Computer Science at School / CS Teacher Education – Koli Working-group report on CS at School

Carsten Schulte
Freie Universität Berlin
Computing Education Research
Königin-Luise Str. 24
14195 Berlin Germany
schulte@inf.fu-berlin.de

Malte Hornung
Freie Universität Berlin
Computing Education Research
Königin-Luise Str. 24
14195 Berlin Germany
hornung@inf.fu-berlin.de

Sue Sentance
Anglia Ruskin University
Department of Education
Chelmsford
Essex CM1 1SQ, UK
sue.sentance@anglia.ac.uk

Valentina Dagiene
Vilnius University
Naugarduko Str. 24
03225 Vilnius Lithuania
valentina.dagiene@mii.vu.lt

Tatjana Jevsikova
Vilnius University
Naugarduko Str. 24
03225 Vilnius Lithuania
Tatjana.Jevsikova@mii.vu.lt

Neena Thota
Uppsala Computing Education Research Group, UpCERG,
Uppsala University, Uppsala, Sweden.
University of Saint Joseph
Macau, S.A.R.
neenathota@usj.edu.mo

Anna Eckerdal
Uppsala University
Dept. of Information Technology
P.O. Box 337
75105 Uppsala Sweden
anna.eckerdal@it.uu.se

Anne-Kathrin Peters
Uppsala University
Dept. of Information Technology
P.O. Box 337
75105 Uppsala Sweden
anne.peters@it.uu.se

ABSTRACT

In an international study, experts reflected on their national state of computer science education in school, and the associated situation and education of computer science teachers. While these situations are shaped by local circumstances, they are also shaped by changes in the discipline. The results of the study showed a number of recurrent themes and patterns such as curriculum difficulties, training and support for teachers, as well as the understanding (e.g. computer science vs. information technology) and relevance of computer science. The study also draws attention to initiatives that are being undertaken at the local and international levels to solve these problems. Finally, the study points out trends which are – according to the experts asked – likely to occur within the next few years.

Categories and Subject Descriptors

K3.2 [**Computers & Education**]: Computer and Information Science Education – *computer science education, information systems education*.

General Terms

Experimentation, Human Factors.

Keywords

CS Ed Research, Pedagogy, CS at school, CS teacher education, curriculum, topics, goals, international comparison, study

1. INTRODUCTION

Computer Science (CS) education in schools is evolving in several countries (like Austria, Germany, Mongolia, Netherlands, UK, USA and others [5, 13, 16, 21, 22]). Some comparisons of computing at schools on international level have been made [13]. Initiatives to support CS, new curricula, new forms of support for teachers, and course materials are being developed [2, 4, 8, 10, 18]. For many years, the ACM/CSTA Model Curriculum for K-12 CS has served as a national standard in the U.S., Canada, Philippines, and Australia for pre-college CS education. Last year, Computer Science Teacher Association (CSTA) formed a committee of specialists from all educational levels to review and revise these standards [18].

This paper reports on an international effort that included an online survey, a workshop at Koli 2011, and a collaborative data analysis. Information about the state of the art and current activities regarding teaching CS at school and CS teacher education in multiple countries was collected and analysed. By asking experts close to the school system, we get an up to date picture of the current situation as it is experienced by the people engaged. The aim of this effort is to get an overview of the current situation, to develop a vision and identify trends, and to offer suggestions for future work.

In the first part of this paper, we describe our methodology including the instrument, data gathering and analysis. After that, we summarize the results, first on CS at school and then on CS teacher education. We point out limitations of our work and discuss results. Based on our findings, we conclude with suggestions for future research.

2. METHODOLOGY

The work was done in three steps. In 2011, an online survey[1] was developed and conducted by the first two authors. During an international workshop at the Koli conference in November 2011, the research group was formed and the outline of the research approach was discussed. Finally, the data was analyzed and the report compiled.

2.1 Instrument

The survey was designed in a small group, and then sent out to a group of experts in several countries, e.g. France, New Zealand. In this pilot evaluation, some questions were changed or added, and especially the description of different age ranges / school types in which CS might be available was fine-tuned to best match the diversity of the national systems.

In the first section of the survey, the participants were asked to provide information on the country and profession or affiliation (school, university, industry). The survey then contained two main parts, CS at school and CS teacher education, each including quantitative and qualitative data items.

The quantitative section (3.2) of the CS at school part included 5-point Likert scales to rate the importance of Topics, e.g. programming, and Goals, e.g. developing thinking skills, in primary, lower secondary, and higher secondary CS education. Furthermore a scale for rating the importance of teaching methods, e.g. lectures, was included. The qualitative section (3.3) asked respondents for problems, trends, and initiatives related to CS at school and names of institutions that support CS at school.

The quantitative section (3.4) of the CS teacher education part asked respondents to rate the importance of Goals for CS teacher education on a 5-point Likert scale. These goals are roughly based on the framework of Pedagogical Content Knowledge [19]. Pedagogical Content Knowledge (PCK) is the integrated teacher understanding of the subject (content), pedagogy and features of the learners that affect learning this particular content, as well as the reasons to teach a certain topic, and the difficulties students encounter while learning such topics [11]. This framework was used with regard to CS by Saeli [17]. The qualitative section (3.5) of the CS teacher education part asked for descriptions of the current situation, problems, trends, initiatives, and names of institutions that support CS teacher education.

Participants were asked to answer from a national perspective, e.g. describing situations, problems and developments on a national or at least state-wide level. For all questions and scales, the respondents had the option to leave questions unanswered, in order to prevent respondents from feeling obliged to answer when they were not sure about the national situation, but only knew the local circumstances. In the introduction of the questionnaire, they were therefore informed that "we are expecting that participants are leaving several questions unanswered".

2.2 Data Gathering

The call to fill in the survey was sent by personal email to experts known from relevant conferences. In addition, the call was sent to the mailing lists of the ACM SIGCSE (Special Interest Group on CS Education), the Computing at School forum (CAS) in UK, the IOI (International Olympiad in Informatics), and to the Computing Education Researchers (FG DDI) list in Germany. Further participants were invited by personal email.

[1] The survey can be obtained from the first author.

2.3 Analysis

A first survey of the statements in the questionnaires showed very diverse answers, some of which were optimistic and others pessimistic. We thus decided that a SWOT (Strengths, Weaknesses, Opportunities, and Threats) inspired analysis was an appropriate scheme to gain an overview of these different perspectives.

From the history of SWOT analysis [12] we can see that "*It is unusual for such a prolifically cited piece of research not to have an original definitive publication as its centrepiece*." The original resource is unclear. It is also stated: "*Again despite their interest in the concept of SWOT Analysis, none of these respected authors actually cite its origins […] It may be that SWOT originated in a number of places, or became common place in the training rooms of corporate America in the 1950s and 1960s.*" [12]

In our work, we used the categories to distinguish internal and external influence factors, both positive and negative. In terms of CS at school and teacher education (at universities or other teacher training institutions), the Strengths, Weaknesses, Opportunities and Threats can be defined as follows:

1) Internal factors refer to aspects inside the system, i.e. schools for CS at school and teacher training institutions for teacher education. For example *Strength*: teachers are receiving high quality training or increasing demand for CS from the students. *Weakness*: teacher education courses in CS are too short or decrease in CS student numbers.

2) External factors refer to aspects outside the system such as government policy, or funding constraints. For example *Opportunity*: positive policy decisions to fund more teacher training places or new CS curriculum developed by the government. *Threat*: CS graduates choosing not to train as teachers or problems at governmental level.

First we did a SWOT analysis on the qualitative data, followed by a thematic content analysis [9] of the SWOT categories. The analyses were done jointly by at least two researchers who negotiated each label and each category. Some responses were difficult to categorize as internal or external. Also within a category there were responses of which some were interpreted as internal and some as external. In these cases, we created a common category. For example, within the category *lack of trained teachers*, we found statements that were general so that it was not possible to categorize them as either a threat or a weakness. Furthermore, within the category, we found statements that explicitly referred to external (governmental) problems or internal (teacher retirement) problems.

The quantitative data was analysed on a descriptive level, to show the level of agreement among respondents to the different aspects asked for. We therefore used mean values to indicate the 'level' of agreement.

3. RESULTS

3.1 Overview

Experts from 22 countries answered the questionnaire. The answers are mainly from Europe and English-speaking countries in America and Australia. In the results presented in Table 1, the (one) expert from India was excluded (we are planning a follow-up study within the Asian context).

Nation	AUS	AUT	BGR	CAN	CHE	CZE	DEU	DNK	FIN	FRA	GBR
No	1	3	2	3	2	1	12	1	3	1	20
Nation	ISR	LTU	LVA	NLD	NZL	POL	PRT	SVN	SWE	UKR	USA
No	3	2	3	5	2	2	5	1	2	1	8

Table 1 Number of participants per country

The 84 participants come from different institutional backgrounds: 36 = school only, 39 = university only, 6 = school and university, 1 = industry only, 1 = school and industry, and 1 = university and industry.

CS is most often available in upper secondary education (see Table 2), with some extensions to lower secondary, and seldom to primary education. In contrast to this typical pattern, 2 people answered that CS is available in lower secondary only.

School	No	P	LS	P + LS	US	P+HS	LS + US	P+LS+US
No	7	-	2	-	50	-	23	2

Table 2: No Answer/ not available; Primary (P) only; Lower Secondary (LS) only; P + LS; Upper Secondary (US) only; Only P+HS; LS + US; P+LS+US

As an overview question, we asked whether there is a "clear distinction of CS as a subject in its own right" (Figure 1).

1 (not at all)	2	3	4	5 (very much)
18	21	17	20	6

Figure 1 Overview on Distribution of Answers. Darker color indicates stronger agreement to the statement given above (White: No answer)

3.2 CS at School (Quantitative)

In this part, we present the results of how the participants rated the items of topics, goals, and methods in computing at school. They were rated for three different age ranges:

1. Primary School (Elementary School; grades 1-4; up to grades 1-7, students are typically 5 to 10-13 years old)
2. Lower Secondary (Middle School; grades 5-9/10, students are typically 10 to 15 years old)
3. Upper Secondary (Secondary School; grades 9/10 - 12/13, students are typically 15 to 18 years old)

Respondents were free to leave out ratings of items. Hence, the number of participants that rated each item of topics, goals, and methods varied. Therefore we decided to provide the number of respondents using ranges. For example, 31-34 respondents mean that at least 31 and maximal 34 respondents rated each item.

3.2.1 Topics

The participants were asked to rate the relevance of ten different topics. Of these, 31-34 participants rated the topics for primary education, 38-41 for lower secondary education, and 45-47 for upper secondary education.

The topics are listed from most to least relevant in upper secondary school:

1. Introductory programming (merely introduction to concepts, language, tools, etc.)
2. Algorithms
3. Advanced programming (merely programming in order to solve problems)
4. Programming project (full lifecycle projects, with e.g. requirements analysis, etc.)
5. HTML
6. Privacy & ethics
7. Applications (e.g. text processing)
8. Database
9. Robotics
10. Theory (e.g. automata)

The following plot shows the results for the different age ranges.

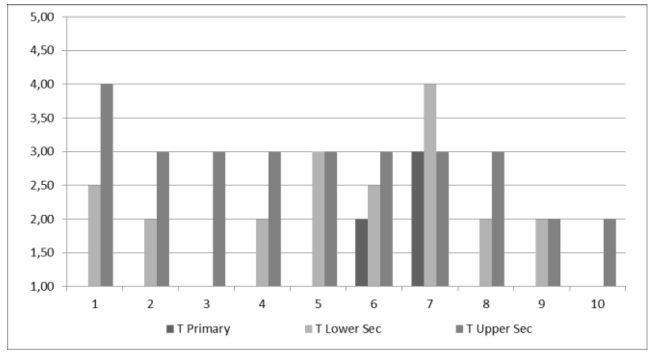

Figure 2: Median values for all age ranges for relevance of topics. Numbers according to the list above (1=very unimportant; 5=very important).

In upper secondary schools, only introductory programming is seen as important. It is followed by seven topics rated as moderately important. Robotics and theory are rated as unimportant topics.

In lower secondary education, applications are seen as important, followed by HTML, privacy and ethics, and introductory programming, which are seen as (more or less) moderately important. All other topics are rated as unimportant or even very unimportant.

In primary education, applications are seen as moderately important, followed by privacy and ethics. All other topics are rated as unimportant or very unimportant.

3.2.2 Goals

Participants were asked for the relevance of 16 given goals for the different age ranges. Questions relating to Goals were answered by 27-30 respondents for primary, 30-33 for lower secondary, and 39-41 for upper secondary education.

The goals are listed from most to least relevant in upper secondary school:

1. Developing thinking skills (logical reasoning, abstraction, etc.)
2. Problem solving skills
3. Learning programming in the small
4. Algorithmic thinking
5. Databases: design and queries
6. Data structures and algorithms
7. Mastering the important applications
8. Preparation of learners to use computers / digital technologies
9. Learning programming and software development process
10. Understanding the nature of computer science
11. Understanding the impact / relationship of CS and the society
12. Knowing careers and opportunities in CS
13. Preparation of learners to cope with the impact of CS on everyday lives (e.g. political issues like privacy, e-Democracy)
14. Learning end user programming (Macros, etc.)
15. Introducing CS as it is presented and conceptualized in Universities
16. Aspects of theoretical CS (e.g. halting problem; complexity)

The following plot (Figure 3) shows the results for the different age ranges.

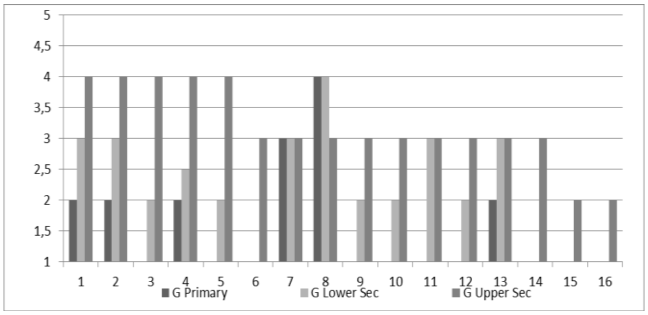

Figure 3 Median values for all age ranges for importance of goals. Numbers according to the list above (1=very unimportant, 5=very important).

The first four goals, rated most important for CS in upper secondary school can be regarded as 'abstract' learning targets.

The fifth and last goal rated as important is about 'Databases: design and queries'. This rating is to some extent different to the rating of the topic 'Databases' (see section 3.2.1).

For lower secondary education, the sixteen presented goals are rated with less importance. The only goal rated as important is 'Preparation of learners to use computers / digital technologies".

In summary, goals are rated on three different levels for lower secondary education. The first level focuses on the mere usage of PCs, the second level on thinking skills and CS and society, and the third level includes all goals rated as more or less unimportant.

In primary school, only one goal is seen as important: 'Preparation of learners to use computers / digital technologies'. This is the same as for lower secondary. One other goal is rated as having moderate importance: 'Mastering the important applications'. Again, this was also the second highest ranked goal for secondary education. All other goals are rated as unimportant or very unimportant. Programming has a quite low rank among this group of very low priority goals. This is interesting, because of some well-known tools developed to allow programming in primary education e.g. Scratch, Storytelling Alice, or Logo.

3.2.3 Teaching Methods

Participants were asked for the relevance of 13 given teaching methods or approaches for teaching CS at school. Questions about teaching methods were answered by 39-41 participants.

The teaching methods are listed from most to least relevant for all levels of education:

1. Classroom based teaching
2. Using standard applications like text processing, mail etc.
3. Pupils work individually or small groups on small tasks at the computer
4. Programming
5. Projects
6. Using editors
7. Pupils work individually on projects
8. Pupils work in small groups on projects
9. Discussions
10. Lectures
11. Using integrated development environments (IDE).
12. Reading
13. Role plays

Attention should be paid to the fact that the questionnaire asked for all age ranges simultaneously, so the results are a rather coarse grained measure (see Figure 4).

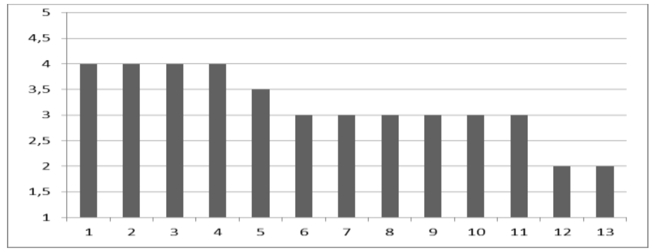

Figure 4 Median values for relevance of teaching methods. Numbers according to the list above (1=very unimportant, 5=very important).

Basically, the teaching methods have been rated on three levels. Four methods have been rated as important ('Classroom based teaching', 'Using standard applications like text processing', 'Pupils work individually or in small groups on small tasks at the computer' and 'Programming'). Within the second group (moderate importance) we find 6 methods (from no. 6 to no. 11). Only two methods are seen as unimportant: 'Reading' and 'Role plays'. The teaching method 'Projects' is rated slightly below group 1 and slightly above group 2.

When taking into account results from the questions on topics and goals we can speculate that some of the teaching methods should be of higher importance in upper secondary education, as they match programming.

3.2.4 Discussion

Overall, some trends can be seen. Topics in primary education are focusing on applications (e.g. text processing) and privacy and ethics. In lower secondary sometimes HTML is added, as well as (on a slightly lower level) introductory programming. In upper secondary, introductory programming is seen as the most relevant topic, and here a whole range of topics seem possible as additions.

The goals of CS education at school show a similar pattern. In primary education, preparation of learners to use computers and other digital technologies is the central focus, including mastering the important applications. In lower secondary, the same goals are central, and supplemented with a reflection of the relationship between CS and society, as well as computational thinking skills. Programming is seen as a goal only in upper secondary education; and for this age range it is among the most important goals. However, programming is a complicated topic to be taught; there are studies on this in higher education (e.g. [14]) but there is a lack of research on a secondary education level.

Applications are seen as a rather important topic at all levels, including upper secondary. A similar pattern can be seen for algorithmic thinking. These results might be due to different traditions and approaches for CS as subject in schools. For some, algorithmic thinking and algorithms are central focus of the subject, whereas for others, applications are the central focus (in all age ranges).

A study with Dutch Chemistry teachers found that the role of subject matter and its impact on society is seen as relevant from a subgroup with a learner-centric view on teaching; while the teacher group with a "subject-matter oriented educational belief" focused on only teaching the fundamental topics of the subject [6]. This may shed some light on how we should interpret the results on teaching methods. *Using computers* and *let students program* are seen as very important. Looking at this data, a typical CS classroom might involve students using computers with a range of applications installed. Besides integrating computers as teaching tools, only classroom-based teaching is rated as important.

3.3 CS at School (Qualitative)

In this section we present the results of the SWOT analysis on CS at school (see Table 3).

<table>
<tr><th></th><th>Opportunities
(External)</th><th>Strengths
(Internal)</th><th>Threats
(External)</th><th>Weaknesses
(Internal)</th></tr>
<tr><td rowspan="2">Prob-
lems</td><td rowspan="2"></td><td rowspan="2"></td><td>CS as optional subject (16)
Negative perceptions of CS (11)
Low student enrolment (10)
No CS (7)
Problems at governmental level (5)</td><td>Diverse capabilities of students (2)</td></tr>
<tr><td colspan="2">Lack of trained teachers (23)
Perceived same as ICT (17)
Curriculum difficulties (10)
Lack of teaching resources (7)
No quality evaluation (5)</td></tr>
<tr><td rowspan="2">Trends</td><td rowspan="2">New CS curriculum (9)
Early/more CS in high schools (8)
Raising achievement standards (5)
More training for teachers (5)
Growing importance of CS (4)
Increase in student numbers (2)
More on-line resources (2)
Different from ICT (1)
Good job prospects (1)</td><td rowspan="2">Increasing demand for CS (4)</td><td></td><td>CS disappearing (3)
Decrease in student numbers (3)
CS not relevant (3)
Unwillingness to learn CS (1)
Misconception of CS (1)
Slow change (1)</td></tr>
<tr><td colspan="2">CS teachers disappearing (3)</td></tr>
<tr><td>Initia-
tives</td><td>Promote CS (23)
Curricular changes (14)
Promote teacher training (14)
Teaching resources (3)
Encourage girls (2)</td><td>Teacher-led initiatives (7)</td><td></td><td></td></tr>
</table>

Table 3: SWOT analysis of survey results for CS education (number of statements in parenthesis)

3.3.1 Problems related to CS at schools

Participants were asked to describe current problems of CS at school, and to indicate which type of school / age range of students they were referring to. Responses referred to threats and weaknesses.

One of the most frequently stated problems was a *lack of trained teachers*. This problem was traced to numerous reasons, such as:

1. CS teachers often have different subject backgrounds;
2. Available teachers lack sufficient knowledge of programming;
3. Too few new teachers are trained in CS;
4. Lack of training courses and no certification for teaching CS.

Another problem that was mentioned often was that CS was *perceived the same as ICT*. Students do not have an informed basis for choosing CS in future studies, as they cannot differentiate between CS and IT skills. There is *low student enrolment* as students are not enthused by ICT content and have not experienced CS. The *negative perceptions of CS* were also attributed to the way CS is taught with a vocational orientation which leads students to think that it is boring.

There are other problems related to the availability of CS at school. In high school there is a competition over students with other sciences. Moreover, either there is *no CS*, or it is offered as an *optional subject* or part of or replaced by ICT. CS *curriculum difficulties* were traced to lack of unified opinion on what to teach and why to teach it, and to curricula being modified to please short term industrial interests. *Problems at governmental levels* are due to the emphasis on professional programs rather than CS for higher education. Budget cuts for CS programs lead to *lack of teaching resources*. Participants also mentioned that there was *no quality evaluation*, CS was only evaluated at the school level with no standardized national exams available.

3.3.2 Trends related to CS at schools

Participants were asked to describe the changes or the situation / demands of CS at school in 5-10 years from now.

In contrast to the problems and initiatives, the trends that were described occur in all four SWOT categories. However, most respondents referred to opportunities.

In several countries, *new CS curricula* will be introduced. This can include more flexibility to set curriculum and changes in programming languages (e.g. Python replaces Java). In some countries, CS will become mandatory in high schools and new computing subjects will replace other existing computing courses with the possibility of a central examination.

Participants also discussed that there might be *early or more CS in high schools*. This can be compared with the previous category of trends on curriculum, in which participants were more certain of actual implementation.

One of the trends that the participants believed in is that there will be *more training* and support for new and existing teachers, and that teachers are more likely to have digital and didactical competences to integrate CS in their teaching (compare section 3.5.2). Another trend was the *raising of achievement standards* by having a final and central exam for CS and opening advanced CS tracks. There is an awareness of the *growing importance of CS* and CS training.

An increasing demand for CS from students was seen as an internal strength. This demand was generated by the interest in games and blogging. On the other hand, ICT was perceived by students as boring.

In contrast to the positive trends, we also found negative trends. The category of *CS teachers disappearing* includes the perceptions of school administration and non-CS teachers that CS is not relevant. Furthermore, the number of CS teachers is decreasing due to retirement or lack of teacher training. Another negative trend was that there is a *decrease in student numbers*. CS as a subject was considered as *not relevant* and *disappearing* from schools due to local school board decisions, and due to the expenses of the facilities to teach the subject. Other weaknesses mentioned were students' *unwillingness to learn CS* and their *misconceptions* that CS was only about gaming and surfing the web. The last weakness that was mentioned was the *slow change* in attitudes of the school principals towards CS.

The picture that emerges from the trend categories is contradictory. There are a number of contrasting categories, e.g. *early / more CS in high schools* vs. *CS disappearing* and *increase in student numbers* vs. *decrease in student numbers*. Even though we do not know the trustworthiness of the statements, we mostly see consistency among the participants from a single country. An example of this is that there are several statements from teachers in UK on *early / more CS in high schools* while we find no statements from teachers in UK in the category *CS disappearing*.

3.3.3 Initiatives related to CS at schools

Participants were asked to describe current initiatives to improve CS at school. Responses referred mostly to opportunities at schools and less to strengths. Initiatives to *promote CS* were mentioned more frequently than ways to *promote teachers* and *changes to curriculum*.

Initiatives to *promote CS* included the following:

1. Holding international CS competitions e.g. Olympiads in Informatics and Bebras contests, Topcoder, and Google Code Jam.
2. Offering extra-curricular distance programs for gifted students.
3. Creating on-line, self-guided programming activities for students with no programming experience.
4. Organizing other activities like LEGO Mindstorms robots and integration of some features of programming in computerized Physics or Chemistry labs.
5. Cooperating with universities in CS subjects.
6. Discussing with the government about incorporating CS as a science rather than as a relation to ICT.
7. Involving younger students (11-14 years) in programming.

Measures to *promote teacher training* refer to pre and in-service teachers. Participants from the UK and Netherlands mentioned support from organizations such as Computing At School (CAS) and academia as well as the provision of funding for teaching resources. *Curriculum changes* such as making CS a part of ICT or STEM subjects, introducing computational thinking, and working with industry and government to change curriculum and assessment standards were also stated. Another external initiative mentioned was to *encourage girls* in high school to study CS through tie-ups with government (Israel) and industry (Google), and to introduce programming to high school girls via Alice. A few responses were categorized as (internal) strengths. They related to *teacher-led initiatives* from dedicated and enthusiastic teachers who offered extra-curricular activities, after school clubs, and lunchtime sessions to learn programming.

3.4 CS Teacher Education (Quantitative)

In this part, we present the results of how the participants rated the goals for teacher education. Participants were free to leave out ratings of items. Hence, the number of participants that rated each item of the goals varied. Therefore we decided to provide the number of participants using ranges. For example, a 31-34 range of participants means that at least 31 and maximal 34 participants rated each item.

3.4.1 Relevance of different Goals for Teacher Education

The participants were asked to rate the relevance of 17 different goals for CS teacher education. 24-26 participants rated them. The following list of these items is ranked in the order of highest ratings (see Figure 5):

1. Basic concepts of CS
2. CS education goals
3. (general) Education / Pedagogy
4. CS specific teaching approaches / methods
5. The nature of CS (What is CS?)
6. Introductory learning of CS (How to introduce students to CS)
7. Student assessment
8. School-related CS curriculum
9. Lesson planning
10. Reconstructing CS content for learners
11. All aspects of CS as university subject
12. Innovation of CS education
13. IT / ICT education vs. CS education
14. CS-specific learning tools (e.g. IDE)
15. The relation of CS education and general education
16. Conducting research about teaching CS
17. History of CS as subject in School

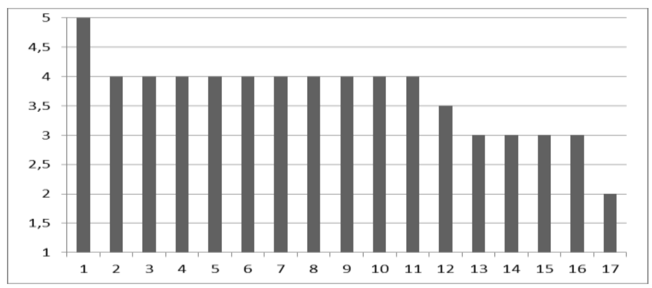

Figure 5: Median values for all age ranges for relevance of goals for teacher education. Numbers according to the list above (1=very unimportant, 5=very important).

The one highest rated goal (in fact, of the whole questionnaire in total) is 'Basic concepts of CS'. Ten other goals are rated as important (from no. 2 to no. 11). The four following items are rated as moderately important (from no. 13 to no. 16). The only one item rated as unimportant is 'History of CS as a subject in school'.

3.4.2 Discussion

A very broad range of goals is important. When adding the need for studying a second subject, teacher education seems very demanding for students: packed with a lot of topics to learn. Interestingly, the second lowest rated goal in this study is seen as important at least in newer publications on CS teacher education: the possibility and engagement into own subject didactic research. For example, the CSTA model requires pre-service students "Writing a research paper in the field of CS education " [8] (p.12). This can – with the background of the demanding list of goals – be seen as an attempt to solve the high workload in teacher education: Instead of learning everything needed, a teacher student should be made competent for ongoing professional development during the job. However, the question arises, as to what competencies and topics are central for university based teacher education programs. This question seems unresolved so far. See the CSTA report [4, 8] with examples from the US, Scotland, and Israel.

3.5 CS Teacher Education (Qualitative)

In this section we present the results of the SWOT analysis on CS teacher education (see Table 4).

	Opportunities (External)	Strengths (Internal)	Threats (External)	Weaknesses (Internal)
Prob-lems			No CS in the curriculum (4) No funding to train teachers in the subject (1) Lack of developmental expertise within education (1)	Very little teacher education to teach CS in school (12) Not enough communication nationwide (1)
			Lack of existing teachers in the subject (15) Training not specific to CS (12) Lack of support for existing teachers (8)	
Trends	Technology will evolve and affect change (7) Increase in interest in CS (5) CS will become a recognized subject (5) Increase in demand for CS teachers (4)	More teachers being trained in CS (7) Teachers being trained in CS in its own right (4) More contact with schools (1)	There will be no change (7) Teachers only teach IT/applications (4) Less interest in CS (4) No increase in demand for CS teachers (1)	Lack of qualified teachers (2)
			Decrease in CS teacher numbers (4)	
Initia-tives	National support for TE (9) International support for TE (7)	In-service training in CS (9) Change in CS TE curriculum (2) Teachers' associations springing up (2) Improving courses using feedback (1)	Lack of support for CS TE (3) Less likely to have national initiatives (1)	Not enough provision (5) No initiatives (4) CS TE requires reform (2)

Table 4 SWOT analysis of survey results for teacher education (number of statements in parentheses)

3.5.1 *Problems related to CS Teacher Education*

Participants were asked to describe particular problems that they were experiencing in their country in the area of CS Teacher Education. Responses to the questions sometimes referred to initial teacher education of new teachers, and sometimes to on-going training for existing teachers in CS. Both are important aspects of CS Teacher Education.

Regardless of country, one of the most frequently stated problems was a *lack of existing teachers in the subject.* This negative factor can be categorized as an internal, as well as external factor for the CS teacher education system. The responses fall into several subcategories:

1. Existing CS teachers do not have sufficient qualifications to teach the subject;
2. Teachers do not wish to develop further;
3. Qualified CS teachers are leaving the profession.

In terms of teacher education, these pose significant problems as there will not be a sufficient number of experienced mentors to guide new teachers whilst they are being trained and need school experience.

Training is not specific to CS was frequently stated as a problem, and this correlates with the OECD survey [7]. Here we can see several problems identified:

1. Teachers are trained to teach ICT/applications, but not CS;
2. CS teachers are taught more Math than CS;
3. Math or Physics teachers take on CS teaching at school;
4. CS teacher education syllabi need to be improved.

A closely related problem to the previous one is *lack of support for existing teachers*. Responses given indicate that there is a lack of CS teacher support (e.g. the national CS curriculum changes very often and teachers cannot keep up to date; lack of didactical materials and conferences for teachers). Another problem that was identified was the training is not of sufficient quality (e.g. in-service CS teacher training is too short; lack of reflection of real competences required for the subject).

Very little teacher education to teach CS in schools: this problem has been categorised as a weakness in our analysis of this data, as represented in most responses. Some participants stated that there is no CS teacher training program in their country; some indicated that there is no CS teacher education for lower secondary school only, and others stated that there is *not enough* CS teacher education in general. It has also been mentioned that CS teachers are self-taught. This problem is closely related to the threats and weaknesses shown in the table above: *lack of existing teachers in the subject, no CS in the curriculum* and that *training is not specific to CS.*

Some participants indicated that there is *no CS in the curriculum*, meaning that CS is either not a mandatory subject, or not recognized as a subject at all. This is the case in some countries, which obviously suggests that CS Teacher Education does not exist either.

In relation to the identified problems, several answers did not identify any problems in CS teacher education indicating that CS teacher education was going well.

3.5.2 *Trends related to CS Teacher Education*

The trends in CS teacher education are interesting to note. There are three key areas of opportunities afforded by this SWOT analysis. The first is how the *evolution of technology is affecting change*. This includes an increase in the variety of ways computers are used at schools, and the new ways of development of learning materials (multimedia applications, e-learning integration, and teachers' involvement in the design process). Another external yet positive trend is the *increase in interest in CS*, which is evident through the desire of schools to reintroduce CS, the increasing demand for CS in schools, and through the development of new CS curriculum. Some participants felt that CS teacher education may help contribute to school development in this way, particularly, as one respondent noted, as every school has computers. This trend is closely related with *CS becoming a rec-*

ognized subject. One opinion suggests seeing CS as a subject in the broader context of digital technologies, that *"...will allow students to understand the full spread of topics in that area so that if they are interested in this area, they will be able to make well informed decisions as to which direction to pursue at tertiary level - computer-based graphics or media design, 'information technology' (computer/network technical), information systems, mechatronics/computer systems engineering/electronics, or computer science/software engineering"*.

Other positive trends from within CS teacher education itself (strengths) complement those identified in sections 3.5.1 and 3.5.3 For example, one trend is for *more teachers to be trained in CS*. This is closely related to the commonly mentioned problem "*Very little teacher education to teach CS in school*". The trends we observe are being achieved either through the improvement of CS Teacher Education (for example, more in-service teacher education courses; making existing courses more practically oriented conversion courses; courses for trainee teachers), or through replacing the large number of older CS teachers with younger teachers. Another answer, identified as strength in this analysis, indicates that more contacts with schools are happening, which is very positive.

A previously mentioned problem in CS teacher education is that some training is not specific for CS. The trend being observed by the participants is a move towards *teachers being trained in CS in its own right*. It has been also predicted that the *demand for CS teachers will increase*.

There were, however, some contradictory statements. It is evident that there are opposing views about trends, e.g., *there will be no increased demand for CS teachers* and even a *decreasing number of teachers*. Other contradictory statements include *teachers will teach only IT or applications* and there is *little interest in CS*.

Finally, a trend towards a *lack of qualified teachers* in CS was mentioned as a weakness of current CS teacher education; it is however, primarily a weakness of the provision of CS in schools and is mentioned in that regard above.

3.5.3 Initiatives related to CS Teacher Education

The participants were asked to describe any initiatives that they were aware of in the area of CS Teacher Education in their country. Again these covered both initial teacher education and in-service teacher education.

One of the opportunities identified was *national and international support for CS teacher education*. Almost all initiatives are related to formal or informal CS education but not purely to teacher education. Of course, teachers learn while doing these activities. Some initiatives originated nationally, but have grown into international ones (e.g. the "Bebras" contest). Some initiatives funded by an international scheme, but implemented through a teacher association (e.g. the Google teaming), were therefore assigned both to international and national initiatives categories. Among "truly" national initiatives new CS teacher education courses to support existing teachers were mentioned, e.g. "Informatik kreativ unterrichten" initiative, Computing at School, and CS Circles Online initiative. More international initiatives include National team for Olympiad in Informatics, and CS teacher education support through EU projects.

In countries where the participants seemed unaware of initiatives, there were a number of responses indicating that there was a *lack of support for CS teacher education* at the state level and that *national initiatives were less likely to appear* (due to reduction of centrally provided support). These are external threats to the provision of new initiatives in CS Teacher Education.

In-service training for CS appears as the most frequently mentioned strength. The participants mentioned that some universities do offer CS teacher training, postgraduate courses in CS are available, CS teachers are being trained from other disciplines, and that there is more praxis available during the studies. Some countries mentioned a *change in CS teacher education curriculum*, which should lead to positive change in CS teacher education. One more mentioned strength is the *associations and networks* that are springing up and the starting of new initiatives. Some universities improve their CS teacher education courses using *students' feedback*.

Some participants' answers indicated that there was not enough provision; this included no conceptual coverage of CS, only short workshops for teachers organized, no ways to improve the situation yet, and training is only ad hoc. Four participants stated that they were unaware of any initiatives in their country, and it was also stated that CS teacher education requires reform.

3.6 Limitations

The results obtained in this study are not representative (whatever one could imagine as the community of which a subgroup participated in the survey). In addition, the survey covers only a subset of possible countries (see section 3.1). These limitations are due to the procedure, in which experts were identified and invited because they were known to someone involved in the project. Besides this, the call went to some mailing lists, which were thought of as consisting of experts in the fields. From 84 participants out of 22 countries, 30 come from only three countries (UK, Germany, USA), so that the sample may be somewhat biased.

Participants were asked to answer from a national perspective, e.g. describing situations, problems and developments on a national or at least state-wide level. During analysis the researchers felt this was done, but not always. Sometimes it was hard to interpret whether arguments were based on data, hunches, wishful thinking and/or only local perspectives instead of national-wide perspectives. In such cases, at least two researchers discussed the relevance of the statement and decided how to categorize it.

The same problem arises with regard to quantitative questions concerning e.g. goals of CS in primary education. Here, too, participants should rate according to their perception of the national level, but seemed to have answered from a local perspective. Participants were asked to answer only when they were sure, so the questionnaire contains a lot of unanswered responses. For example, quantitative questions for USA were answered by only one person.

One of the limitations of the study is the different terminology used. In some countries, the term Computer Science may be broader than in other countries, and include some aspects of digital literacy, whereas in others, these topics are taught as ICT. In some countries Informatics or Computing is used with a slightly different meaning.

The answers in the quantitative parts also have many missing values; this is because the questionnaire explicitly asked participants to answer a question only when they were familiar with the topic.

It was difficult to distinguish internal and external aspects, for example *lack of trained teachers* can be interpreted as an internal problem but could also refer to external governmental policies.

It was not always clear if participants really distinguished between students' competencies and teachers' competencies (e.g. some referred to national educational standards in the latter context).

The results of the analysis of the trends complement those of the problems and initiatives. Some of the trends seem however to be based more on mere guesses and predictions rather than actual facts. However it does not appear that the trends are uniformly in the same direction. Some participants report an increase in uptake and provision, but some are more despondent about the lack of initiatives in their area. It might have been expected that the trends were in the same direction (with different degrees), but this is not the case. Particularly in the SWOT analysis of CS in teacher education, the responses are quite contradictory. This suggests quite a localized pattern of change. Some local initiatives are making significant differences, and perhaps in some countries it is easier to implement national initiatives than in others.

4. DISCUSSION

From the analysis of the two different parts of the questionnaire, CS at school and CS teacher education, we can see similarities. The most general similarity is that the pattern in the data shows change rather than stagnation. There are a few statements predicting "no change". However, most of the categories reveal changes and we have also found contradictory categories as explained in the previous sections. This change mirrors the constant change within the discipline itself. This in turn implies a challenge for students, educators, curriculum developers, and companies, i.e. all stakeholders.

Several reports [3, 18, 23] also state that CS education is subject to reform which naturally influences the change in CS teacher education. The UK Royal Society report, after an 18 month consultation, describes the teaching of CS in many schools in the UK as "*highly unsatisfactory*" [21], (p.11). It is therefore not surprising that we found common concerns, both in CS at school and teacher education, such as curriculum difficulties, training and support for teachers, as well as the understanding (e.g. CS vs. IT) and relevance of CS.

4.1 CS at School

The results of our analysis reflect typical problems also mentioned in other publications, e.g. [15, 20, 21, 23].

- A frequently mentioned problem was lack of trained teachers, which we discuss in the following section.
- Another problem that was mentioned often was that CS was perceived the same as ICT; students often choose (or not) CS based on such misconceptions.
- Similar misconceptions by school boards are sometimes responsible for the organization of the subject in school (e.g. offered as optional or mandatory; offered in which level). Participants also mentioned the lack of quality control as CS was only evaluated at the school level with no standardized national exams available.

Initiatives to promote CS were mentioned more frequently than ways to promote teachers and changes of curriculum. Some issues in the curriculum are shared among our participants, while others are unclear: Programming has its merits, as well as applications, but to which extent and in which grades is somewhat questionable; the same is true for abstract goals and thinking skills, and the idea of algorithms (see Figure 3).

In several countries, new CS curriculum will be introduced. Participants also discussed that there might be more CS in high schools or an earlier introduction of CS in schools.

Based on these results we can draw suggestions for further development of CS at school:

1. Develop a shared vision of CS at school from primary to upper secondary education so that the value of CS becomes clear.
2. Support initiatives to promote CS (see section 3.3.3), so that (prospective) learners can choose to pursue CS education on an informed basis.

4.2 CS Teacher Education

The results of our analysis identify the same problems for CS teacher education as are mentioned in the Royal Society report [21]:

- There is a shortage of teachers who are able to teach beyond basic ICT or computer applications.
- There is a lack of continuing professional development of CS teachers.

The survey results have shown that there is a lot of national and international support for initiatives in CS teacher education. This support should be leveraged to improve CS teacher education, as well as to raise the competency of current ICT teachers to teach CS. As identified in our analysis, the technology will evolve and affect change in CS teacher education. This also complies with UNESCO's transforming stage: the school will become a high level connective learning community [1].

We are aware that there are other initiatives occurring in CS teacher education in some countries that do not appear in our data; however, this analysis reflects the participants' knowledge at the time of the survey and is not a comprehensive list of activities and initiatives. What it demonstrates is that there is a move towards developing teacher education in a number of countries, but that this may be sporadic and that some countries may not be focusing on this as a priority at the current time.

Based on the results we offer suggestions for further development. These relate to our interpretation of the problems, trends and initiatives as described by the participants. We draw attention to the following points in particular:

1. CS teacher education should support the development of CS as a recognized subject. Therefore trainee teachers should be aware of a number of issues: the (changing) nature of the discipline, the role of CS at school, including the difference and integration of ICT and CS in school, and the value of CS education for their future learners.
2. Together with the changing role of technology, and the relation of ICT and CS, as well as the inclusion of ICT in different subjects, CS teachers should have the skills to support school development with regard to ICT.
3. The need for innovation is somewhat contested (see Figure 5). CS teachers should be able to trigger and maintain innovation in their own subject (e.g. with regard to the suggestions made in section 4.1). School based continuing CS teacher education is seen as successful activity (see section 3.5.2) supporting such innovation.

5. CONCLUSION

The results of this study point to the importance of further investigations by countries (governments) of current CS developments in schools. In contrast to other subjects like mathematics, the changing nature of CS necessarily needs to be taken into account when planning teacher training and curriculum. Governments that want to keep up with the pace of global development of CS need policies and procedures for revisions as well as financial provisions for training, curricular development, infrastructures in schools, and also further research in the area. Furthermore, the implications of the changing nature of CS need to be addressed in education, both for students and teacher trainees.

In summary the main contribution of this study has been to shed light on the kind of problems within CS at school and CS teacher education. It draws attention to the initiatives that are being undertaken at local and international levels to solve these problems. Finally the study points out trends that are likely to occur within the next few years. This report merits considerations by governments and school advisory boards to meet CS students' and teachers' expectations, industry demands, and global challenges.

Future work should aim to refine the analysis and results, maybe by using a Delphi-method, in which experts can comment on the results, and by repeating the study in other regions of the world. Another interesting continuation would be to compare national documents (e.g. curricula or standards) with the opinion of experts' from this study.

6. REFERENCES

[1] Anderson, J. and van Weert, T.J. 2002. Information and Communication Technology in Education. A curriculum for schools and programme for teacher development. UNESCO.

[2] Blum, L. and Cortina, T.J. 2007. CS4HS: an outreach program for high school CS teachers. SIGCSE Bull. 39, 1 (Mar. 2007), 19–23.

[3] CAS 2012. Computer Science as a school subject. Seizing the opportunity. Computing at School Working Group Report.

[4] CSTA 2007. Computer Science State Certification Requirements - CSTA Certification Committee Report. Computer Science Teachers Association Association for Computing Machinery.

[5] Diepen, N. van et al. 2011. Which way with informatics in high schools in the Netherlands? The Dutch dilemma. Informatics in Education. 10, 1 (2011), 123–148.

[6] Van Driel, J.H. et al. 2007. The relationships between teachers' general beliefs about teaching and learning and their domain specific curricular beliefs. Learning and Instruction. 17, 2 (2007), 156–171.

[7] Enochsson, A.-B. and Rizza, C. 2009. ICT in Initial Teacher Training: Research Review. Technical Report #38. OECD Publishing.

[8] Ericson, B. et al. 2008. Ensuring exemplary teaching in an essential discipline: Addressing the crisis in computer science teacher certification. Final Report of the CSTA Teacher Certification Task Force. ACM. (2008).

[9] Ezzy, D. 2003. Qualitative Analysis. Routledge Chapman & Hall.

[10] Gal-Ezer, J. and Stephenson, C. 2010. Computer science teacher preparation is critical. ACM Inroads. 1, 1 (Mar. 2010), 61–66.

[11] Grossman, P.L. 1989. A Study in Contrast: Sources of Pedagogical Content Knowledge for Secondary English. Journal of Teacher Education. 40, 5 (Jan. 1989), 24–31.

[12] History of SWOT Analysis: http://www.marketingteacher.com/swot/history-of-swot.html#. Accessed: 2012-06-15.

[13] Jones, S.P. 2011. Computing at School International Comparisons. http://www.computingatschool.org.uk/data/uploads/internationalcomparisons-v5.pdf

[14] Kinnunen, P. 2009. Challenges of teaching and studying programming at a University of Technology. Viewpoints of students, teachers and the university. Dissertation, Helsinki University of Technology.

[15] Marina, P. 2008. Are Computer Science and Information Technology still masculine fields? High school students' perceptions and career choices. Computers & Education. 51, 2 (Sep. 2008), 594–608.

[16] Micheuz, P. 2008. Harmonization of Informatics Education – Science Fiction or Prospective Reality? Informatics Education - Supporting Computational Thinking. R.T. Mittermeir and M.M. Sysło, eds. Springer Berlin Heidelberg. 317–326.

[17] Saeli, M. Teaching Programming for Secondary School: a Pedagogical Content Knowledge Based Approach. Technische Universiteit Eindhoven.

[18] Seehorn, D. et al. 2011. CSTA K–12 Computer Science Standards Revised 2011. Computer Science Teachers Association Association for Computing Machinery.

[19] Shulman, L.S. 1986. Those Who Unterstand: Knowledge Growth in Teaching. Educational Researcher. 15, 2 (1986), 4–14.

[20] Taub, R. et al. 2012. CS Unplugged and Middle-School Students' Views, Attitudes, and Intentions Regarding CS. Trans. Comput. Educ. 12, 2 (Apr. 2012), 8:1–8:29.

[21] The Royal Society 2012. Shut down or restart? The way forward for computing in UK schools. The Royal Society.

[22] UYANGA, S. 2006. The Current Situation of Informatics Education in Mongolia. Informatics in Education. 5, 1 (2006), 133–146.

[23] Wilson, C. et al. 2010. Running on empty: The failure to teach K-12 computer science in the digital age. http://www.acm.org/runningonempty/