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FOREWORD

Promoting Science Teacher Ownership through STL Teaching

Miia RANNIKMÄE

University of Tartu, Estonia
Department for Science Education

Email: miia@ut.ee

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Abstracts

A sad fact of teaching is that once the classroom door is closed, teachers are on their own under 'normal' conditions. They are in charge of the teaching direction, the choice of materials, the pace of learning, the atmosphere created and the learning emphasis.

Developing these skills requires expertise and experience and is aided by interactions with other teachers, especially in the same subject areas.

There is a need for teachers to exchange experiences and to be made aware of new ideas and developments. A peer group professional support , where developments driven by teachers for teachers is essential which contrasts with a top-down model of pushing teachers towards the implementing of "ready-cooked programmes", in which they can rather act like a technician than a translator.

The current paper explores possibilities how to give ownership on teaching science accordingly to the needs for the 21st century. However the philosophy behind this, has been introduced by ICASE through several workshops, supported by UNESCO around the world (Holbrook & Rannikmäe, 1997), empirical data to evaluate the operationalisation of the philosophy, were collected among Estonian science teachers as part of longitudinal study (Rannikmäe, 2001; Rannikmäe & Laius, 2004). The potential for developing social issue based -students participatory, supplementary teaching materials by teachers and seeking teachers feedback that involves both conceptual and values education has been considered as an essential component of teacher ownership.

STL Teaching

Scientific and technological literacy (STL) has been defined as the skill to use science knowledge in solving everyday problems, making reasoned decisions and considering values of society (Holbrook & Rannikmäe, 2002). Promoting STL among students has become a major target of science teaching over the last decade. Teaching for STL has been linked with a paradigm shift and a re-think of science education. Therefore this current foreword makes reference to a previous foreword (Holbrook, 2004) describing explicitly the philosophy of STL and its relationship to the rethink and relevance in science education.

Different countries have been approaching the process of promoting scientific literacy 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 an easy task for teachers. Research has shown, that there are big gaps between students wishes and traditional teaching, heavily influenced by teachers' attitudes (Yager, 2000, Rannikmäe 1998, Hofstein et.al, 2000, Fortus et.al, 2005), 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). In post Soviet countries, there appears also to be a lack of interdisciplinary knowledge among science teachers (Rannikmäe, 1998).

Teachers are afraid of change – teacher try to avoid change especially change where their expertise may be undermined and therefore they need to 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). More recent studies have discussed the balance of teachers' pedagogical and subject content knowledge, showing the first as the leading power towards relevant science teaching for students (Bond-Robinson, 2005).

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 the teachers' professional ownership of, and greater control over, their own work. The importance of teacher ownership of their work has been valued since the Nuffield curriculum projects of the 1960 and 1970 (Jenkins, 2000). Jenkins also noted that teachers have not been using the maximum freedom of choice to choose teaching materials and methods and kept ignoring new ideas and resources. Science teachers' ownership of their own work imposes limits on the power of external agencies to effect change.

Teachers assimilate new content better and use varied teaching methods when they are actively participating in the development of teaching or evaluation methods - this has been shown long time ago (Sabar & Shafriri, 1982), or when they cooperate in the framework of a teacher team in planning their work (Oakland, 1995). However – 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. Current research has considered outcomes documented in the Iowa Project (Yager, 2000), Learning Science Project (Teacher Development) (Bell, 1998) and Science - an Ever Developing Entity Project (Mamlok, 1998).

For teaching STL (Holbrook & Rannikmäe, 2002; Holbrook, 2004), 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. However, simply using new types of teaching materials, which include also a teaching strategy, does not give the expected outcomes. It appears there is also a need for special in-service programmes to help teachers understand and acknowledge the importance of socially oriented, student centred, approaches and the need for assessing all components of science education. Without the special in-service programmes, teachers only adopt teaching materials against their traditional teaching and continue assessing only subject knowledge (Rannikmäe, 1998).

Here I do not introduce so called new type of materials (Rannikmäe, 2001), nor criteria for developing those (Holbrook & Rannikmäe, 1997) – but **show how the process of developing materials** by teachers will help to meet and reach the ownership on teaching towards needs for the 21st century- very much called STL teaching (Holbrook, 2004).

Consequence Map

The incorporating of the issue, the socio-scientific decision making into the teaching, sandwiching the concept learning, provides a new approach to the teaching of science. The new schema – a consequence map – heavily influences the teaching approach. The consequence map is thus a useful tool for the teacher. The consequence map differs from a simple "what if" consequence maps (Lock & Ratcliffe, 1998) in its complexity. By making the resolving of the issue, the focus of the whole teaching topic, means that the issue forms the framework through which science concepts are introduced. The consequence map thus incorporates the issue followed by the scientific concepts. Only those concepts that play a role in a subsequent socio-scientific decision making are included. The society now forms the limits on the concepts needed and hence the size of the concept map component. This is no longer left to a purely theoretical, scientific framework.

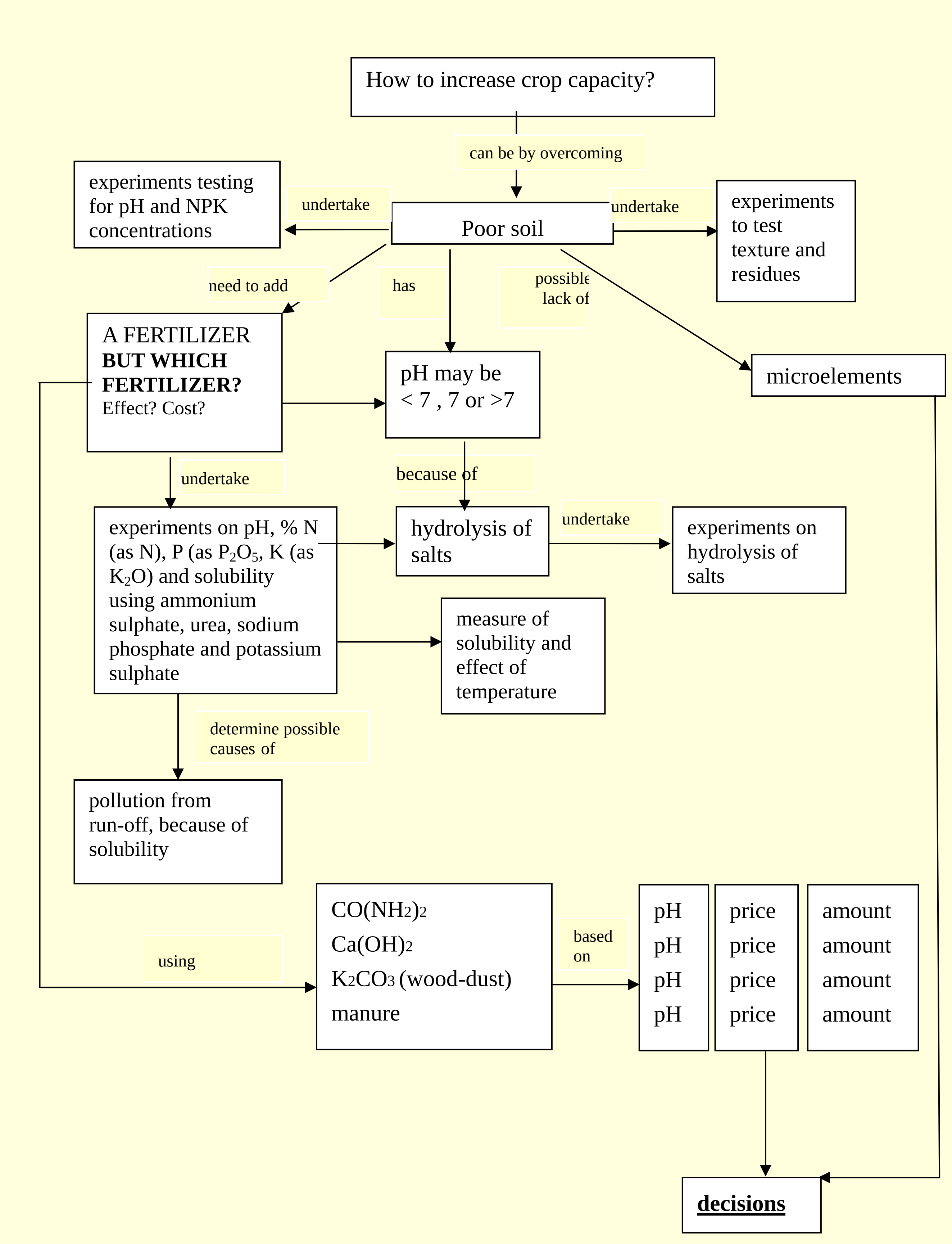
The consequence map thus included the following components:

- relevant problem for the students, determined by the teacher who supposedly should know much about the students needs and preferences and interests
- different teaching approaches which led to introducing science content helpful to the finding of a solution, or making a decision;
- science content as a heart of the teaching (could be presented as a concept map)
- and not necessarily come from one subject domain;
- solutions which lead to the final decision-making

The hierarchy within the consequence map can be expressed in terms of the amount of information/skills needed (taken) from the previous steps. Figure 1 gives an example of a teacher created consequence map. However this example does not highlight the state of art; it is a typical example by a chemistry teacher. All necessary components for the consequence map are included. The weakness appears in terms of involving ideas-solutions from other science subjects areas, rather than just chemistry and paying little attention to the development of social skills through students centred activities, other than experimentation.

Figure 1

Scenario – The farmer started growing grain 3 years ago. Unfortunately every year he is getting less and less grain. He is using the same land and even the same fertilizers. At the same time, his potatoes and vegetables are growing in the same conditions very well. He is very concerned and thinking who to consult to find out how to increase the grain crop.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experiments on hydrolysis of salts
measure of solubility and effect of temperature
determine possible causes of
pollution from run-off, because of solubility
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$CO(NH_2)_2$
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Teachers ownership and readiness to teach STL

This was the subject of a study in which teachers were encouraged to develop their own supplementary teaching material meeting the STL criteria (Rannikmäe, 2001, Holbrook, 2004) and to try it out in the classroom. The layout used included a detailed description of a suggested teaching strategy with a consequence map, where the emphasis was on social issue or concern arising from the scenario (a story modeling real life issue, where students could be involved) and also on describing different ways to approach this problem-solving and/or decision-making situation.

Altogether, twenty chemistry teachers, highly motivated to work with the principal investigator, were invited to participate in a longitudinal study undertaken in 1999-2003. All teachers had been involved in earlier in-service courses by the principal investigator and had at least 10 years of experience in teaching high school chemistry. The teachers formed peer supporting groups, working together and exchanging information which was seen as an encouraging factor.

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 (to measure student achievement). All teachers were asked to use also already existing STL materials, created during earlier ICASE & UNESCO workshops (Holbrook & Rannikmäe, 1997) and develop these, by themselves, into teaching material suitable for grade ten students (Chemistry is taught as separate school subject in Estonian schools) . 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’s change over the 4 years period - immediately after the 6 month intervention, 12 month after the end of the 6 month intervention and finally, 3 years later. The data collection included the use of semi-structured pre- and post- intervention interviews with teachers, observations and written records from all stages in the development of teaching materials (called scripts). Longitudinal data were collected using similar interviews and observation schemes.

A pre-intervention, semi-structured interview was planned to determine teacher's perceptions and beliefs in three areas:

- goals for teaching chemistry in grade 10;
- understanding about the development problem-solving and decision-making skills among the students;
- the meaning of student centred teaching.

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

- student achievement;
- teacher 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 and student achievement during the 6 month intervention study.

Research findings

From the pre-intervention interviews with teachers, it appeared that teachers were separating subject knowledge from skills. Skills were linked with students involvement in the learning process, whereas knowledge was given by the teachers' talk or the textbook. (i.e. 'to teach general properties of metals', or 'skill to write ionic equations using the table of solubility'). In the interview, the teacher's 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 illustrates the focus of goals, where the division is based on the teachers answers and does not cover all possible domains. Social goals were linked mainly with environmental issues; only very few teachers mentioned goals linked to careers, or daily life needs. All teachers who recognised social goals, also emphasised the need to teach general skills in chemistry lessons ('to develop a responsibility to protect the environment', or 'to understand possibilities for linking future life with chemistry').

Table 1: Stated Goals of Teaching (pre-intervention interview with teachers)

Teacher=20 / Focus of goals	Number of teachers giving goals in this domain	Number of goals given by the 20 teachers	Manner in which goals were worded: teacher centred way	Manner in which goals were worded: student centred way
Subject oriented goals	20	74	71	3
Goals oriented to general skills	16	21	16	5
Social goals	9	12	4	8
Total	-	107	91	16

The manner in which teachers worded the goals illustrated their actual approach to teaching. The fact that less than 20% of goals were presented (orally in the interviews) in a student centred way was partly based on their understanding of student centred activities. Problem solving and decision making were not seen as components of student centred teaching. Student centred teaching was expressed in terms of solving numerical tasks, doing individual work with the textbook, or conducting an experiment. Communication between students was never highlighted. Problem-solving often appeared as a lower level thinking activity where there was little link with everyday life, if at all.

As Einstein put it, “the formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill” (Penick, 1996). The findings indicate the need for suitable in-service for teachers. “Why” type of problems demand only one certain answer and do not develop the creativity of the learner. Teachers need be taught to look beyond the textbook and recognise wider problems.

After becoming familiar with the STL philosophy and the existing materials, the teachers started developing their own STL materials. The most difficult part was finding an issue or concern coming from the society and formulating it as a scenario – the starting point for STL teaching. Teachers gave mainly examples that illustrated scientific theories and their application. In the process of the development of the scripts, the following observations were noted:

- The teachers' skill to formulate the first draft of the scenario (a story leading towards a consequence map) depended on their previous perceptions about problem-solving situations - teachers who acknowledged socially derived problems in their interviews were able to find applications within the curriculum material.
- Teachers who stated, besides subject oriented goals, general and social goals for their everyday teaching, or presented large number of subject oriented goals a variety of ways, were easily guided to reformulate the scenario.
- The process of developing the consequence map encouraged teachers to overemphasise activities based on process skills and the scientific method.
- The emphasis in the scenario finally chosen by the teacher was linked with the quality of the consequence map created by the teacher. Well designed, socially derived scenarios indicating several strategies for seeing and solving the problem – the social issue based scenario.
- Poor consequence maps (teaching strategy leading to a simple concept map without decision-making in a social context) came from teachers whose priority for teaching was and remained to teach subject content and find, due to the intervention, more examples to show the application of conceptual science outside the school.
- The need for guidance decreased from workshop to workshop. Teachers picked up each others ideas and could interact orally, for example, in the consequence map formation. In so doing, teachers slowly moved in the direction of be able to create exemplary STL supplementary materials through their own ownership.

Science Teacher Ownership of STL Teaching

Teacher ownership of STL teaching was defined as the phenomenon of adaptation of everyday teaching by the teacher, accordingly to the STL philosophy. A major factor illustrating effectiveness of teacher –developed STL materials was teacher ownership of STL teaching, as expressed in terms of the ability to develop consequence maps. Based on the structure of consequence maps three categories of teachers were described against the level of STL ownership:

- subject learning activity based- dominance on facts and concepts encouraged by examination system;
- sequenced activity based with the emphases on process skills;

- social issue based, including problem solving and decision making strategies;

Subject learning activity based teachers (5 of the 20 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 (6 teachers) were a very mobile group of teachers. Although the teachers finally belonged to this group, this stage was passed by a number of other teachers during the workshops. These teachers approached problem-solving situations overwhelmingly using scientific method. There was a strong component of practical work in their teaching materials and in the consequence maps.

Social issue based teachers (9 teachers) put emphases on problem-solving and decision-making, and sometimes value judgments were included in the teaching materials. This group of teachers developed well structured consequence maps and showed competency in assessing students against STL criteria. Social communication was seen as the biggest value during the intervention.

Irrespective of the type of ownership most teachers, during the intervention, developed a more advanced perception regarding their role as facilitators of learning. The teachers increased 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 materials developed by the teacher, were used.

The teachers, however, did not recognise their growth in curriculum related knowledge and skills, as their marking scheme (even though it had changed) still gave high emphasis to the role of subject knowledge. The fact that students' essays were more developed than in the pre-test was not recorded 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 student's responses again. All teachers agreed with the increased students' achievement in the problem-solving and decision-making areas and, through that, were able to recognise 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 that when I look again at the test, and if I had marked the test against these criteria – 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 teacher interest in publishing them. Here again, the value of team work was highlighted and the need for looking through and discussing together all the developed materials. The idea of the teacher as a researcher was acknowledged.

Here I have described more precisely how ownership on teaching STL was formed as result of 6 month intervention. Ten month later, as well 3 years later, conducted observation and interview showed that all 16 teachers (4 dropped out for different reasons) kept ownership on STL, expressed in terms of using socially derived scenarios in their teaching. Seven teachers, from the 9 who initially had reached to the highest level of ownership, were still collaborating between each other and exchanging teaching ideas in terms of consequence maps. The lower two categories of teachers were approaching to each other and, after 3 years, it was not possible to separate the different categories of ownership. We can conclude that the most important aspect for STL ownership was acknowledgement of socio-scientific decision making in the classroom and the skill to express this process in the consequence maps by teachers.

The Way Forward – what can be suggested worldwide

The following conclusions can be put forward:

- 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- scenario type approach seemed to be part of permanent (and any) change
- Teacher ownership is important in directing teachers to follow developments and for motivation to work as a team. – continuous collaboration was the major factor to determine the longitudinal permanent change towards ownership on teaching STL
- Consequence maps are effective tools in developing STL ownership among teachers.

This article was initiated by the fact that teachers have been left alone in the classroom. We tried to show that just developing a new curriculum or new materials – for example, textbooks, are not the most essential tools for initiating better teaching. More than anything else teachers need to gain ownership of the idea, of measures of achievement, of self confidence and in stimulating peer-group support which is officially recognised.

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