Determining support of Estonian stakeholders for a new competence-based science education curriculum

A. Laius, A. Post, and M. Rannikmäe

Abstract**—**This study solicits views about the goals of science education from a wide range of stakeholders within the science education community and employees from private and public sectors. Its purpose is to raise the confidence levels of teachers in meeting the goals of the new competence-based curriculum introduced through relevant in service programs and also to compare students' needs, expressed through stakeholder expectations, with the current situation in science education. This study used a modified Delphi method with 111 participants in the 1st round and 172 participants in a 2nd round of Delphi study. The results revealed significant gaps between the expectations of all investigated groups and the actual realization of levels of obtained competences by students at school. All investigated groups differed significantly, but the teachers and science educators follow a similar pattern with minor differences, valuing academic knowledge the most. The scientists were most skeptical about the present state of science education at school and employers expected good personal attributes in future employees.

Keywords**—** Stakeholders, science education, competence-based curriculum, Delphi study.

I. Introduction

OVER the past few decades, the nature of work – what we do, how we do it and with whom – has transformed radically, triggered by technological and business model innovation, globalization, and changing expectations among employees and society [1]. The widely known problem in science education for knowledge-based societies continually seems to be the lack of citizens who are able to use their gained science knowledge in everyday life.

The future societies need people who are able to use scientific knowledge to solve problems and make decisions in everyday-life or work situations. Even though there is much effort put into science education reforms and rejuvenation processes, there is still little information on the kind of knowledge and skills expected by those providing employment or education. Nevertheless, there is a need for a scientifically literate workforce and for citizens who are provided with the appropriate skills and knowledge [2], [3], [4], [5], [6].

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In 2011, Estonia introduced a new competence-based curriculum, intended to initiate a paradigm shift from memorization of knowledge to transferable skills [7].

The goals for science education were specified as to foster scientific literacy through: problem solving, decision making, reasoning and creative thinking skills. The development of the educational system required changes and action, but it was difficult to create strategies of development for schools that were located in a social context that was also in continuous change. Fullan [8], an appreciated expert, highlighted the complicated relationship between educational development and change, as demonstrated in any educational system [9].

The role of science education in promoting scientific literacy is to offer support for the ideas that innovation plays the central role in national success and fostering innovation requires a supportive social environment [10].

With the emergence of increased attention to competences required by citizens for a knowledge-based society, schools and educational systems around the world have been called upon to make changes to their curricula [11]. It has been argued that implementing 21st century competences is a matter not only of trading the current content and goals of education for those that are required by the knowledge society, but also of re-defining what should be considered as core elements in the curriculum. Such a change cannot be achieved through a pure rational discussion only, but requires the questioning and refocusing of beliefs, values, assumptions, and perceptions that researchers, practitioners, and policy-makers currently hold about the school system [12].

Success in school reforms depends on societal support and need to be based on the recognition of the importance of studying the understanding and attitudes towards science and technology [13].

The Partnership for 21st Century Skills identifies 21st Century student outcomes and skills as: (1) Core Subjects and 21st Century Themes (including science and scientific and technological literacy); (2) Learning and Innovation Skills (Creativity and innovation skills; Critical thinking and problem solving; Communication and collaboration skills); (3) Information, Media and Technology Skills (ICT) and (4) Life and Career Skills (Flexibility, Initiative and Leadership and responsibility).

Among those skills, the 4Cs (**C**ritical thinking and problem solving, **C**ommunication, **C**ollaboration, and **C**reativity and innovation) are seen as core skills for students to be successful in the future [14].

Key competences in the shape of knowledge, skills and attitudes appropriate to each context are fundamental for each individual in a knowledge-based society. They provide added value for the labour market, social cohesion and active citizenship by offering flexibility and adaptability, satisfaction and motivation. The European Reference Framework [15] defined key competences as knowledge, skills and attitudes appropriate to the context of communication; mathematical competence and basic competences in science and technology; digital competence; learning to learn; social and civic competences; sense of initiative and entrepreneurship and cultural awareness and expression. Each has a concise definition of its scope and all emphasise: (1) critical thinking, creativity, (2) initiative, (4) problem solving, (5) risk assessment, (6) decision taking, and (7) constructive management of feelings.

Any further interpretation is left to Member States in the specific contexts of their education systems. In comparison with subject knowledge and skills, the challenge of assessing key competences across the curriculum is acute and ongoing [16].

The impending skills gap has made its way into the common lexicon. Workforce data and the increasing clamour of employer voices asking for more skilled workers have caused education to take notice. Research has shown that there are gaps between students' wishes and how school science has been taught, gaps between employees' opinions and school science education goals while teachers are still quite content oriented [17]; [18], [19], [20].

There are very few studies about different stakeholders' views on the goals of science education [13], but during the last years, several European Commission funded projects have focused on exploring types of support stakeholders offer to science education. The ESTABLISH project [21] carried out cross country surveys (related to organizational support collaboration with textbook authors, teachers freedom to choose textbooks, in service provision goals, industry support in implementation of curriculum, *etc.*). Under the PROFILES project [22], a Delphi curricular study was carried out in all 21 participating countries involving stakeholders from science and the science education community and focusing on the content taught in science classes and contexts to include into the curriculum [23].

The current study targeted varies groups within the science education community plus employees from private and public sectors (industry) with the following goals:

a) To solicit views about the goals of science education from a wide range of stakeholders so to raise the confidence levels of teachers in introducing competence-based science teaching through relevant in service programmes.

b) To compare students' needs expressed through stakeholders expectations with the current situation in science education leading towards meeting the goals of the new competence-based curriculum.

This study focused on determining the current and also the expected vision by the science education community and the expectations from different stakeholders in society. The study additionally focused on whether the new Estonian competence-based science curriculum [7] met the demands of these groups.

The Delphi method is an iterative process that enables researchers to collect and distil the judgments or views or thoughts of different fixed groups, using a series of questionnaires or questions interspersed with feedback. The Delphi technique was chosen for the current study because it enables researchers to collect information and views from a wide range of stakeholders or experts and, at the same time, make stakeholders aware of potentially useful views coming from others [24].

The method is usually undertaken in several rounds or stages where the number of rounds varies. There is general agreement that at least two rounds are required [25], [26]. There are risks of losing participants when using the Delphi techniques, especially when the target group is large and data collection goes beyond personal contacts [22]. In order to minimize the risk, this study uses a mixed method, which enables the sample size to be kept at a statistically trustable level.

This study posed two research questions:

a) How does the current state of science education fulfil the expectations of the science education community and society?

b) Are the learning outputs of the new science curriculum in accordance with the expectations of different stakeholders?

II. Research Methodology

This study actually used a modification of the typical Delphi method, as an extended sample of the different groups was used to validate the results of the 2nd round. As the results of the sample of the Delphi study and the sample of extended groups' respondents did not indicate statistically significantly differences (Appendix I), the coherence within the extended group was calculated, using the Mann-Whitney Test and the results were summarized and analyzed together.

Sample

The sample for the first round consisted of 111 participants from 6 different groups of stakeholders in society. The groups were chosen against the following criteria: secondary school students, science teachers, science educators, pre-service science teachers as the parts of science education community and scientists and employers as representatives of society. Whereas the pre-service and science educators had have similar teacher training courses at the University of Tartu in line with new paradigm of contextual and competence-based science education, their views to science education are quite in accordance.

In the second round, the study involved 172 participants, from the same extended groups as the dropout rate from the 1st round (8 persons) used to obtain a more valid and consensual results. An additional 69 respondents were involved in this mixed-method study.

Instruments

1st round.

The instrument used in the first round of the Delphi study consisted of three open-ended questions for which the participants were asked to give their opinions. These open-ended questions focused on:

a) The preferred kind of science knowledge and skills the students are expected to possess when they enter the labor market and/or society after completing secondary school;

b) An evaluation of the current state of science education in Estonian gymnasium schools from the competence-based curriculum perspective;

c) Suggestions for improving the science education/scientific literacy of students.

All given responses of the first round of Delphi study, were divided into 5 different categories, according to the nature of the statements:

a) Personal attributes (e.g. exhibiting responsible behavior; working independently; exhibiting initiative, etc.);

b) Academic skills (e.g. problem solving, decision making, socio-scientific reasoning etc.);

c) Creativity (e.g. openness to new ideas/ways of working; participating in brainstorming/suggesting new ideas)

d) Communication skills (e.g. interacting collaboratively with others; developing communication skills – written/tabular/graphical etc.; negotiating to reach a consensus *etc.*);

e) Scientific knowledge (e.g. indicating possessing of specific knowledge in science in given areas; knowledge about biological systems; energy, *etc.*).

2nd round.

A 6-point Likert scale second round questionnaire was compiled based on the five categories derived from the 1st round responses, expanded with questions on important traits identified related to 21st century skills [27], [28] and the new Estonian science curriculum [7]. Altogether, 72 statements were compiled, referring both to the importance of these skills in a future career and to the current realization of science education at school.

III. Results and analysis

The overall results from the mixed method research is illustrated in Fig. 1 and Fig. 2, which compares the importance of different competences with their current realization in school between the different science education community and society groups involved in the study.

Considering that the mean of the 6-point Likert type questionnaire is 3,5, it can be seen from the overall results (Table I) that all groups of stakeholders value the different competence categories very highly: from a mean of 4,73 (scientific knowledge) to 5,17 (academic skills). The realization of three of the five (competences (creativity, academic skills and personal attributes) was below average and the highest (3,82) evaluation is given to the realization of scientific knowledge). The results indicate that the most homogeneous groups are the science educators and pre-service teachers who have received similar training in pedagogical development.

Application of the Kruskal Wallis Test (Table II) for statistical significance of the mean differences between the groups showed that the majority of opinions by different groups on the realization of investigated competences needed for scientific literacy plus the gaps between importance and their realization varied between groups. On the other hand, all groups valued similarly the importance of communication skills, creativity and personal attributes indicated by a lack of statistically significant differences (Chi-Squares 8,52; 4,21 and 7,06 respectively).

It can be concluded from the results (Fig. 1 and Fig. 2) that the most satisfied with the appropriate description of competences are the secondary school students and they are also the most satisfied group with the actual realisation in all categories of competencies, e.g. creativity, communication skills, academic skills, personal attributes and scientific knowledge. The opinions of students differ statistically significantly from science teachers' opinions about the importance of academic skills (Z= -2,764) and from science educators' opinions about the importance of scientific knowledge (Z= -2,072 and -2,051, accordingly). A significant difference occurred also between the opinions of students and scientists in the area of the importance of communication skills (Z= -2,479).

Differences of opinions about importance of competences between the groups

The least differ (Table III) in opinions (only 9 differences) about the importance of competences that should be developed in secondary school graduates before entering the labour market of science education community groups and society groups (scientists and employers).

The practising teachers differ from science educators within the categories of personal attributes (Z= -2,208) and scientific knowledge (Z= -2,130). The only difference in the opinions between teachers and the science educators occurred in the importance of academic skills (Z= -2,253). One of the biggest differences in valuing the scientific knowledge occurs between the opinions of science educators and employers (Z= -3,365).

The scientists and employers as representatives of society are in accordance in valuing all categories of competencies except scientific knowledge (Z= -2,767). The pre-service teachers are similar in their opinions about the importance of all competencies to scientists and differ only in valuing more the scientific knowledge from employers (Z= -3,104).

Differences in realisation of current school competencies between all groups

The most differentiations (36 significant differences) between science education community groups and society groups' opinions (Table IV) occurred in the evaluation of the realisation of competences for the present state in Estonian schools. The biggest differences are in the need to realise the fostering of creativity, communication, academic skills and scientific knowledge. Results show that employers and scientists are in accordance with the degree of realisation of all competence categories, but have opposite viewpoints from students and teacher groups in most competences, especially in creativity, academic skills and knowledge. The scientists value more creativity and academic skills development whereas employers recognise the need for academic skills more than scientific knowledge. The current state of science education, considering the future needs of the labour market, do not fulfil the expectations of students and teachers and even less the needs felt by scientists and employers.

Table I. Means and standard deviation in terms of importance and realisation for the competence categories for each stakeholder group

Group		Personal attributes		Academic skills		Creativity		Communication skills		Scientific knowledge	
		Importance	Realisation	Importance	Realisation	Importance	Realisation	Importance	Realisation	Importance	Realisation
Employers (N=25)	Mean	5,26	3,20	5,08	2,99	4,95	2,93	5,17	3,28	4,18	3,77
	SD	0,57	0,72	0,57	0,64	0,68	0,84	0,66	0,82	0,89	0,44
Science educators (N=25)	Mean	5,29	3,76	5,12	3,62	5,09	3,64	5,19	3,91	5,07	4,03
	SD	0,51	0,67	0,48	0,55	0,49	0,66	0,53	0,54	0,64	0,73
Pre-service teachers (N=26)	Mean	5,31	3,04	5,29	3,25	5,04	3,13	5,14	3,38	4,99	3,44
	SD	0,57	0,79	0,59	0,76	0,67	0,90	0,65	0,80	0,77	0,85
Scientists (N=30)	Mean	5,12	2,97	5,27	2,98	4,76	2,65	4,84	3,01	4,89	3,40
	SD	0,67	0,71	0,56	0,76	0,81	0,80	0,83	0,82	0,87	0,88
Students (N=34)	Mean	5,12	3,50	5,35	4,00	4,85	3,29	5,35	4,15	4,67	4,65
	SD	1,09	1,38	0,88	0,95	1,08	1,29	0,81	1,13	0,84	0,95
Teachers (N=32)	Mean	4,80	3,36	4,88	3,24	4,74	3,48	4,86	3,57	4,59	3,53
	SD	1,21	1,06	0,74	0,74	1,09	1,08	1,30	1,05	0,97	1,13
Total (N=172)	Mean	5,13	3,31	5,17	3,34	4,89	3,19	5,09	3,56	4,73	3,82
	SD	0,86	0,98	0,68	0,84	0,85	1,02	0,87	0,97	0,88	0,98

Table II. The statistical significance of the differences between the means of groups according to Kruskal Wallis Test

Competences	Chi-Square	df	Asymp. Sig.
Personal attributes			
importance	7,06	5	0,216
realisation	14,96	5	**0,011***
difference between importance and realisation	14,30	5	**0,014***
Academic skills			
importance	11,55	5	**0,042***
realisation	29,57	5	**0,000****
difference between importance and realisation	20,29	5	**0,001****

Competences	Chi-Square	df	Asymp. Sig.
Creativity			
importance	4,21	5	0,520
realisation	20,77	5	**0,001****
difference between importance and realisation	17,27	5	**0,004****
Communication skills			
importance	8,52	5	0,130
realisation	31,71	5	**0,000****
difference between importance and realisation	16,02	5	**0,007****
Scientific knowledge			
importance	16,76	5	**0,005****
realisation	32,04	5	**0,000****
difference between importance and realisation	44,15	5	**0,000****

*Significant difference at the 0,05 level of confidence
** Significant difference at the 0,01 level of confidence

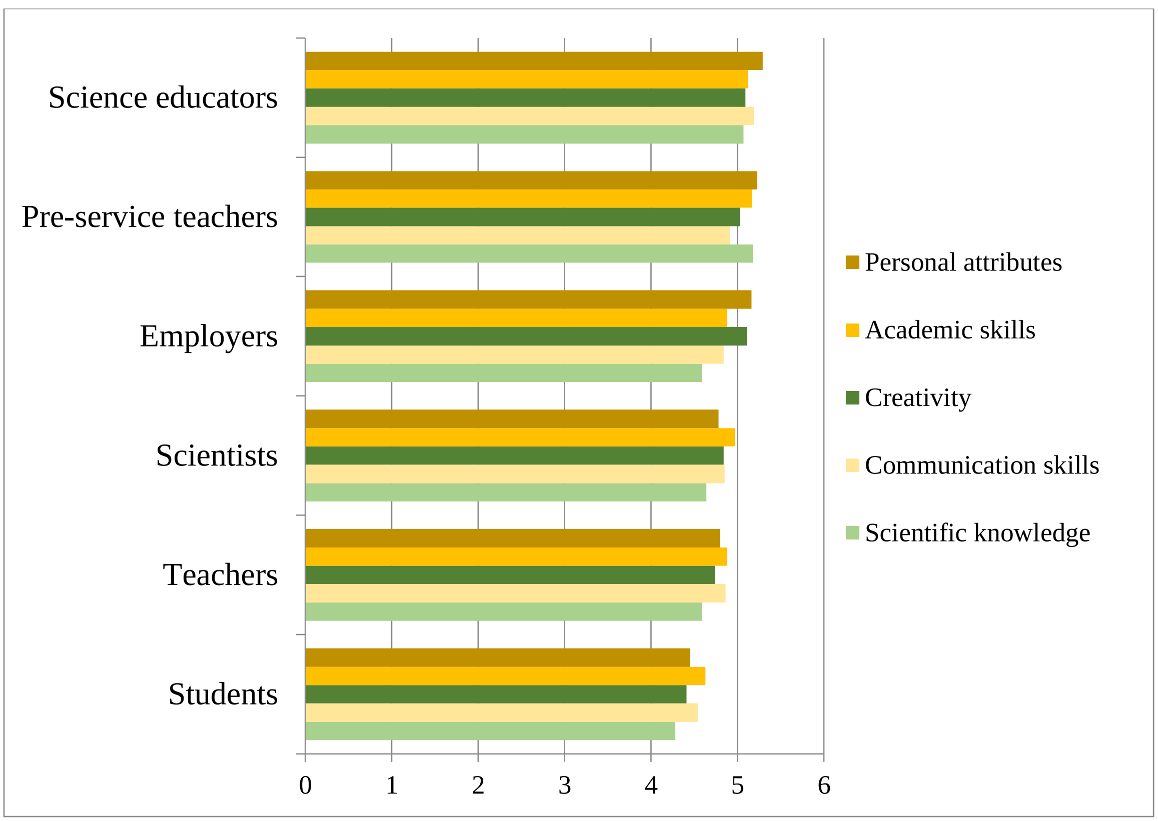

Fig. 1. The results of the 2nd round questionnaire, showing the importance of different interest groups' opinions about competences.

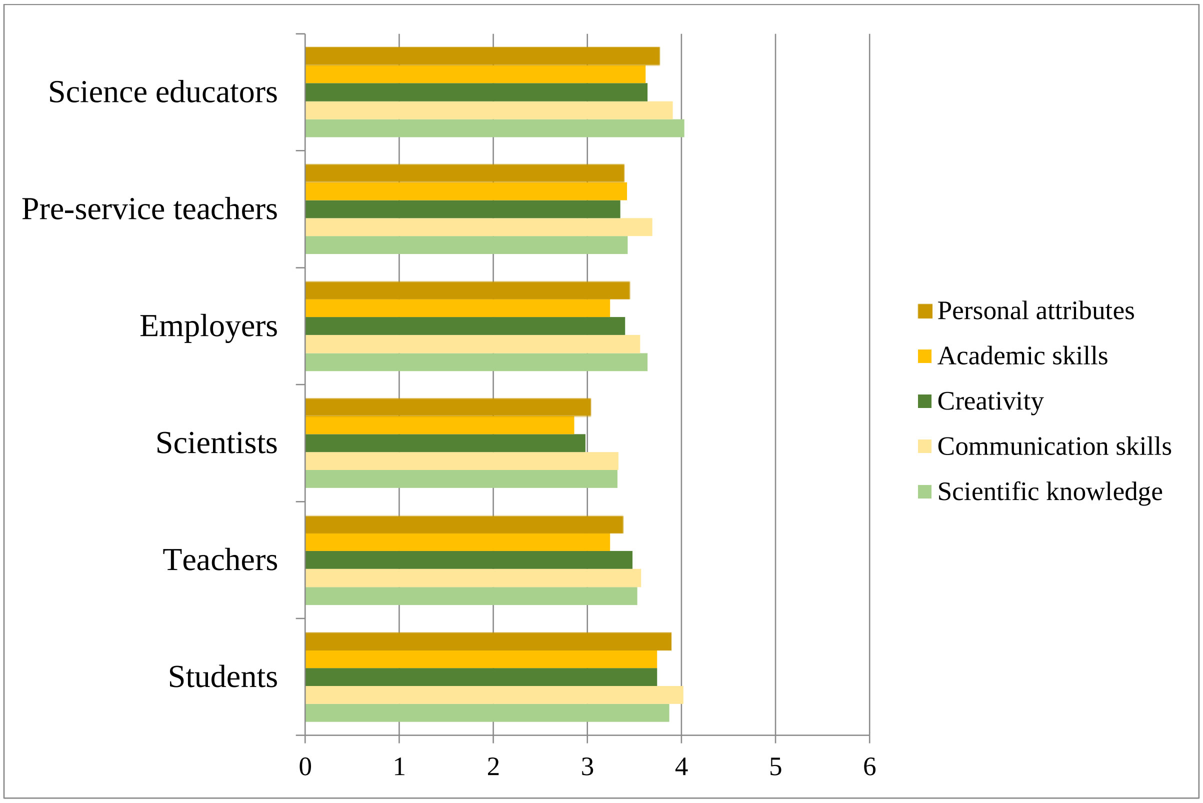

Fig. 2. The results of the 2nd round questionnaire, showing the realisation of different interest groups' opinions about competences.

Table III. The differences of importance of competencies between the groups

Group	Compared groups	Personal attributes		Academic skills		Creativity		Communication skills		Scientific knowledge	
		Wilcoxon Z	Asymp. Sig.	Wilcoxon Z	Asymp. Sig.	Wilcoxon Z	Asymp. Sig.	Wilcoxon Z	Asymp. Sig.	Wilcoxon Z	Asymp. Sig.
Students	Teachers	**-1,650**	0,099	-2,764	**0,006****	-1,095	0,274	-1,527	0,127	-0,13	0,897
	Science educators	-0,734	0,463	-2,072	**0,038***	-0,351	0,725	-1,695	0,090	-2,051	**0,040***
	Employers	-,562	0,574	-1,806	0,071	-0,189	0,850	-1,407	0,159	-1,795	0,073
	Scientists	-0,856	0,392	-1,314	0,189	-0,878	0,380	-2,479	**0,013***	-1,092	0,275
	Pre-service teachers	-0,432	0,665	-0,964	0,335	-0,205	0,837	-1,385	0,166	-1,345	0,179
Teachers	Science educators	-2,208	**0,027***	-1,389	0,165	-1,402	0,161	-1,000	0,317	-2,130	**0,033***
	Employers	-1,696	0,090	-0,695	0,487	-1,179	0,239	-0,081	0,935	-2,195	0,028
	Scientists	-,864	0,388	-1,791	0,073	-0,410	0,682	-1,344	0,179	-1,259	0,208
	Pre-service teachers	-1,602	0,109	-2,253	**0,024***	-0,737	0,461	-0,440	0,660	-1,432	0,152
Science educators	Employers	-,0243	0,808	-0,720	0,471	-0,545	0,585	-0,156	0,876	-3,365	**0,001****
	Scientists	-0,874	0,382	-0,697	0,486	-1,545	0,122	-1,636	0,102	-0,585	0,559
	Pre-service teachers	-0,047	0,962	-1,012	0,311	-0,132	0,895	-0,444	0,657	-0,350	0,726
Employers	Scientists	-0,682	0,495	-1,030	0,303	-1,005	0,315	-1,383	0,167	-2,767	**0,006****
	Pre-service teachers	-0,095	0,924	-1,486	0,137	-0,444	0,657	-0,067	0,947	-3,104	**0,002****
Scientists	Pre-service teachers	-0,772	0,440	-0,568	0,570	-1,224	0,221	-1,506	0,132	-0,240	0,810

*Significant difference at the 0,05 level of confidence
** Significant difference at the 0,01 level of confidence

Table IV. The differences of realisation of competences between the groups

Group	Compared groups	Personal attributes Wilcoxon Z	Personal attributes Asymp. Sig.	Academic skills Wilcoxon Z	Academic skills Asymp. Sig.	Creativity Wilcoxon Z	Creativity Asymp. Sig.	Communication skills Wilcoxon Z	Communication skills Asymp. Sig.	Scientific knowledge Wilcoxon Z	Scientific knowledge Asymp. Sig.
Students	Teachers	-0,620	0,535	-3,259	**0,001****	-0,851	0,395	-2,524	**0,012***	-3,442	**0,001****
	Science educators	-0,362	0,717	-1,638	0,101	-0,594	0,553	-2,053	**0,040***	-2,721	**0,007****
	Employers	-1,014	0,310	-3,798	**0,000****	-1,240	0,215	-3,477	**0,001****	-3,674	**0,000****
	Scientists	-1,815	0,070	-3,999	**0,000****	-2,289	**0,022***	-4,292	**0,000****	-4,485	**0,000****
	Pre-service teachers	-1,254	0,210	-3,299	**0,001***	-1,022	0,307	-3,028	**0,002****	-4,177	**0,000****
Teachers	Science educators	-1,466	0,143	-1,981	**0,048***	-0,290	0,772	-0,854	0,393	-1,485	0,138
	Employers	-0,854	0,393	-1,354	0,176	-2,110	**0,035***	-1,869	0,062	-0,226	0,821
	Scientists	-2,362	**0,018***	-1,439	0,150	-3,598	**0,000****	-3,076	**0,002****	-1,101	0,271
	Pre-service teachers	-1,974	**0,048***	-0,125	0,900	-2,192	**0,028***	-1,676	0,094	-1,034	0,301
Science educators	Employers	-2,254	**0,024***	-3,075	**0,002****	-2,837	**0,005****	-2,889	**0,004****	-1,251	0,211
	Scientists	-3,540	**0,000****	-3,093	**0,002****	-4,029	**0,000****	-3,972	**0,000****	-2,416	**0,016***
	Pre-service teacher	-3,074	**0,002****	-1,955	**0,050***	-2,104	**0,035***	-2,680	**0,007****	-2,484	**0,013***
Employers	Scientists	-1,579	0,114	-0,273	0,785	-1,606	0,108	-1,114	0,265	-1,624	0,104
	Pre-service teachers	-0,982	0,326	-0,767	0,443	-0,236	0,813	-0,104	0,917	-1,761	0,078
Scientists	Pre-service teachers	-0,313	0,754	-1,196	0,232	-1,395	0,163	-1,403	0,161	-0,033	0,974

*Significant difference at the 0,05 level of confidence
** Significant difference at the 0,01 level of confidence

IV. Discussion

The results of this study show that the current state of science education, considering the future needs of the labour market, do not fulfil the expectations of students and teachers and even less the needs felt by scientists and employers. All groups in this study admitted there are considerable gaps between the ideal expectations and actual realisation of the achievements of science education. The smallest gaps between importance and realisation of useful competences for scientific literacy of the future workforce occur with the secondary school students. This indicates that the demands of new curriculum are not enough implicated in students' everyday school life, although they validate the need for academic skills most and this is a good trend towards paradigm shift in science education as the students have understood from teachers instructions the necessity of problem solving, reasoning and other academic skills.

All the other groups differ from students significantly, but the practising science teachers have also changed the priority of scientific knowledge against the academic skills, following the need of new curriculum. The other two groups of teachers (science educators and pre-service teachers) follow the similar pattern at a bit different levels, valuing personal traits and communication skills of students a bit more than scientific knowledge.

The scientists are most sceptical about present state of science education at school, especially the level of academic skills and creative thinking skills of students do not satisfy their needs as they recognise evidently the lack of potential for innovative knowledge-based society.

The employers are at the same opinion about bad situation of academic skills and creativity at school, but they differ from scientists with expecting more developing of high personal attributes for future employees as well as science educators and pre-service teachers who share the understanding that personality traits are agreed to be valid predictors of success in education and job performance [29].

These results are in line with international trends, where school science does not meet the needs for 21th century skills [12], [13], [18], [23], yet and the focus of science education should be more vigorously pointed on developing before mentioned 21st century core skills: (1) Core Subjects and 21st Century Themes; (2) Learning and Innovation Skills; (3) Information, Media and Technology Skills (ICT) and (4) Life and Career Skills. It is very promising in the light of future education that all these topics are covered by the categories created upon the stakeholders perceived and supported needs for education: scientific knowledge and skills, creativity, communication skills and personal attributes.

Among those skills, the 4Cs (Critical thinking and problem solving, Communication, Collaboration, and Creativity and innovation)Although the learning goals of the new science curriculum are actually in accordance with the expectations of different stakeholders, especially for scientists and employees, focusing on students' creativity, academic and communication skills and personal attributes of innovative and knowledge-based society as declared in most science education communities in the world [14]; [13], [10] [22], [9], there is still the gap between the expectations and realisations of stakeholders needs but fortunately the education community has started to realise and implement the new curriculum benefits in the context of 21^{st} century skills

As the new competence-based science curriculum reform in Estonia (2011) is in the direction of competence-based and inquiry learning, including a strong emphasis on developing creativity and communication skills, it is possible to presume that the expectations of different stakeholders could be fulfilled if the new curriculum will be implemented truly.

V. Conclusion

To conclude the results of current study it can be stated that:

a) The current state of the Estonian science education at gymnasium level neither fulfils the expectations of the science education community nor the other stakeholders' groups of society;

b) The learning outputs of the new competence-based science curriculum in the context of the needs for future citizenship are not in the accordance with the expectations of different groups of stakeholders so far.

APPENDIX

Appendix I. The comparison of groups of Delphi study 2nd round results with the extended 2nd round sample's results with Mann-Whitney Test

Group		Personal attributes (importance/ realisation)	Academic skills (importance/ realisation)	Creativity (importance/ realisation)	Communication skills (importance/ realisation)	Scientific knowledge (importance/ realisation)
Students						
	Z	-0,600	-1,082	-1,076	-1,402	-0,220
	Asymp.Sig (2-tailed)	0,548	0,279	0,281	0,161	0,828
Teachers						
	Z	-0,419	-0,420	-0,267	-0,076	-0,840
	Asymp.Sig (2-tailed)	0,675	0,674	0,790	0,939	0,401
Science educators						
	Z	-1,555	-0.999	-1.111	-0.612	-0,556
	Asymp. Sig (2-tailed)	0,119	0,317	0,266	0,540	0,578
Employers						
	Z	-1.264	-1.774	-1.547	-1.339	-1.944
	Asymp.Sig (2-tailed)	0,206	0,075	0,121	0,180	0,051
Scientists						
	Z	-0,421	-0,167	-0,334	-0,599	-0,293
	Asymp.Sig (2-tailed)	0,673	0,867	0,737	0,547	0,768
Pre-service teachers						
	Z	-1,031	-1,214	-0,309	-1,805	-0,954
	Asymp Sig (2-tailed)	0,302	0,224	0,756	0,071	0,339

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