 month intervention, all 25 teachers changed. Students taught by teachers showed positive results and attitudes in STL related areas. As a major finding from the research, three categories of teachers were found related to STL ownership:

A. Subject learning activity based teachers (5 teachers).

B. Sequenced activity based teachers (8 teachers).

C. Social issue based teachers (12 teachers).

These categories describe teachers' change towards STL teaching and were developed from the following components:

- pre-intervention perception about goals for teaching chemistry;
- understanding about socially related problem–solving situations; acknowledgement of the need to assess against STL criteria;
- opinions about values education in the intervention.

The above factors were given a differing importance for each group.

Subject learning activity based teachers put continued emphases on facts and concepts, encouraged by the examination system. They placed dominance in assessing subject knowledge, even in socially related test items. They did not express the value of collaboration during the pre–intervention interview for the intervention. Supplementary teaching materials developed by them carried a strong science content, including applications as add-ons.

Sequence activity based teachers were a very mobile group of teachers. Although 8 teachers finally belonged to this group, this stage was passed by a number of other teachers during the workshops. These 8 teachers approached problem–solving situations overwhelmingly using scientific method.

There was a strong component of practical work in their teaching materials..

Social issue based teachers put emphases on problem–solving and decision–making, and sometimes value judgements were included in the teaching materials. This group of teachers developed well structured teaching maps involving social issues and showed competency in assessing students against STL criteria. Social communication was seen as the biggest value during the intervention.

## CONCLUSIONS

1. To effect teacher change, it is essential to use techniques similar to the writing workshop, which give teachers ownership of developed materials and teaching methods.
2. Teacher ownership is important in directing teachers to follow developments and for motivation to work as a team.
3. Students gains in problem–solving and decision–making areas encourage teachers to acknowledge the need for change.

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