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IMPACT ON STUDENT CHANGE IN SCIENTIFIC CREATIVITY AND SOCIO-SCIENTIFIC REASONING SKILLS FROM TEACHER COLLABORATION AND GAINS FROM PROFESSIONAL IN-SERVICE

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Abstract. *This study examines the impact on 9th grade students' change in socio-scientific reasoning and scientific creativity skills as a result of their science teachers' professional change, as a result of participating in longitudinal in-service courses. Eight chemistry and four biology teachers participated in two consecutive intervention studies, each running for 8 months, both designed to guide teachers on promoting the level of scientific literacy in their students. During the in-service courses, the teachers created teaching materials for 4 integrative teaching modules and taught their students using a designed STL teaching approach. The students' development was determined in terms of scientific creativity and socio-scientific reasoning skills, as indicators of scientific literacy gains, with an initial pre-test in the fall of the school year and a post-test in the spring after the STL intervention. The results of the study revealed that the degree of teachers' professional level in promoting problem solving and decision making teaching and its impact on student gains, as well as the number of teachers collaborating together in the teaching within a school, had a significant impact on their students' improvement in skills associated with socio-scientific reasoning and scientific creativity.*

Key words: *in-service courses, role of science teachers' professional change, socio-scientific reasoning and argumentation skills, scientific creativity, STL teaching.*

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Introduction

According to the results of the international survey on science education - PISA, Estonian 9th grade students are very good at acquiring factual and conceptual knowledge, but weaker at solving problems and making reasoned decisions. This is suggested to point to a lack of meaningful use of scientific evidence in their reasoning and argumentation (OECD, 2007).

A relevant way for students to foster their reasoning, verbalised through argumentation, is found to be the use of socio-scientific issues (Sadler *et al*, 2006), involving socially derived scientific situations from everyday life. But developing such skills in students is very demanding for teachers and their professionalism. As all countries in the developed world aspire to ever higher standards of education and training, developments along these lines clearly depend, at least in part, on having a sufficient supply of high-quality school teachers (Brighouse, 2008).

An essential outcome, put forward in school science curricula worldwide, is to enable students to use their understanding of science to contribute to public debate and make informed and balanced decisions about socio-scientific issues that impact on their lives. The rationale underpinning this important outcome is the notion of scientific literacy (Dawson, 2009). In contemporary knowledge societies, the production of scientific knowledge is increasingly reflexive, interdisciplinary and rapidly developing and this puts a great demand on teachers' professionalism to cope with this demanding situation in school science (van Eijck, 2010). There is a recognition today that the purpose of science education is to produce a scientifically literate citizenry in a form that is appropriate for describing and theorizing in the everyday world that we share with others (as opposed to testing situations in classrooms and laboratories) and, inherently therefore, science education takes on

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a societal meaning (van Eijck & Roth, 2010). The socially driven teaching and learning of science is an important essence of STL philosophy that combines, in science lessons, the relevant motivational beginning and identification of a socio-scientific problem, the teaching/learning of scientific concepts and processes, the solving of the problem, the making of reasoned socio-scientific decision and the drawing of conclusions (Holbrook & Rannikmae, 2007).

The definition of STL highlights the need for developing the creativity of students. The term "creativity" is used in the literature to refer to teaching and learning processes based on recognizing problems and discrepancies in accepted content, looking at things in different ways, making unexpected links among apparently discrepant elements of information and developing one's own solutions to problems and similar processes, rather than simply memorising prescribed content (Cropley & Cropley, 2008). Creativity is currently receiving increased attention in education; more and more school curricula now mention it, but the increased interest in creativity has occurred without reference to any value framework (Craft, 2006). The concept of creativity is hard to define as creativity is found in any domain of human activity (Clegg, 2008). The creativity of students as future citizens is an important goal advanced as important by most educators (Edwards & Blake, 2007; Shoshani & Hazi, 2007; Kaufman, 2006; Craft, 2006). Isaksen, Dorval, and Treffinger (2000) noted that CPS (creative problem solving) is based on the following principles: (a) the potential for creativity exists and can be expressed in every person at different levels and degrees; (b) creativity is related to personal preferences, style, and interests; and (c) one's level of creative functioning can be enhanced (Bahr *et al*., 2006). The problem however, is how to get teachers prepared to improve students' creativity through their everyday work in the classroom and to assist their own development in this area.

As the conception of creativity is very broad, the focus for this research is narrowed to scientific creativity. The definition of "scientific creativity" can be conceptualized as an individual and social capacity for solving complex scientific and technical problems in an innovative and productive way (Heller, 2007). The measurement of creativity has caused much discussion, but since the 1950-s, the Torrance Test of Creative Thinking (TTCT) has been accepted as a valid measure through 4 indexes (fluency, originality, flexibility, and elaboration). The same scoring is used in Hu and Adey's (2002) scientific creativity test applied in this study.

A further component of STL, as highlighted through the proposed definition, is the process of reasoning that is expressed in verbalized form as argumentation. Everyday communication includes argumentation providing humans with a very powerful thinking tool, given that it allows individuals to deny, criticise and justify concepts and facts, as well as find opposing views and generate a new perspective in social interaction or in self-deliberation. In addition, argumentation is important because it prepares individuals for scientific language. Thus, when learning science, students do not learn only from their own perceptions, but also from the ways students describe, explain, justify and argue in this domain. In conclusion, argumentation provides a rich terrain for research and inquiry, given its importance for solving differences and reaching consensus, as well as its central role in thinking and scientific language (Venville & Dawson, 2010).

The study by Topcu, Sadler and Ozgul (2010) has provided new evidence related to informal reasoning in the context of socio-scientific issues. At the sample level, this study provides an initial picture of the reasoning practices of pre-service teachers as opposed to science learners. The results indicate that teachers would benefit from learning experiences that support their own informal reasoning practices as well as their ability to foster development of these practices among their students.

Background to the Research

This article reports on an evaluation of teacher changes through the impact of a longitudinal in-service programme, and on interrelated students' scientific literacy gains in terms of scientific creativity and socio-scientific reasoning. For this study, a definition of scientific and technological literacy (STL) is taken to be "STL, as the major goal of science education, is the need to develop the ability to utilise sound science knowledge creatively in everyday life by solving problem and making reasoned decisions, involving value judgements and communication skills" (Rannikmäe *et al.,* 2010).

In-service courses were planned on the basis of previous research which had revealed that the teachers lacked interdisciplinary knowledge (Rannnikmäe, 2008) and that better results in influencing students' attitudes towards science learning, and accordingly their better achievement, were obtained by teachers' collaborative team-work using a STL teaching approach (Laius & Rannikmäe, 2006). A further important finding from previous research was that the only criterion for an effective STL in-service course was ownership of created STL materials meeting specified requirements (Rannikmäe, 2005; Rannikmäe, 2001).

Taking into consideration these previous research findings and the theoretical background, a longitudinal in-service programme for teachers was designed and the possibility of change of both teachers and students, in the sense of STL teaching and learning, investigated. The effectiveness of two STL in-service courses, on teachers' possible readiness to change professionally, was determined and published as the first part of this longitudinal study (Laius, Kask & Rannikmäe, 2009).

This article focuses on the impact of teachers' professional change on their students' socio-scientific reasoning and scientific creativity skills, these being taken as measures of their scientific literacy. Bearing in mind that one factor improving the effective role of teacher is ensuring teacher–teacher dialogue, this is included as a component of the professional development (Penlington, 2008; Williams, 2008) and teacher collaboration during the intervention is specifically encouraged. However this research focuses overall on the outcomes from developments from science teachers' in-service courses that support scientific literacy as the major goal for teaching.

Considering the previous background and focus, the following research questions are put forward:

1. How does the professional level of science teachers and the induced change, within a STL in-service provision, influence their students' scientific literacy, measured through socio-scientific reasoning and scientific creativity skills?
2. How does teachers' integrative teamwork impact on their students' socio-scientific reasoning and scientific creativity skills?

Methodology of Research

This longitudinal study (2004 – 2008) included two consecutive school years of interdisciplinary in-service training courses for chemistry and biology teachers: "The up-to-date trends in molecular and medical biology" (30 teachers), followed by "The development of students' creative and critical thinking skills through real-life situations" (12 teachers from the previous in-service). Based on outcomes from these in-service courses, an 8-week teaching programme using 4 teacher interdisciplinary socio-scientific modules (Table 1) were created and the impact of the subsequent STL teaching on their student's socio-scientific reasoning and scientific creativity skills was measured using pre- and post-tests. The structure of the STL teaching modules (each 3-4 lessons) included three stages: (1) motivational beginning and identifying socio-scientific problem; (2) teaching/learning scientific concepts and processes and creative problem solving; (3) the reasoned socio-scientific decision making and drawing conclusions to the problem, initiated in the first lesson.

Table 1. Description of the developed socio-scientific teaching modules.

Scientific focus of the Module	Key conceptual aspects	Student involvement in socio-scientific reasoning	Student involvement in scientific creativity
Senses	Smelling, olfactory organs, structure of skin, absorption	Developing sensitivity to science and social problems, Introducing the structure of argumentation, enhancing divergent reasoning skills, problem-solving and decision-making tasks.	Creating research questions, creative experimental ability tasks, creating informative posters, identifying alternative uses and choices, role playing activities.
Metabolism	Diets and food energy, digestion, nutrients		
Biotechnology	GMOs and cloning, Ethics		
Environmental issues	Fossil fuels, oil contamination of the Baltic sea, consequences for nature		

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Sample

The sample consisted of 248 9th grade students (one class in 8 schools, chosen against their 8 chemistry and 4 biology teachers, who had been participating in both in-service programmes). By requiring students to undertake all pre- and post-tests, the number of students was reduced to 224 students when forming the final sample for longitudinal analysis. This approximate 10% dropout was not taken to change the representativeness of the sample

Instruments and Procedures

To analyse students' socio-scientific reasoning skills before the study (measured in terms of quality of argumentation), a real-life situation was created including both scientific (absorption, smell and olfactory organs, senses) and social (smoking as a risk behaviour and ethics) concepts. After engaging students in the situation, in which two boys we suspected of entering the class after smoking, they were asked why the teacher was able to detect different smells from the boys and whether the boys were telling the truth. An additional task was to write their reasons for their statements (Laius *et al.,* 2008).

The post-test was a socio-scientific situation, created on the cloning of a favourite puppy with the title 'to clone or not to clone?' Science teachers (14) validated both instruments during an initial first in-service course. A total of 61 nine-grade students, in one randomly chosen secondary school, piloted these instruments giving results which were not statistically different (the Wilcoxon Signed Ranks T-test significance value was given by p=0.61). These tests were therefore taken to be comparable and used respectively as pre- and post-test for measuring socio-scientific reasoning through the quality of argumentation put forward.

To assess the students creative thinking skills, the scientific creativity test developed by Hu and Adey (2002) was translated into Estonian, slightly modified (two items were dropped because of lack of relevance to the Estonian curriculum and to students, as determined by the results of a pilot study). The 5 test items were assessed by summing scores of fluency, flexibility, and originality considered by Torrance (1990) as central features of creativity. The students' overall scores from the scientific creativity test were grouped into five hierarchical levels, the first being the lowest and the fifth the highest in order to standardise the test results to make them comparable with the argumentation test. The scientific creativity test was validated by 7 expert teachers during a science teachers' summer school (Laius & Rannikmäe, 2006).

To score the students' argumentation skills, a series of characteristics were identified after reading all the student answers. These characteristics were utilised in finding patterns of students' reasoning skills. According to the quality of the arguments, the students were categorised into five levels, taking into the consideration the components of argumentation and their logic in reasoning:

- Level 1 – no argumentation, just description of the situation (1 point);
- Level 2 – weak argumentation with logic mistakes (2 points);
- Level 3 – argumentation only in the social part of the situation (3 points);
- Level 4 – logical reasoning, using data from one area (social or scientific – either biology or chemistry) (4 points);
- Level 5 – sound and logical, interdisciplinary, reasoning and argumentation (5 points).

Data Analysis

The research data obtained as a result of standardisation or categorisation is ordinal in character and to develop descriptive statistics (means and standard deviations) as well as undertake non-parametric tests, Wilcoxon Signed Ranks Test was used to analyse related samples and the Mann-Whitney U Test was employed for independent samples. One-way ANOVA was utilised for comparing means of more than two groups and specifically for comparing students of different groups and also non-parametric correlation analysis. All data were analyzed and figures created using the SPSS 18.0 statistical analysis program.

Results of Research

The effectiveness of the science teachers' professional change resulting from the STL in-service course, considering the impact on their 9th grade students, was considerable. In all participating schools, the increase in students' scientific creativity and socio-scientific reasoning skills was statistically significant (Table 2).

Table 2. A comparison of the mean differences in scientific creativity and socio-scientific argumentation test results by schools.

School No.	No. of students	No. of teachers	Scientific creativity Mean *(SD)*					Socio-scientific reasoning Mean *(SD)*				
			Pre-test (max = 5)	Post-test (max = 5)	Change	Wilcoxon Signed Ranks Test Z	Wilcoxon Signed Ranks Test p	Pre-test (max = 5)	Post-test (max =5)	Change	Wilcoxon Signed Ranks Test Z	Wilcoxon Signed Ranks Test p
1	25	2	1.72 (0.74)	2.76 (0.78)	1.04 (0,61)	-4.25	0.000	2.00 (0.76)	3.68 (0.56)	1.68 (0.90)	-4.37	0.000
2	31	2	2.03 (0.87)	2.77 (0.67)	0.74 (0.68)	-4.07	0.000	1.48 (0.63)	3.10 (0.91)	1.62 (0.72)	-4.89	0.000
3	30	2	3.23 (0.97)	3.70 (0.88)	0.47 (0.57)	-3.30	0.001	1.67 (1.03)	3.13 (0.68)	1.46 (0.82)	-4.57	0.000
4	33	2	2.64 (1.03)	3.24 (1.00)	0.60 (0.56)	-4.19	0.000	2.21 (1.05)	3.42 (0.79)	1.21 (0.74)	-4.78	0.000
Average		2	2.28 (1.09)	2.99 (0.97)	0.71 (0.62)	-7.90	0.000	1.94 (0.96)	3.35 (0.76)	1.41 (0.81)	-9.23	0.000
5	19	1	1.26 (0.45)	2.05 (0.71)	0.79 (0.54)	-3.64	0.000	2.58 (0.96)	3.53 (0.61)	0.95 (0.60)	-3.49	0.000
6	29	1	2.10 (0.62)	2.41 (0.57)	0.31 (0.47)	-3.00	0.003	2.38 (0.49)	3.45 (0.69)	1.07 (0.65)	-4.66	0.000
7	29	1	1.48 (0.57)	2.17 (0.38)	0.69 (0.47)	-4.47	0.000	2.41 (0.57)	3.62 (0.56)	1.21 (0.62)	-4.78	0.000
8	28	1	2.46 (0.74)	2.93 (0.60)	0.47 (0.51)	-3.61	0.000	2.50 (0.58)	3.32 (0.61)	0.82 (0.67)	-4.07	0.000
Average		1	2.01 (0.76)	2.50 (0.61)	0.49 (0.50)	-7.42	0.000	2.43 (0.54)	3.47 (0.63)	1.04 (0.66)	-8.52	0.000
Difference between 1- and 2-teacher schools (Mann-Whitney U Test)						-1.81	0.071	*Difference between 1- and 2-teacher schools (Mann-Whitney U Test)*			-4.88	0.000

Figures 1 and 2 illustrate the impact on students of the differences in teachers' integrative and interdisciplinary teamwork in the favour of two teachers working as a team. Figure 1 shows that the number of students taught by two teachers is smaller in the case of zero change and bigger for two changes of level, although the overall difference in the increase of students' scientific creativity is not statistically significant (Mann-Whitney U Test $Z = -1.81$; $p = 0.071$). Figure 2 illustrates change in students' socio-scientific reasoning skills (Mann-Whitney U Test $Z = -4.88$; $p = 0.000$). These results show that two teachers induce the greater number of students' change of level, both in scientific creativity and socio-scientific reasoning skills.

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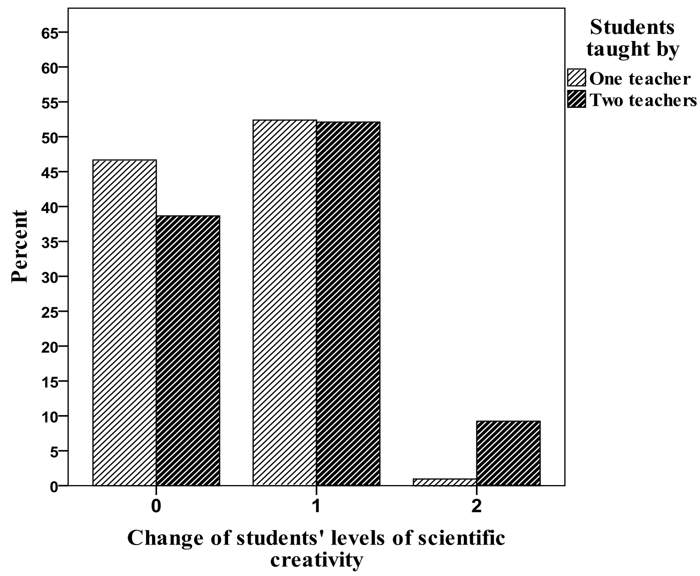

Figure 1: The percentage of students against number of changes of levels for scientific creativity according to the number of teachers collaborating.

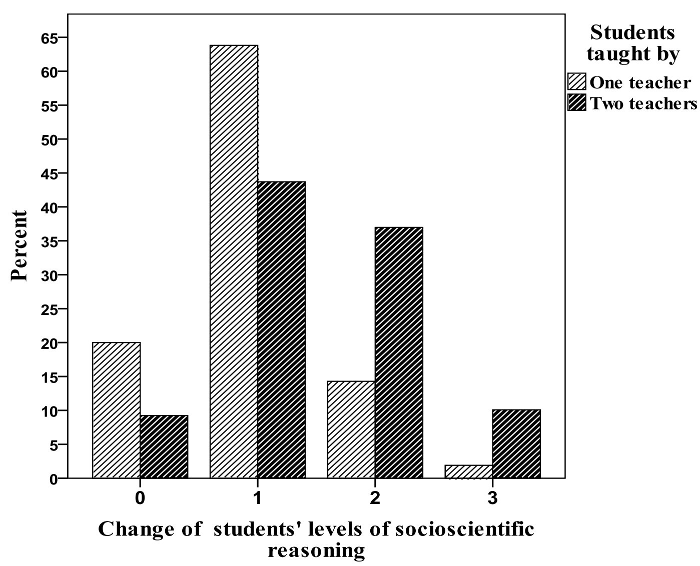

Figure 2: The percentage of students against number of changes of levels in socio-scientific reasoning skills, according to the number of teachers collaborating.

To relate student gains with teacher impact, either from two teachers collaborating in the same school, or only from being involved in the in-service programmes, it is convenient to combine the student change of levels from both scientific creativity (maximum change of levels = 2) and the levels of change of socio-scientific reasoning (maximum change of levels = 3). This leads to a 6 point scale, ranging from 0 change to a change of 5 levels.

Figure 3 shows the distribution of total change of levels in student's socio-scientific reasoning and scientific creativity skills, taught by one or by two teachers. The students taught by two teachers had the larger number of changes (mostly 2 to 5) in their development of scientific creativity and socio-scientific reasoning, whereas the students, taught by one teacher, stayed more on the same level of change (0 change), or made 1 or 2 changes. With one teacher involved, no students increased their level by 5 steps (Mann-Whitney U Test; $Z = -5.47$; $p = 0.000$).

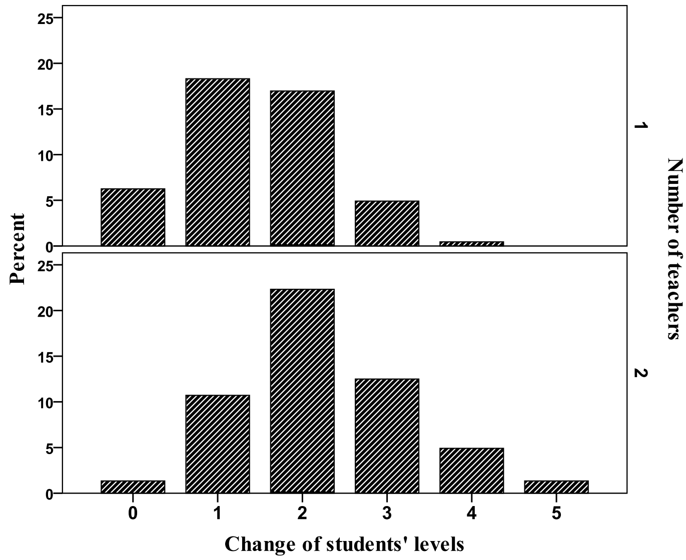

Figure 3: Total number of students' changes of socio-scientific reasoning and scientific creativity skills in comparison of one and two teachers, using STL teaching approach.

Figure 4 illustrates the dependence of teachers' acquired professional level, measured by four professional levels of teachers, as described in Laius *et al*. (2009), on the students' total number of changes of scientific creativity and socio-scientific reasoning.

The teachers' higher professional levels of STL teaching had a positive effect on their students measured skills significantly, as indicated by one-way ANOVA analysis results between groups of different teacher professional levels ($F = 8.33$, $df = 2$, $p = 0.000$).

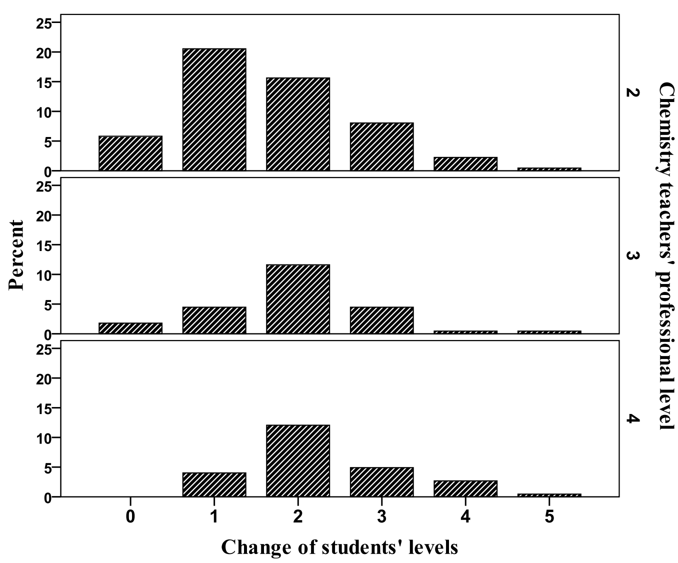

Figure 4: Comparing the levels of knowledge of Chemistry teachers after in-service (see Laius *et al.*, 2009) with the change of levels of students' scientific creativity and socio-scientific reasoning skills.

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Figure 5 illustrates the dependence of obtained professional level of teachers during the in-service course, in combination with the number of teachers collaborating in the teaching, on the students' total number of changes of levels for scientific creativity and socio-scientific reasoning. Not surprisingly the results show that the higher professional level attained by the teacher relates to greater changes of level by some of their students (3–4), but most effective in inducing more students to achieve five changes in levels is the collaboration of two teachers. Only in this case are some of their students able to go through five changes related to increases in their scientific creativity and socio-scientific reasoning skills.

Table 3 illustrates the dependence of teachers' professional level changes (measured by four categories of teachers, based on the four identified teaching characteristics: the quality of the constructed teaching materials, teachers' teamwork within the in-service groups and in school-based teams, the evaluation and fostering of the students' creative thinking skills, and the development and assessment of the students' reasoning skills) on the students' total number of changes of levels for scientific creativity and socio-scientific reasoning. Where the teachers had increased their category of STL teaching by at least one step, their students, at a class level, also improved their measured skills significantly more, compared to the students of those teachers who had not raised their professional level. The one-way ANOVA analysis of scientific creativity test results between groups ($F = 8.23$, $df = 2$, $p = 0.000$) and socio-scientific reasoning test ($F = 10.33$, $df = 2$, $p = 0.000$) are significant as are the correlations between the number of changes in teachers' levels and students' change in levels for scientific creativity and socio-scientific reasoning skills (Spearman's rho 0.242** and 0.289** respectively).

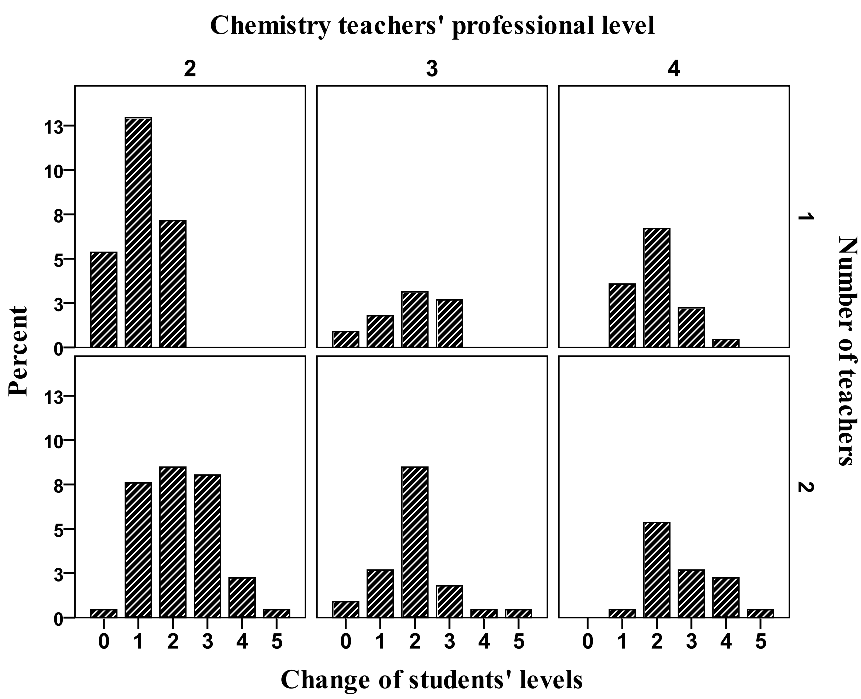

Figure 5: The impact of the number of teachers collaborating, related to the chemistry teachers' obtained level of knowledge (during in-service), on change of levels by students in scientific creativity and socio-scientific reasoning skills.

Table 3. The impact of teachers' change in STL teaching category, (resulting from in-service programmes), on students' change of level of scientific creativity and socio-scientific reasoning skills.

School	Number of students (N)	Change of Chemistry teacher's category	Change of Biology teacher's category	Percentage of total number of students' changes of levels					
				0	1	2	3	4	5
1	25	3 ⇒ 4	2 ⇒ 3	0	4	48	24	20	4
2	31	1 ⇒ 2	1 ⇒ 2	0	19	26	42	10	3
3	30	2⇒ 2	2 ⇒ 2	7	20	37	33	0	3
4	33	2 ⇒ 3	2 ⇒ 3	9	15	61	9	6	0
5	19	2 ⇒ 3		11	58	26	5	0	0
6	29	2 ⇒ 2		21	45	34	0	0	0
7	29	3 ⇒ 4		0	28	52	17	3	0
8	28	2 ⇒ 2		21	57	21	0	0	0

The overall outcomes show that only 5 students (2.2 %) who participated in this study were at the highest level (5th) of scientific creativity, based on the pre-test and only 2 (0.9 %) students associated with the fifth level of socio-scientific reasoning. However, after the 8-months teaching intervention, 10 students (4.5 %) illustrated the highest level of scientific creativity and 20 students (8.9 %) in socio-scientific reasoning skills based on outcomes from the post-test.

Discussion

The integrative science teachers STL in-service model was seen to be effective, as determined by statistically significant increases of students' scientific literacy components (scientific creativity and socio-scientific reasoning). Our research revealed also that Estonian students' socio-scientific reasoning (argumentation) skills and scientific creativity results were relatively low (the average of quality of arguments according to the pre-test was 2.38 (SD=1.05) on the scale of 5), as these skills were not purposefully fostered in Estonian science classes (agreeing with the PISA outcomes). Even though the general part of the curriculum identified the need for developing students' creativity, reasoning, problem-solving and decision-making abilities, Estonian teachers faced the dilemma, just like their colleagues in other countries, especially Post-Soviet, as whether to put their efforts into encouraging students to increase these skills, or to put their major effort into raising the society-identified importance of external examination performance (Burnard & White, 2008; Nicholl & McLellan, 2008; Simmons & Thompson, 2008), the external examination unfortunately paying scant attention to skills associated with creativity, reasoning, problem solving and decision-making.

In the identified situation, it could be said that the intervention promoting STL teaching/learning approaches was effective in increasing students' argumentation skills significantly (average results of socio-scientific post-test). The latter skills enabled the students to solve problems and make well-grounded socio-scientific decisions in their everyday lives. As reasoning skills and scientific creativity were important premises for both problem solving (PS) and decision making (DM) abilities, according to the earlier-mentioned definition of STL, the increase of students' socio-scientific reasoning and scientific creativity skills can be seen as resulting in higher scientific literacy levels.

The impact of the teachers' change of professional level related to STL teaching on the students' development of scientific creativity and socio-scientific reasoning skills illustrated the fact that both students' socio-scientific reasoning skills and scientific creativity skills can be developed; (only 19 students (8.5 %) (in schools 3,4,5,6 and 8) were not sufficiently guided by their teacher(s) to undergo change (neither in scientific creativity nor in socio-scientific reasoning skills). However the general trend was that teacher's change towards STL teaching related to change in their students' scientific creativity and socio-scientific reasoning ability, with greater change when two teachers collaborated compared with one teacher working in isolation. The latter expands the outcomes from previous research (Rannikmäe, 2005) which indicated that the category of teacher ownership in creating teaching materials is important in directing teachers to adopt change, recognises motivation to work as a team is an important contribution to enhance in in-service programmes and that in turn is effective in developing their students' scientific literacy, in terms of scientific creativity and socio-scientific reasoning.

Conclusions and Implications

The degree of teachers' professional change towards STL teaching as a result of in-service training had a positive impact on change of levels related to scientific creativity and socio-scientific reasoning by their students who underwent an 8 month longitudinal STL intervention undertaken by their teachers.

The development of students' scientific creativity and socio-scientific reasoning skills was influenced by whether one science teacher was involved in a school, or whether two science teachers collaborated together in the same school, using the STL teaching approach in chemistry and biology lessons. The gains were more strongly illustrated where two teachers were involved working collaboratively.

Limitations of Study

The study had limitations because of the comparatively small sample number of teachers, who could not be taken as representative of Estonian teachers as a whole, and by the specific conditions under which the teachers were involved in the STL in-service programmes.

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