JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898

UPPER SECONDARY STUDENTS` SELF-PERCEPTIONS OF BOTH THEIR COMPETENCE IN PROBLEM SOLVING, DECISION MAKING AND REASONING WITHIN SCIENCE SUBJECTS AND THEIR FUTURE CAREERS

Abstract. *Science education is expected to play a major role in developing abilities of students and in conjunction with meaningful learning in science lessons, its impacting on students' future careers. A three part instrument was composed, based on a review of relevant international literature plus competences emphasised in the Estonian curriculum, related to process operational thinking, gathering students' perceptions of the science provision offered and students' future career preferences. The study was carried out in November 2011 on grade 10 students (N=2217) and in April 2012 on grade 11 students (N=1821) from the same set of schools. Findings indicated that students' perceived competence, despite grade, gender or school average examination results, was similar. Even more, students felt that Biology and Geography subjects focused more on skills development than Physics and Chemistry. As in previous studies, conducted at the lower secondary (grade 9) level, students indicated they were not interested in science related careers and preferred to seek employment in the field of social science.*

Key words: *career preferences, perceived competence, science subjects.*

Regina Soobard, Miia Rannikmäe
University of Tartu, Tartu, Estonia

Regina Soobard,
Miia Rannikmäe

Introduction

The purpose of science education in schools is seen as promoting scientific literacy (Bybee, 1997; Holbrook & Rannikmäe, 2009; Murcia, 2009; DeBoer, 2011; Deng, 2011; Roberts, 2011; Soobard & Rannikmäe, 2011), enabling students to solve meaningful scientific problems and make relevant justified decisions (Holbrook & Rannikmäe, 2009; Feinstein, 2010; Choi et al., 2011) and to deal with science-related issues related to their own lives when the need arises (Aikenhead et al., 2011). Thus, scientific literacy is not taken here to be about the gaining of science knowledge itself, but capabilities of utilising such knowledge in a new or unfamiliar situation for problem solving and decision making (Holbrook & Rannikmäe, 2009). This requires students indicating multiple operational skills through demonstrating a (high) degree of cognition associated with undertaking scientific processes, e.g. (posing scientific question for problem solving, explaining phenomena scientifically, drawing evidence based conclusions, making justified decisions).

One factor influencing achievement in science lessons is views towards self (Hansford & Hattie, 1982; Pajares, 1996; Marsh & Craven, 2006; Huang, 2011) and for improved achievement, Taras (2002) suggests students need opportunities to take responsibility for their learning through understanding their own cognition and cognitive ability thus increasing their competences related to scientific literacy and their thinking about thinking (metacognition) (Choi et al., 2011). Focusing on the perceived competences is necessary as one's understanding of his/her competence can lead to improved overall learning, becoming an independent life-long learner, and enhancing achievement of higher levels of scientific literacy (Taras, 2002; Blumenfeld et al., 2005; Choi et al., 2011). According to Fraser and Greenhalgh (2001), feedback about performance enhances the extent to which individuals continue to improve.

In other words, this is important for raising the level of being scientifically literate (Choi et al., 2011) and leads to self-directed learners (Fraser and Greenhalgh, 2001), a goal put forward in promoting scientific literacy (Choi et al., 2011). Students need also to be responsible for their learning (Taras, 2010) so as to better feel the usefulness of science in their own lives (Feinstein, 2010) and also become aware of their academic achievement (Huang, 2011). This suggests that enhanced scientific literacy is also governed by perceived competence of students' operational skills and application of the science curriculum and how it is implemented in science education (Deng, 2011). Even more, science subjects need to provide students with the necessary skills for entering into the future workforce (Bybee & Fuchs, 2006). In the 21st century, students need to cope with challenging employment demands (Bybee & Fuchs, 2006). Therefore science education has an impact on students' future career choices and teachers need to take this into account when planning teaching activities in their science classes (Lavonen, 2008).

This study seeks to clarify students' perceived competence in operational skill components of scientific literacy (taken to be associated with problem solving, decision making and reasoning). Self-perceptions are seen as a meaningful way to indicate the achievement of higher scientific literacy. The role of science subjects for developing wider scientific literacy is also investigated to see how science lessons are enhancing the development of operational skills components. Additionally, students' career preferences are studied, to determine whether there is any possible relationship between school science experiences and career preference for science related careers.

The following research questions were posed:

1. How do grade 10/11 students perceive their competence in operational skill components of scientific literacy seen as important in science learning?
2. How do grade 10/11 students perceive their competence in operational skill components of scientific literacy developed in the different science subjects?
3. How do grade 10/11 students perceive their future careers?

Background

Perceived Competence

The role of understanding a person's own competence is recognised as a purpose of comprehending real life situations, choosing and keeping science related occupations and leading to lifelong learning (Aikenhead et al., 2011). In other words, students' perceived competence influence their performance and it is recognised that views towards self are connected with actual achievement (Wong, Wiest & Cusick, 2002; Marsh & Craven, 2006; Huang, 2011; Law, Elliot & Murayama, 2012; Froiland & Oros, 2014).

Perceived competence has been associated with Self-Determination Theory (SDT) (Deci & Ryan, 2000). This theory indicates that the perceived (or felt) competence is the ability to understand or grasp the meaning behind the task and an ability to enact it. Perceived competence has also been defined as a person's subjective beliefs about their capabilities of successful task performance (Cho, Weinstein & Wicker, 2011). Findings by Ryan and Deci (2000) show that students feel higher competence, if they have the necessary skills to cope with, and understand, the tasks. This suggests that students need to be provided with the meaningful and challenging situations in their learning tasks (Ryan & Deci, 2000; Vaino, Holbrook & Rannikmäe, 2012). Also, perceived (or felt) competence has connections with students' intrinsic motivation (Harter, 1978; Deci & Ryan, 2000) and for this, students need also to experience self-determination of their behaviour (Ryan & Deci, 2000), e.g. includes both autonomy and competence.

A number of researchers have suggested that the evaluation of perceived competence should be undertaken in a domain specific context (Marsh & Craven, 2006; Chang & Cheng, 2008; Huang, 2011); e.g. achievement in science for science related perceived competence. PISA studies (OECD, 2007; Bybee & McCrae, 2011) used mainly non-contextualised student questionnaires, including general questions about interest, attitudes, and self-efficacy. The few contextualised questions in the PISA test for scientific literacy (*Interest in 'learning about' science* and *Support for scientific enquiry*) were asked directly after contextualised questions to add value to the assessment by providing data on whether students' answers differed when assessed was within or outside a context and whether answers varied between contexts. In other studies, besides using science achievement tests, non-contextualised (general) questions about attitudes, interests or self-efficacy were also asked (Chang & Cheng, 2008; Thomas, 2008, Bybee & McCrae, 2011). According to Thomas (2008) and Schraw (2000), this was problematic because general measures might not relate in students minds with themselves, in the sense of their actions in science classrooms. Additionally, Marsh and Craven (2006) noted that the relationship between views towards self and academic achievement was domain-specific, because this kind of relationship was stronger than global or general views toward self and academic achievement.

Science Learning

Identifying scientific issues in real life and using sufficient evidence and reasoning to support claims in problem solving and decision making issues, are put forward as aspect of learning in science subjects (OECD, 2007; Holbrook & Rannikmäe, 2009; Choi et al., 2011). Applying those components of scientific literacy in new situations, different from the learning situation, students can understand their own cognitive ability, to transfer their competence into new situations to undertake problem solving or decision making. If learning situations in science subjects allow students to experience challenges in undertaking tasks and they are successful, then it makes students feel themselves more competent, e.g. higher perceived competence (Vaino, Holbrook & Rannikmäe, 2012). In the end, this leads to valuing life-long learning (European Commission, 2007).

To investigate the development of competence in scientific problem solving, decision making and reasoning as a relevant part of science teaching, the science curriculum is analysed to ensure these competences are included. The National Curriculum of Estonia for upper secondary school identifies these competences as learning outcomes, as given below (Estonian Government, 2011):

1. Problem solving - solving problems using scientific methods (e.g. recognising problems, posing scientific questions, planning scientific investigations, controlling variables, analysing and interpreting results, drawing conclusions).
2. Decision making and reasoning - making reasoned decisions taking into account scientific, environmental, social, economic, political and ethical-moral considerations.
3. Understanding the nature of science and appreciating creativity in science.
4. Positive attitudes towards science within society and is competent to make reasoned decisions in career choices.

This description shows that those competences are seen as important components of the Estonian school curriculum (Estonian Government, 2011) and at the same time, today's society is moving towards more complex situations, which require a competence to recognise problems, solve problems, critically examine issues, and define a person's own position (Choi et al., 2011).

Career in Science

A component long associated with enhancement of scientific literacy is attitude towards science (OECD, 2007; Simon & Osborne, 2010), which is likely to impact on students' future career choices (Holbrook & Rannikmäe, 2007; OECD, 2007). Park et al. (2009) note that students' future career aspirations in the field of science appear to be positively affected by their achievement in science education. Yet it is well known that, in general, students' attitudes towards school science are not sufficiently high for choosing a science related career in the future, or for holding an interest to engage with science related issues (OECD, 2007; Simon & Osborne, 2010). This is suggested because most students find science difficult and careers in science unattractive (Lavonen, 2008). However, findings by Lavonen together with colleagues (2008) show that both boys and girls hold a neutral opinion about the role of school science in improving their career chances and in helping them to become familiar with new and exciting jobs in science. This leads to the conclusion that to facilitate students choosing science related career, science lessons need to more intensively develop competence in components of scientific literacy, which are needed for employability in today's workforce (Bybee & Fuchs, 2006; DeBoer, 2011). Findings from a previous investigation also indicate that, along with other factors, the quality of science teaching and the personal encouragement (e.g. feedback leading to accurate picture for perceived competence) given to students by science teachers plays an important role in choosing science related careers (Lavonen, 2008).

Methodology of Research

Research Sample

All grade 10 and 11 students were selected from a representative sample of schools (N=44) in Estonia. Schools were chosen based on location (the capital; towns with at least two gymnasiums; rural areas). Location was taken into account to ensure that schools in all areas had an equal possibility to be involved. After choosing schools based on location, schools were divided into three groups based on the students' average national examination results (high, average, low), where equal numbers of students were included in each group. Exam scores were between 82-32. High achieving schools were identified where the average school mark was taken as 82-65, average as 64-58 and low achieving schools where the average school mark was taken as 57-32. This division was made when the sampling was composed. Group 1, with averages from 65 to the highest (82), was called the high achieving group and included mainly larger schools from the capital. Because of this, these schools provided the largest number of students participating in this study (N=2445). Group 2, included schools, with average exam results 58-65 and involved 961 students. Group 3 students were from low achieving schools (student N= 632), where students were mainly from rural areas and the number of students per school is low. All grade 10 and 11 students were included in the study in the selected schools.

The final data set contained returns from 2217 10th grade students and 1821 11th grade students. The total number of boys participating in this study was 1648 and the number of girls was 1987. Unfortunately, in approximately 10% of returned questionnaire the gender was not marked. Such data was omitted when referring to gender differences. The data gathering period was November 2011 – April 2012.

Instrument and Procedures

The instrument consisted of three sections:

Section 1 – This consisted of 8 items seeking students' perception of their own competence in general scientific process skills, seen as part of the curriculum. The 8 items covered skills expected to be somewhat acquired before and enhanced during gymnasium teaching, related to problem solving through scientific inquiry (items 1-5), familiarity with figures and graphs (item 6), giving explanations (item 7), and undertaking decision making (decisions made in the face of multiple options) (item 8). As it was important to keep the questionnaire to a reasonable length, these 8 items were chosen because they gave a reasonable coverage of student expected process learning in science outside of any specific content area associated with lessons in biology, chemistry, geography and physics.

Section 2 – This consisted of 8 items, repeated for each of the 4 science subjects taught in grades 10-12, seeking students' perceptions towards the science teaching received and hence giving an indication of the teachers' orientation towards science as process versus science as product. Section 2 was the longest section, but each of the 8 questions was applied to chemistry subjects, biology subjects, geography subjects and physics subjects in turn. Item coverage went beyond operational skills and also incorporated whether values (item 1), nature of science (item 5) and the area of creativity (item 8) were promoted through science classes, as perceived by students.

Section 3 – This consisted of 10 items seeking students' perceptions towards a future career. Section 3 sought to interlink learning in science lessons with career expectations (items 1, 2, 3 and 4), whereas items 5 and 6 tried to relate careers to specific skills promoted in section 2. The remaining items asked more specifically the careers domains students had in mind.

The instrument is indicated in Table 1.

ISSN 1648–3898

Table 1. Overview about the instrument.

Section in the instrument	Examples of items (English translations)
1	• I am able to identify problems with a science content • I am able to pose scientific questions for investigations. • I am able to plan scientific investigation. • I am able to solve problems • I am able to draw conclusions based on results obtained • I am able to use information from figures and tables • I am able to explain phenomena using scientific knowledge • I am able to make evidence based decisions.
2	• Teaching in [science subjects] i.e. chemistry or biology or geography or physics includes paying attention to the importance of science and technology in society. • Teaching in [science subjects] includes the ability to pose scientific questions for investigation. • Teaching in [science subjects] includes the ability to solve scientific problems. • Teaching in [science subjects] includes the ability to plan an investigation. • Teaching in [science subjects] includes coverage of ideas on the Nature of Science. • Teaching in [science subjects] includes making decisions, where there is a need to take into account not only the scientific content but also the social, economic, ethical and moral aspects. • Teaching in [science subjects] includes the ability to explain phenomena using science knowledge. • Teaching in [science subjects] helps us to develop creative thinking.
3	• After high school I am planning to take up a science related career. • In the future I am planning to have a science related job • From my science lessons I have been able to obtain an overview of science related professions • I wish to seek a job that requires me to use knowledge and skills obtained from science lessons to solve problems • I wish to have a job that requires creative thinking • I wish to have a career that involves decision-making. • In the future I wish to work in the following fields: 1. Medicine 2. Social sciences (economics, law) 3. Natural sciences (chemistry, biology, geography, physics) 4. Engineering and technology

The instrument consisted of 50 items within a 4 point Likert scale (strongly disagree; disagree; agree; strongly agree). Four points were used to ensure that students indicated either their agreement or disagreement. The instrument was validated using opinions from 5 experienced science teachers, whose role was to ensure that items were relevant in terms of science teaching. The instrument was also piloted among pre-service science teacher students and a sample of grade 10 and 11 students. Their role was to ensure that questions were understandable for upper secondary school students. The reliability, calculated using Cronbach alpha for the overall instrument, was 0.93, with Cronbach alpha for each section 0.79, 0.92 and 0.72 respectively. Item-total correlations and Cronbach alpha, if items were deleted, were also analysed. Analyses indicated a generally high level of response consistency within the instrument items as a whole and to the items contained within each section. Data were solicited from grade 10 students towards the beginning of their grade 10 studies and from grade 11 students towards the end of grade 11. Therefore similarities and differences indicated student self-perception development across 2 grade levels.

Data Analysis

Data from the completed questionnaires were examined and eliminated if there was a lack of meaningful participation (e.g. only one section was answered); eliminated questionnaires were under 5%.

Data were analysed using Rasch analysis (RUMM2030) and PASW Statistics 18. Rasch analysis was used to determine the quality of the developed instrument, e.g. to determine how well items and persons matched each other, as well as to establish the internal consistency and reliability of the set of items (Oon & Subramaniam, 2013). PASW Statistics was used to determine how responses to single items within the sub-sections varied between three exam sub-groups, grades and gender (Cohen et al., 2007).

Results of Research

Assessment of the Quality of the Instrument (outcomes from the Rasch analysis)

The outcomes from administering the instrument were analysed using Rasch analysis. The distribution graphs (Figure 1) indicate that on the whole, items targeted the persons being measured. This figure shows not only items from the whole questionnaire (50), but also students' answer distributions from three sections in this instrument (150 choices). Only a few item responses fall out outside the range of person's threshold locations and the items seem to be well distributed across the identified person ability range.

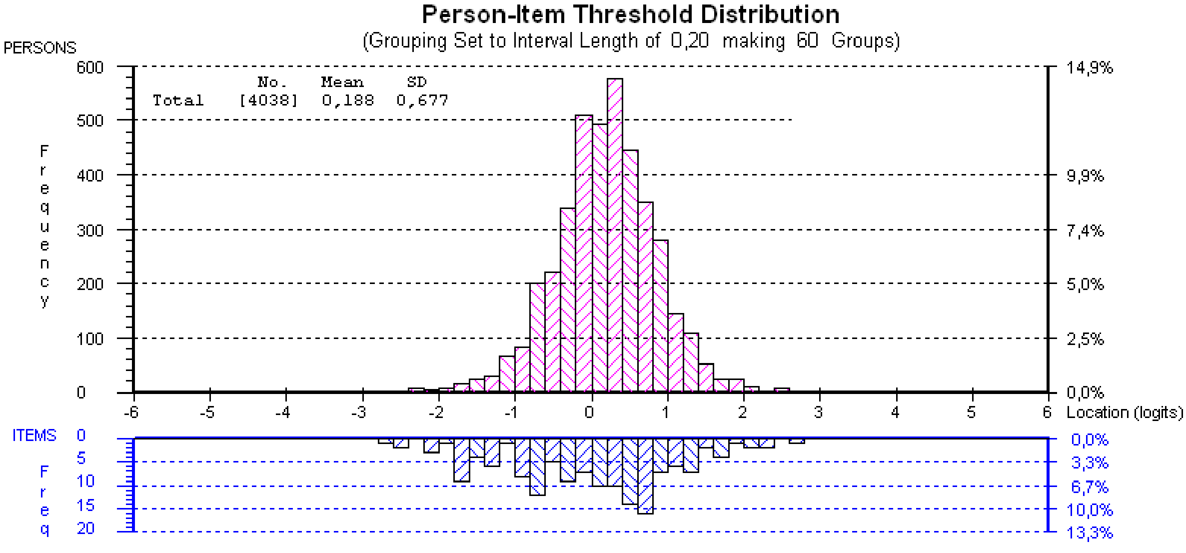

Figure 1: Person-item threshold distribution for the full scale.

Section 1 - Students' perceptions towards 8 skills

Students' self-perceptions towards the 8 skill related items in section 1 were examined overall (Table 2) and also in three categories: grade 10 versus grade 11 students, boys versus girls (Table 2) and perceptions of students from each of the three school groups based on average examination results (Table 3). Results indicated that overall students agreed that their self-perceptions were higher in recognising problems (55.9% agreed), drawing conclusions (76.8% agreed), using figures and tables as a source of information (78.7% agreed) and making evidence based decisions (57.3% agreed). At the same time, they were not confident in problem solving in general (62.4% agreed), in reasoning (54.8% agreed), in planning scientific investigation (58.9% agreed) and in posing scientific questions for investigations (54.1%). Similar pattern were found across grades, among boys and girls and between the three exam groups.

Table 2. Students agreement/disagreement with 8 sub-components of operational skills (overall, grade and gender).

Items in section 1		Overall		Grade				Gender			
				10		11		Boys		Girls	
		Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
Recognising problems	N	2241	1765	1245	956	996	809	975	660	1027	945
	%	55.9	44.1	56.6	43.4	55.2	44.8	59.7	40.3	52.0	48.0

ISSN 1648–3898

Items in section 1		Overall		Grade				Gender			
				10		11		Boys		Girls	
		Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
Posing scientific questions for investigation	N	1848	2181	1022	1191	826	990	774	873	898	1081
	%	45.9	54.1	46.2	53.8	45.5	54.5	47.0	53.0	45.4	54.6
Planning scientific investigation	N	1651	2372	855	1351	796	1021	718	928	772	1203
	%	41.1	58.9	38.7	61.3	43.8	56.2	43.6	56.4	39.0	61.0
Solve scientific problems	N	1513	2509	847	1358	666	1151	735	906	610	1368
	%	37.6	62.4	38.4	22.7	36.7	63.3	44.8	55.2	30.8	69.2
Drawing conclusions	N	3092	932	1706	500	1386	432	1252	393	1533	444
	%	76.8	23.2	77.3	19.3	76.2	23.8	76.1	23.9	77.6	22.4
Figures and tables as a source of information	N	3168	860	1785	426	1383	434	1312	332	1536	445
	%	78.7	21.3	80.7	53.3	76.1	23.9	79.8	20.2	77.5	22.5
Explaining phenomena scientifically	N	1817	2201	1032	1176	785	1025	835	801	784	1195
	%	45.2	54.8	46.7	42.5	43.3	56.7	51.0	49.0	39.6	60.4
Evidence based decision making	N	2297	1711	1264	934	1033	777	1004	637	1059	908
	%	57.3	42.7	57.5	42.5	57.0	43.0	61.2	38.8	53.9	46.1

Table 3. Students agreement/disagreement with 8 sub-components of operational skills based on examination groups.

Items in section 1		Exam groups					
		1		2		3	
		Agree	Disagree	Agree	Disagree	Agree	Disagree
Recognising problems	N	1421	1006	516	438	304	321
	%	58.5	41.5	54.1	45.9	48.7	51.3
Posing scientific questions for investigation	N	1176	1264	406	553	266	364
	%	48.2	51.8	42.4	57.6	42.2	57.8
Planning scientific investigation	N	1057	1379	395	563	199	430
	%	43.4	56.6	41.2	58.8	31.7	68.3
Solve scientific problems	N	945	1491	335	621	33	397
	%	38.7	61.3	35.0	65.0	37.0	63.0
Drawing conclusions	N	1914	525	734	223	444	184
	%	78.5	21.5	76.7	23.3	70.7	29.3
Figures and tables as a source of information	N	1958	418	742	217	468	162
	%	80.3	19.7	77.6	22.4	74.3	25.7
Explaining phenomena scientifically	N	1115	1319	427	532	275	350
	%	45.8	54.2	44.6	55.4	44.0	56.0
Evidence based decision making	N	1436	989	525	433	336	289
	%	59.2	40.8	54.8	45.2	53.8	46.2

Section 2 - Students' perceptions towards science subjects

Table 4 compares the student perceptions related to chemistry, biology, geography and physics lessons overall. Results showed that overall, students agreed that science subjects develop competence to recognise the importance of science in society and reasoning (in both 52.2% agreed). However, students disagreed that science subjects in general focus on problem solving (55.1%) and parts of problem solving (posing scientific questions or planning scientific investigation). It was surprisingly noted that according to students' perceptions, science subjects focused on developing an understating of the nature of science (59.2% agreed).

Table 4. Overall responses to perceptions of teaching emphasis in the 4 science subjects in agreement/disagreement.

Components of science subjects		Overall		Science subjects							
				Chemistry		Biology		Geography		Physics	
		Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
Importance of science in society	N	2083	1906	1764	2219	2924	1040	3133	848	2527	1455
	%	52.2	47.8	44.3	55.7	73.8	26.2	78.7	21.3	63.5	36.5
Posing scientific questions	N	1362	2625	1571	2406	2459	1500	2300	1673	2037	1935
	%	34.2	65.8	39.5	60.5	62.1	37.9	57.8	42.2	51.3	48.7
Solve scientific problems	N	1795	2199	1896	2072	2725	1227	2840	1140	2161	1817
	%	44.9	55.1	47.8	52.2	69.0	31.0	71.3	28.7	54.3	45.7
Planning scientific investigation	N	1156	2825	1384	2576	2127	1818	2054	1903	1431	2522
	%	29.1	70.9	34.9	65.1	53.9	46.1	51.9	48.1	36.2	63.8
Nature of science	N	2242	1547	2571	1202	2672	1074	2578	1178	2883	881
	%	59.2	40.8	68.1	31.9	71.3	28.7	68.7	31.3	76.6	23.4
Decision making	N	1436	2510	1436	2486	2468	1434	3157	772	1557	2360
	%	36.4	63.6	36.6	63.4	63.3	36.7	80.3	19.7	39.8	60.2
Explaining phenomena scientifically	N	2068	1895	2178	1766	2819	1103	3071	871	2398	1533
	%	52.2	47.8	55.2	44.8	71.9	28.1	77.9	22.1	61.0	39.0
Creativity	N	1624	2329	1831	2109	2397	1519	2516	1416	1952	1978
	%	41.1	58.9	46.5	53.5	61.3	38.7	64.0	36.0	49.7	50.3

Analysis of single subjects showed that biology and geography subjects were seen as more supporting the development of components part of scientific literacy (students agreed with all items). Chemistry was not seen supporting the development of competence in general scientific process skills. Perceptions towards physics subjects were more similar to chemistry than to biology and geography. Similar pictures appeared from the analysis between grades, gender and exam groups. In all groups, biology and geography were valued more than chemistry and physics.

Section 3 - Perceptions towards future career

Table 5 gives the overall, grade and gender responses to items in section 3. Students disagree that they like to continue science related studies (73.6%) and they prefer have science related career (76.8%). They also note that science subjects do not provide them with overviews of possible science related occupations (62.2% disagreed). However, they prefer professions requiring creativity (75.2% agreed) and decision making (76.8% agreed) and at

ISSN 1648–3898

same time, students don't prefer professions requiring competence in problem solving (70.7% disagreed). These perceptions are similar in all sub-groups (grade, gender, exam groups).

In future, students would like to work in the field of social science (57.3% agreed), and not in medicine, natural sciences and in engineering and technology. This distribution was similar among all groups, except in boys, who preferred also to work in engineering and technology (67.3% agreed).

Table 5. Responses to perceptions of career emphasis in overall, grade and gender groups in agreement/disagreement.

Items in section 3		Overall		Grade				Gender			
				10		11		Boys		Girls	
		Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
Science related studies	N	1058	2951	586	1614	472	1337	463	1172	478	1494
	%	26.4	73.6	26.7	73.3	26.1	73.9	28.3	71.7	24.2	75.8
Science related career	N	931	3078	520	1680	411	1398	403	1230	413	1561
	%	23.2	76.8	23.6	76.4	22.7	77.3	24.7	75.3	20.9	79.1
Introduction of science related professions	N	1511	2483	853	1333	658	1150	662	960	686	1284
	%	37.8	62.2	39.0	61.0	36.4	63.6	40.8	59.2	34.8	65.2
Professions requiring problem solving	N	1174	2823	653	1541	521	1282	527	1102	508	1459
	%	29.3	70.7	29.8	70.2	28.9	71.1	32.4	67.6	25.8	74.2
Profession requiring creativity	N	3019	997	1645	556	1374	441	1251	386	1450	526
	%	75.2	24.8	74.8	25.2	75.7	24.3	76.4	23.6	73.4	26.6
Profession requiring decision making	N	3063	925	1673	510	1390	415	1292	336	1452	509
	%	76.8	23.2	76.6	23.4	77.0	23.0	79.4	20.6	74.0	26.0
In the future I wish to work in the following fields:											
• Medicine	N	963	2931	551	1580	417	1351	302	1282	569	1353
	%	24.8	75.2	25.9	74.1	23.6	76.4	19.0	81.0	29.6	70.4
• Social science (economics, law)	N	2254	1678	1291	867	963	811	844	751	1180	763
	%	57.3	42.7	59.8	40.2	54.3	45.7	52.9	47.1	60.7	39.9
• Natural sciences (chemistry, biology, geography, physics)	N	1028	2870	573	1557	455	1313	470	1118	426	1491
	%	26.3	73.7	26.9	73.1	25.7	74.3	29.8	70.2	22.2	77.8
• Engineering and technology	N	1734	2187	985	1161	749	1026	1079	526	470	1452
	%	44.2	55.8	45.9	54.1	42.2	57.8	67.3	32.7	24.4	75.6

Discussion

The study focused on the determination of students` perceived competence related to operational science skills related to scientific literacy, the role of teaching of science subjects in developing such literacy components and students' perceptions towards future careers.

Section 1 Students' perception of their operational science competences

The students' overall perceived competence in being able to undertake operational science skills, identified through 8 Likert scale items, can be described as neither in agreement nor disagreement. The item on being able to use figures and tables as a source of information has the highest agreement nearly 79% students agreeing. Clearly students are generally very confident of their skill in this area whereas less than 40% students agree they are confident in being able to solve problem using a science content. It is interesting to note that students perceive their competence, in general, to be greater in using scientific evidence for decision making (57% agreeing) than for being able to explain phenomena using scientific knowledge (45% agreeing). Explaining phenomena scientifically requires science knowledge and can relate for students with particular science subjects. Decision making goes beyond only using science knowledge and includes informal reasoning, which includes arguments based on one's relevant knowledge and experiences (Sadler & Zeidler, 2005; Eysenck, 2012) and it may be easier for students to express themselves this way. However, they may also have misunderstandings about decision making processes.

More understandable, perhaps, is the perceived competence (46% agreeing) for formulating science questions and (41% agreeing) for planning scientific investigations. These suggest that less attention is being paid to student-centred teaching in these areas.

Students from both grades 10 and 11 perceived competences in the various components in a similar manner (see table 2) and hence findings differ little from the overall pattern. This, of course, is a matter of concern, because despite the additional two years of learning for grade 11 students, perceived competence in operational skills is no higher. It is noteworthy that students perceived a lack of competence in coping with situations requiring planning of an experiment in grade 11 (56% disagreeing) as opposed to (61% disagreeing) in grade 10; explaining phenomena using scientific knowledge (42% disagreeing in grade 10) and (56% disagreeing in grade 11), and posing scientific questions for investigation (54% disagreeing) in grade 11 and (55% disagreeing) in grade 10. This suggests that little emphasis is placed on these aspects of science learning at the gymnasium level. At the same time, it takes time to develop these skills, but the base for such skills can be expected to come from basic school (until grade 9) and it may be that before gymnasium level these skills are less well emphasized among students. However, PISA studies have shown that Estonian grade 10 students' level of scientific literacy is quite high, but at the same time, all these skills investigated here are not part of the PISA study (OECD, 2007).

Generally the perceived competence responses are less positive for girls than for boys. This is most noticeable in the case of being able to solve problem with a science content (for girls 69% disagreeing and for boys 55%). Girls' problem solving competences seems to be lower than boys and possible reasons for this can be and area for research in further studies.

Differences in perceived competence are noted between students from the 3 different levels of examination school groupings (see table 3). Unsurprising, students in the higher examination school group tend to agree that their level of competence is more positive than students in the middle group and that these students have a higher perceived competence than the students in schools from the lowest group. Difference are minimal where students in general have lower perceived competence (solving problems; explain phenomena) and greatest in recognising problems and planning investigations. This seems to suggest that little teaching is taking place related to the skills and more able students gain through greater self-determination.

These outcomes suggest that gymnasium students' perceived competence is not sufficiently high in science operational skills needed for being scientific literate. Previous studies have indicated that perceived competence plays an important role in terms of achievement and lifelong learning (Deci & Ryan, 2000; Marsh & Craven, 2006; Huang, 2011) and Law et al. (2012) findings show that even moderate concerns about doing poorly is sufficient to avoid the activity and this may lead to a situation where students prefer not to even start demonstrating competence, because of their fear of being unsuccessful. Therefore, as students perceived competence is not high in those science operational skills investigated here, then they may not present their competence in actual situations where this is needed. However, even if a person has the necessary skills and knowledge, it is not enough just having those; the person needs to be able to select from available knowledge and skills in such a way that efficient behaviour occurs (Westera, 2010). This suggest that besides having knowledge and skills, student should know how to select those most appropriate for given situation (e.g. for problem solving) and this activity needs to be promoted in science subjects, e.g. supporting the development of science operational skills.

It is surprising that although the strength of agreement is higher in better achieving schools based on exam groups, there is almost no difference in the sequence in which students agreed or disagreed. This leads to a conclusion that despite students' success in national exams, there is no difference between students from different schools in perceiving their competence and therefore it may be assumed that the teaching is similar in all schools – some competences are better established than others. This, however, is related with teachers' teaching methods and their awareness of the purposes of the science curriculum at the gymnasium level.

ISSN 1648–3898

Section 2 Students' perception of their science subjects

This study also investigated the role of teaching in science subjects in developing students' operational competences to enhance scientific literacy.

Overall, students agreed that science subjects developed competences in scientific process operations, especially in recognising the importance of science in society (52% of students agreed), understanding about the nature of science (59%) and explaining phenomena using scientific knowledge (52%). Other competences in scientific process operations were not seen as being developed in science subjects, based on students' perceptions.

Outcomes showed that despite the overall expected learning outcomes in the science curriculum (Estonian Government, 2011) Biology and Geography subjects were seen to be paying more attention to developing competence in scientific process operations compared with Chemistry and Physics teaching. This should clearly be seen as a concern. This could be related to the way science subjects were presented in the curriculum, but even so, teachers should know better that to ignore important learning. Although overall expected learning outcomes were related with scientific literacy, a deeper analysis in the way single subject content was presented to teachers suggested that Biology and Geography subjects were more focused on everyday life situations. Physics and Chemistry focused more on science content in an abstract manner than on applications in meaningful, real life situations. Therefore, it could be important to review how science was being presented to students. If it was too abstract, too much content oriented and too difficult, students were surely going to have difficulty relating to those subjects in an operational sense and also directly with their own lives (Gilbert, 2006). The implication was that students were likely to memorise and once the examination were finished, they simply forgot. Inevitably, this approach was pretty useless if i formed the base for learning in higher grades. It also suggested that teachers were not interpreting the curriculum correctly and were focused more on the science knowledge and skills. However, this was related with the fact that national exams were more focused on the science knowledge than skills in science subjects and teachers were preparing students to cope with examinations and not how to deal with real life situations. As a result, students perceived Physics and Chemistry subjects as being too difficult, because it seemed that Chemistry and Physics tended to be more abstract compared to Biology and Geography, either as intended by the curriculum or by misplaced perceptions by teachers of these subjects. Therefore, the way the science content was presented to students in those two subjects could be more meaningful for them and they have gained the perceptions of their actual competence in those subjects and based on this they could conclude that Biology and Geography supported the development of science process skills. At the same time, Chemistry and Physics seemed to be more focused on the development of knowledge, because students didn't see skills promoted in a similar manner than in the other two subjects.

It was noteworthy that there were similar views towards science subjects within grades, among boys and girls and exam groups. This suggested that there was no difference in teaching during a two-year period or in examination groups and little emphasis was placed on these aspects of science learning at the gymnasium level. For example, this was illustrated by the outcome that both grades, and boys/girls, evaluated Chemistry in a same way than as the overall pattern among science subjects. Differences in opinions towards Chemistry appeared in the examination groups. Students in group 3 disagreed in almost all items that the subject of Chemistry supported the development of these science process skills, while opinions by other groups seemed to be more similar to the overall picture. This was related with the teaching, with another key aspect, related to the activities and content of science subjects, being the values held by the schools and teachers. Students perceived competence in components, if they had experienced situations, which required utilising such competences. However, interpretation of the curriculum and choosing learning situations depended on teachers and their values and beliefs on what was important for students (Corrigan et al., 2013). This study suggested that there was evidence that teachers focused only on those components in science education which were assessed, especially in high-stakes examinations, or in international comparisons. This was in agreement with Fortus & Krajcik (2012). Should this be the case, then it became clearer why students didn't see science subjects supporting the development of science operational skills – these were not the focus of assessment in schools. Furthermore, as students were not given a chance to experience learning situations developing competence in scientific process operations, then they were not aware of their competence and therefore were not able to evaluate this in a sufficient manner. Based on the outcomes of this study, it could be assumed that in Biology and Geography subjects students provided more opportunities to develop an awareness of their competence as they probably experienced situations which required those competences more than in Chemistry and Physics.

This study showed that outcomes from separate analysis of science subjects, according to students' perceptions, science subjects were not focusing on decision making, planning an experiment nor posing scientific questions for investigations (leading to problem solving). Based on findings, those components, which were seen as part of scientific literacy, were not part of common assessment in schools or examinations within a meaningful context for students and were therefore neglected by teachers.

Section 3 Students' perception of their future careers

This study identified students' future career preferences in the light of their perceptions and the perceived science teaching emphasis in school. Overall, students were not interested in science related studies (nearly 74% disagreeing) and careers in science (nearly 77% disagreeing). This finding was in line with previous studies (e.g. OECD, 2007) and suggested that although Europe needed a scientifically literate workforce (European Commission, 2007; Eurydice, 2011), students were not interested in working in the science field at all. One reason for this was that science subjects were not preparing students with the necessary skills for a future workforce and therefore their self-perceptions were not high and they could not even think about choosing science related professions in the future. This was seen as an important finding because Lavonen et.al. (2008) noted that science education had an impact on students' career choices and therefore teaching methods should focus on improving students' competence in science operational skills. This was also seen as important because the same skills, which students were developing in subjects, could be used in their future professions.

Previous studies among grade 9 students have noted that students were more interested in a career in social sciences (Teppo & Rannikmäe, 2006; OECD, 2007). This study also found that 57% of students would like to have a profession in the social sciences, while only 26% saw their career related with biology, chemistry, physics or geography. At the same time, not all students should work in the science field (Simon & Osborne, 2010), but the educational system needed to look after the demands of the labour market, to prepare citizens for coping with complex situations in real world through formal schooling (Bybee & Fuchs, 2006) and to focus more on "Education through science" (see Holbrook & Rannikmäe, 2007). Furthermore, science subjects should introduce students with science related professions, but based on this study, only 38% of students agreed that science subjects had done this.

Comparison between grades, gender and examination groups showed no big differences; students agreed and disagreed with the same items. Students from both grades disagreed that they would like to have science related studies towards science related careers. Similar patterns emerged from comparisons between boys' and girls' career perceptions. The major difference was that boys had higher perceptions of wishing to work in engineering and technology career areas than did girls. Similar finding were found related to Estonian grade 9 students' opinions towards future career preferences from the ROSE study (Teppo & Rannikmäe, 2006). In other items, boys and girls agreed and disagreed with the same items as did grade 10 and 11 students. This trend supported the finding from this study, that science subjects had not introduced science related professions to students. One component of scientific literacy was career awareness and if there was no change over almost a two year period, then some aspects of learning were missing from the their studies in science subjects. Students should be presented with a wide range of career options in science education so as to raise their willingness to choose science related professions.

Findings from this study suggest that, students, in general, don't see their future careers directly related with science. Sadly it seems students recognise that science is not particularly seen as promoting these key learning aspects. This is in line with previous research (OECD, 2007; Lavonen, 2008; Osborne, 2010). There is no difference between the two grades and between genders in this aspect and also, noting the ROSE data, it seems perceptions do not change over the 2 years of extra study. Of course, it is not expected that all students prefer careers in science (Osborne & Dillon, 2010), but it is known that students make their choices based on previous experiences in school and life (Lavonen, 2008). There is a need to change the focus in science subjects, not only to pay more attention to developing competences, but also to raise students career awareness as one part of scientific literacy (Holbrook & Rannikmäe, 2009; Estonian Government, 2011).

Conclusions

Based on the outcomes from the questionnaire, it was found that the items, as a whole, seemed well targeted to the persons who participated in this study.

Outcomes from the perceived competences suggest that grade 10 students perceived a higher competence in process components associated with scientific literacy than grade 11 students. However, a more detailed analysis reveals that students in both grades perceive high and low competence in the same components. This fuels the proposition that during the two year period, there is no shift in students' perceived process competences. While girls seem to have less positive perceptions towards their competence than boys, the pattern of answers by boys and girls are similar. Students from schools in the higher examination group tend to have higher perceived competence than students from schools in the other examination groups. Students' competences towards oneself don't change much during gymnasium years and teaching taking place doesn't support the whole range of competence related to operational science skills as a component of scientific literacy.

Students agree that some process components of scientific literacy are promoted in science subjects while others are not. It seems that science subjects promote single skills as part of problem solving and decision making, but the focus on the problem solving or decision making as a whole are not promoted in a sufficient manner. Even more, there seems to be a difference how science subjects are perceived by students. Yet, at the same time, differences between competences promoted within subjects vary to a similar degree across the different subjects. There is little change going on in the way the science content is presented to students during gymnasium years; grade 10 and 11 students perceive science subjects in a similar manner and so do boys/girls and students in the various examination groups. Therefore, although students' self-perceptions play an important role in actual achievement, Estonian gymnasium students don't have an opportunity to develop accurate awareness of their self-perceptions as they are not exposed to all competences related to operational science skills as part of scientific literacy emphasized in the curriculum.

Students, studying at the gymnasium level, were not interested in science related studies and a career in science. Students did not see science subjects introducing science related professions and they preferred future employment in the service sector. A similar pattern emerged from grades, gender and examination groups. However, boys tended to have more positive perceptions towards career section items than girls and this difference was almost always significant. Also, students from higher examination groups didn't agree that they would like to work in science or have a science related career.

Limitations

One limitation is the assumption that students accurately evaluate their own perceived competences, recognizing that, because this is also a skill like any other, it needs practice (Dearnley & Meddings, 2007).

Acknowledgements

This study has been supported by European Social Fund programme EDUKO grant LoTeGüm and Estonian Science Foundation grant GLOLO8219.

References

Aikenhead, G., Orpwood, G. & Fensham, P. (2011). Scientific literacy for a knowledge society. In: C. Linder, L. Östman, D. Roberts, P Wickman, G. Erickson, A., MacKinnon (Eds.), *Exploring the Landscape of Scientific Literacy* (pp. 28-44). New York: Routledge.

Blumenfeld, P. C., Kempler, T. M., & Krajcik, J. S. (2005). Motivation and cognitive engagement in learning environments. In: R.K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 475-488). Cambridge: Cambridge University Press.

Bybee, R. W. (1997). Toward an understanding of scientific literacy. In: W. Gräber & C. Bolte (Eds.), *Scientific literacy: An international symposium* (pp. 37-68). Kiel, Germany: IPN.

Bybee, R.W., & Fuchs, B. (2006). Preparing the 21st century workforce: A new reform in science and technology education. *Journal of Research in Science Teaching*, *43* (4), 349-352

Bybee, R., & McCrae, B. (2011). Scientific literacy and student attitudes: Perspectives from PISA 2006 science. *International Journal of Science Education*, *33* (1), 7-26.

Chang, C., & Cheng, W. (2008). Science achievement and students' self-confidence and interest in science: A Taiwanese representative sample study. *International Journal of Science Education*, *30* (9), 1183-1200.

Cho, Y., Weinstein, C. E., & Wicker, F. (2011). Perceived competence and autonomy as moderators of the effects of achievement goal orientations. *Educational Psychology*, *31* (4), 393-411.

Choi, K., Lee, H., Shin, N., Kim, S. W., & Krajcik, J. (2011). Re-Conceptualization of scientific literacy in South Korea for the 21st century. *Journal of Research in Science Teaching, 48* (6), 670-697.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education (6th Edition)*. London: Routledge.
Corrigan, D., Buntting, C., Jones, A., & Gunstone, R. (2013). Valuing assessment in science education: An introductory framework. In: D. Corrigan, R. Gunstone & A. Jones (Eds.), *Valuing Assessment in Science Education: Pedagogy, Curriculum, Policy* (pp. 1-10). The Netherlands: Springer.
Dearnley, C. A., & Meddings, F. S. (2007). Student self-assessment and its impact on learning – A pilot study. *Nurse Education Today*, *27*, 333-340.
DeBoer, G. E. (2011). The globalization of science education. *Journal of Research in Science Teaching*, *48* (6), 567-591.
Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behaviour. *Psychological Inquiry*, *11* (4), 227-268.
Deng, Z. (2011). Scientific literacy: Content and curriculum making. In: C. Linder, L. Östman, D. Roberts, P Wickman, G. Erickson, A., MacKinnon (Eds.), *Exploring the Landscape of Scientific Literacy* (pp. 45-56). New York: Routledge.
Estonian Government (2011). Gümnaasiumi riiklik õppekava (National curriculum for gymnasium). Regulation of the Government of the Republic of Estonia), No. 2. Tallinn.
European Commission. (2007). Science education now: A renewed pedagogy for the future of Europe. Report by a High Level Group on Science Education. Brussels.
EURYDICE (2011). *Science education in Europe: National policies, practices and research*. Brussels: Education, Audiovisual and Culture Executive Agency.
Eysenck, M.W. (2012). *Fundamentals of Cognition*. *Second Edition.* New York, NY: Psychology Press.
Feinstein, N. (2010). Salvaging science literacy. *Science Education, 95* (1), 168-185.
Fortus, D., & Krajcik, J. (2012). Curriculum coherence and learning progressions. In: B.J., Fraser, K.G., Tobin & C.J. McRobbie, (Eds.), *Second International Handbook of Science Education (Volume 2) (*pp. 783-798). The Netherlands: Springer.
Fraser, S. W., & Greenhalgh, T. (2001). Coping with complexity: educating for capability. *British Medical Journal*, *323*, 799-803.
Froiland, J. M., & Oros, E. (2014). Intrinsic motivation, perceived competence, and classroom engagement as longitudinal predictors of adolescent reading achievement. *Educational Psychology*, *34* (2), 119-132.
Gilbert, J. K. (2006). On the nature of "context" in chemical education. *International Journal of Science Education*, *28* (9), 957–976.
Hansford, B. C., & Hattie, J. A. (1982). The relationship between self and achievement/performance measures. *Review of Educational Research*, *52* (1), 123-142.
Harter, S. (1978). Effectance motivation reconsidered. Toward a developmental model. *Human Development*, *21* (1), 34-64.
Holbrook, J., & Rannikmäe, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education*, *29*, 1347-1362.
Holbrook, J., & Rannikmäe, M. (2009). The meaning of scientific literacy. *International Journal of Environmental & Science Education*, *4* (3), 275-288.
Huang, C. (2011). Self-concept and academic achievement: A meta-analysis of longitudinal relations. *Journal of School Psychology*, *49*, 505-528.
Lavonen, J., Gedrovics, J., Byman, R., Meisalo, V., Juuti, K., & Uitto, A. (2008). Students` motivational orientations and career choice in science and technology: A comparative investigation in Finland and Latvia. *Journal of Baltic Science Education*, *7* (2), 86-102.
Law, W., Elliot, A. J., & Murayama, K. (2012). Perceived competence moderates the relation between performance-approach and performance-avoidance goals. *Journal of Educational Psychology*, *104* (3), 806-819.
Marsh, H. W., & Craven, R. G. (2006). Reciprocal effects of self-concept and performance from a multidimensional perspective: Beyond seductive pleasure and unidimensional perspectives. *Perspectives on Psychological Science*, *1*, 133–163.
Murcia, K. (2009). Re-thinking the development of scientific literacy through a rope metaphor. *Research in Science Education*, *39*, 215-229.
OECD. (2007). *PISA 2006. Science competencies for tomorrow's world. Volume I: Analysis*. Paris: OECD.
Oon, P. T., & Subramaniam, R. (2013). Factors influencing Singapore students` choice of Physics as a tertiary filed of study: A rasch analysis. *International Journal of Science Education*, *35* (1), 86-118.
Osborne, J. (2010). Science for citizenship. In: J. Osborne & J. Dillon (Eds.), *Good Practice in Science Teaching. What research has to say. Second edition.* (pp. 46-67). UK: Open University Press.
Osborne, J., & Dillon, J. (2010). How science works: what is the nature of scientific reasoning and what do we know about students` understanding? In: J. Osborne & J. Dillon (Eds.), *Good Practice in Science Teaching. What research has to say. Second edition.* (pp. 20-45). Berkshire, England: McGraw-Hill Education.
Park, H., Khan, S., & Petrina, S. (2009). ICT in Science Education: A quasiexperimental study of achievement, attitudes toward science, and career aspirations of Korean middle school students. *International Journal of Science Education, 31* (8), 993-1012.
Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research, 66*, 543-578.
Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, *25*, 54-67.
Sadler, T. D., & Zeidler, D. L. (2005). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching*, *42* (1), 112-138.
Simon, S., & Osborne, J. (2010). Students` attitudes to science. In: J. Osborne & J. Dillon (Eds.), *Good Practice in Science Teaching. What research has to say. Second edition.* (pp. 238-258). UK: Open University Press.
Soobard, R., & Rannikmäe, M. (2011). Assessing student's level of scientific literacy using interdisciplinary scenarios. *Science Education International*, *22* (2), 133-144.

Taras, M. (2002). Using assessment for learning and learning from assessment. *Assessment & Evaluation in Higher Education*, *27* (6), 501-510.

Taras, M. (2010). Student self-assessment: processes and consequences. *Teaching in Higher Education, 15* (2), 199-209.

Teppo, M., & Rannikmäe, M. (2006). Towards a model of relevance in science education: categorization of Estonian grade nine students' opinions about school science. In: S. Yoong, M. Ismail, A. Nurulazam Md. Zin, F. Saleh, F.S. Fook, M. Lim Chap Sam (Eds.), *XII International Organisation for Science and Technology Education Symposium (XII IOSTE 2006)* (pp. 393 - 398). Universiti Sains Malaysia: Science and Technology Education in the Service of Humankind; Penang, Malayisia; 30th July - 4th August 2006. Zillion Circle (M) Sdn. Bhd.

Thomas, G., Anderson, D., & Nashon, S. (2008). Development of an instrument designed to investigate elements of science students' metacognition, self-efficacy and learning processes: The SEMLI-S. *International Journal of Environmental & Science Education, 30* (13), 1701-1724.

Vaino, K., Holbrook, J., & Rannikmäe, M. (2012). Stimulating students' intrinsic motivation for learning chemistry through the use of context-based learning modules. *Chemistry Education Research and Practice*, *13* (4), 410-419.

Westera, W. (2010). Competences in education: A confusion of tongues. *Journal of Curriculum Studies*, *33* (1), 75-88

Wong, E. H., Wiest, D. J., & Cusick, L. B. (2002). Perceptions of autonomy support, parent attachment, competence and self-worth as predictors of motivational orientation and academic achievement: An examination of sixth- and ninth-grade regular education students. *Adolescence*, *37* (146), 255-266.

Received: *April 14, 2014* Accepted: *June 19, 2014*

Regina Soobard	Master of Science in Natural Sciences, PhD Student, University of Tartu, Faculty of Science and Technology, Centre for Science Education, Vanemuise 46-226, Tartu 51014, Estonia. E-mail: regina.soobard@ut.ee
Miia Rannikmäe	PhD, Professor of Science Education, University of Tartu, Faculty of Science and Technology, Centre for Science Education, Vanemuise 46-226, Tartu 51014, Estonia. E-mail: miia.rannikmae@ut.ee