# A comparison of current trends within Computer Science teaching in school in Germany and the UK

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**Abstract.** In the last two years, CS as a school subject has gained a lot of attention worldwide, although different countries have differing approaches to and experiences of introducing CS in schools. This paper reports on a study comparing current trends in CS at school, with a major focus on two countries, Germany and UK. A survey was carried out of a number of teaching professionals and experts from the UK and Germany with regard to the content and delivery of CS in school. An analysis of the quantitative data reveals a difference in foci in the two countries; putting this into the context of curricular developments we are able to offer interpretations of these trends and suggest ways in which curricula in CS at school should be moving forward.

**Keywords:** CS Ed Research, ICT, CS at school, CS curriculum, topics, international comparison, international study

## 1 Introduction

The second decade of the new millennium has started with growing attention to Computer Science (CS), Informatics or Computing in school education. Many countries are becoming inspired by the challenges posed by the Computer Science Teacher Association in USA [17] and Computing At School in the UK [3]. Readers can gain an impression of this recent attention by just observing the titles of articles of the third volume of the “ACM Inroads” 2012 publication: ‘Transforming High School Computing’; ‘Reforming K-12 Computer Science Education…what will your story be?’. All of these papers, and there are more, are devoted to the questions of CS education in schools.

In 2011, the annual international Koli Calling conference on computing education research held a workshop group on teaching computing at school and computing teacher education. Before the workshop, a group of researchers created an online survey, and gathered information about the state of the art and current activities regarding teaching CS at high school and CS teacher education in multiple countries. The aim of this research was to get an overview of CS promotion at general education, to develop a vision and/or identify trends, and to offer suggestions for future work. Experts and teaching professionals were asked for their opinions on what was happening in their own country at that time, given that the pace of change is fast [15].

It is necessary to mention briefly the terminology used in different countries. Many European countries have titled the subject Informatics as equivalent to CS in USA. Recently the Royal Society in the UK has identified that the term 'Computing' should be broader than the ICT course and include CS: "*Every child should have the opportunity to learn Computing at school, including exposure to Computer Science as a rigorous academic discipline*" ([18], p. 6). Michal Armoni wrote: "*CS should be taught as another different stand-alone subject (under the title CS, computing, informatics or any other similar in nature) with a stand-alone curriculum that introduces CS as a discipline of its own*" [1] (p. 20). In this paper we will use the term Computer Science (CS) to refer to this academic discipline and it is equivalent to Informatics (Informatik) used in Germany.

## 2 Methodology

The data presented here is a subset of the data obtained by an international working group on the situation of CS as subject in schools. Experts from the international community of CS education and teaching professionals worldwide, were asked to answer an online questionnaire [15].

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.

Participants were instructed to answer from a national perspective, e.g. describing situations, problems and developments of CS education at school on a national or at least state-wide or province level. For all questions and scales, respondents were able to leave some questions unanswered. In the introduction to the questionnaire, participants were informed that they could leave out questions that did not refer to their personal knowledge or experience. This was done in order to avoid participants having to provide superficial information or referring to a local situation instead of the national one. We expected many experts to be aware of some aspects of the national system, but probably not about e.g. each type of school/age level. The results reflect this assumption, as the data has many unanswered questions.

Experts from 22 countries answered the questionnaire (Table 1). There were primarily up to 3 responses from most countries; however, from the UK, Germany and USA there were more respondents.

Part of the questionnaire addressed topics and goals covered in CS Education in three age ranges (primary education, lower secondary education, and upper secondary education), as well as teaching methods. In each of these parts the participants were asked to rate the importance of different aspects of CS at school on a 5-point Likert scale. It is the responses to this section of the questionnaire, and what it reveals about the differences between nations, that we are addressing in this paper.

**Table 1.** Number of respondents*

| 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 |

* We use three-letter country codes defined in ISO 3166-1.

The questions used for goals, topics and methods were designed in a small group, and then sent out to a group of experts in several countries. In this pilot, only some changes were needed. The most disagreement was on age ranges, which were finally defined as follows: 1) Primary School (Elementary School; grades 1-4/7 students are typically 5 to 10 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 to 12/13, students are typically 15 to 18 years old).

## 3 Data analysis

In this section we present data from the questions described above from two countries, UK and Germany. As can be seen in table 1, there are also other countries with some more answers. E.g. USA, but here we got only one answer for the quantitative questions. Similar was the situation for the Netherlands.

Due to the large number of unanswered questions, we use a qualitative description of the visualized quantitative data, assuming that the few experts from one country indeed were able to rate the situation of the country on the given scale. The data was visualized using bar charts showing mean values. Thus, differences in these ratings are considered as indicators for possible differences in the educational approaches between the countries. We do not consider these indications as the final results, but as themes we should take into account when discussing the current situation in these countries, as they might reveal different possibilities, developmental stages or just local/national differences.

For more results on the study, see [15].

### 3.1 Topics

Questions were asked about the coverage of the following topics in schools:

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

In primary schools, it can be seen (Fig. 2) that Germany and UK are covering broadly similar topics, with UK covering more with regard to applications than anything else. In Germany there is a strong focus on privacy and ethics, much higher than in the UK. Programming, HTML and robotics are also rated somewhat higher.

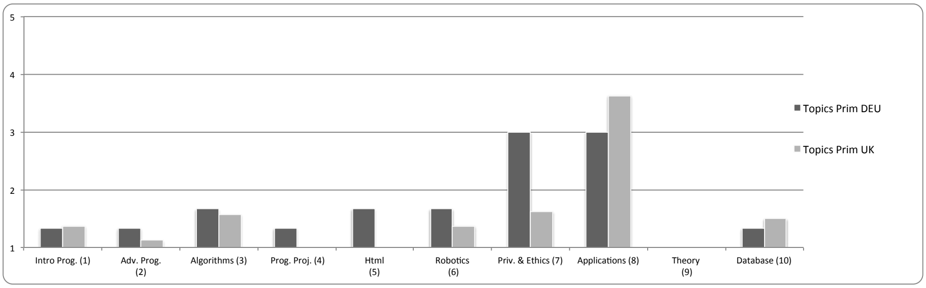


**Fig. 1.** Topics covered at primary school (3, DEU and 8, UK experts answered)

By *lower secondary* more of all these topics are covered in both countries (Fig. 2). However, the differences between the countries are more pronounced as we can see that Germany is including more programming and HTML, while UK still focuses mostly on applications, including now databases and projects.

In Germany, there is still a high focus on privacy and ethics, and also robotics. There is also a relatively high emphasis on applications.

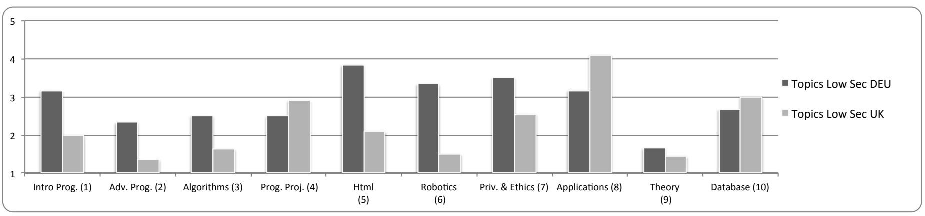


**Fig. 2.** Topics covered at lower secondary school (6 and 11 experts answered)

By *upper secondary*, more of each topic is covered in both countries (Fig. 3). There is no difference with respect to the amount of HTML scripting covered, but Germany is showing a greater emphasis on computer programming and computational theory, whereas the UK still has its greatest emphasis on software applications, with databases the next greatest. In Germany, the focus on privacy and ethics again is very high, and there is some focus on this in the UK.

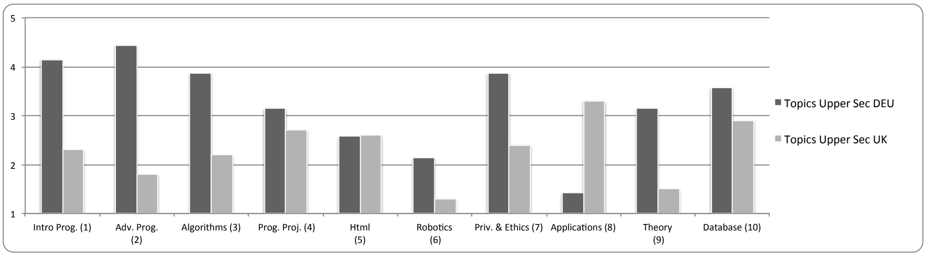


**Fig. 3.** Topics covered at upper secondary school (7 and 10 experts answered)

Results from other countries in our questionnaire reveal some differences with Germany and the UK data. For example, in Israeli primary schools there is more focus on Applications, HTML and Robotics. This difference is not observed in lower secondary school, except for Applications that are still slightly more focused on. In Israeli upper secondary school considerably more attention than in Germany is paid to Algorithms, Programming projects and Theory, and slightly more focus is on Advanced programming. This may be explained by the fact that Israeli upper secondary school has developed and implemented a strong CS curriculum with five courses: 1) Fundamentals (2 units, introducing the central concepts of solving algorithmic problems and teaching how to apply them in a programming language); 2) Software design (data structures and design of complete system); 3) Second paradigm (introduction to a second programming paradigm, logic programming, functional programming and system-level programming are three of the current possibilities; 4) Applications (focuses on a particular application, emphasizing both theory and practice; and 5) Theory (exposes to selected topics in theoretical CS, e.g. models of computation, finite automata) [10].

### 3.2 Teaching Methods

We asked questions about the choice of the following teaching methods:

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

Looking at the average responses with respect to teaching methods (Fig. 4) there are only slight differences, with more individual work being carried out by UK students and more group work in Germany. Students in Germany attended slightly more lectures and worked on programming tasks using IDEs and editors, whereas UK students used more standard applications. This reiterates the difference in topics alluded to above.

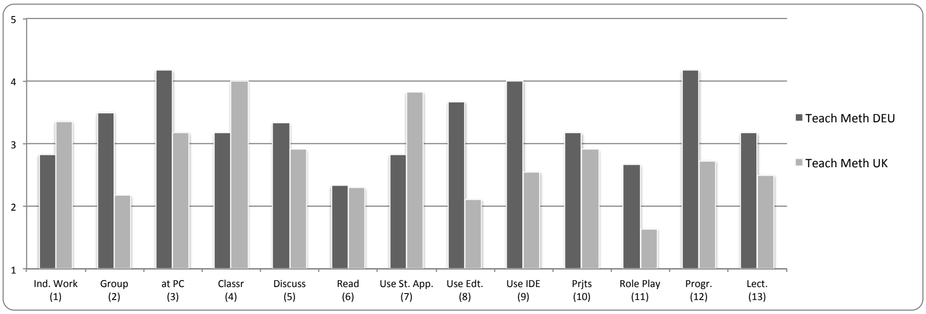


**Fig. 4.** Teaching methods used in different countries (6 and 11 experts answered)

### 3.3 Goals

We asked questions about the goals of CS programs in schools:

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

The goals that schools were working towards in terms of CS education in primary were again broadly similar, as for topics. There were some exceptions: in Germany, there was more emphasis on the nature of CS, its impact on society, personal computer use, and thinking skills (Fig. 5).

Interestingly, we found somewhat reversed ratings for Using PC and Applications. In addition, Impact on society as a goal the somewhat reversed ratings for Using PC and Applications. In addition to Impact on society as goal, also understanding Nature of CS was rated very high in Germany.

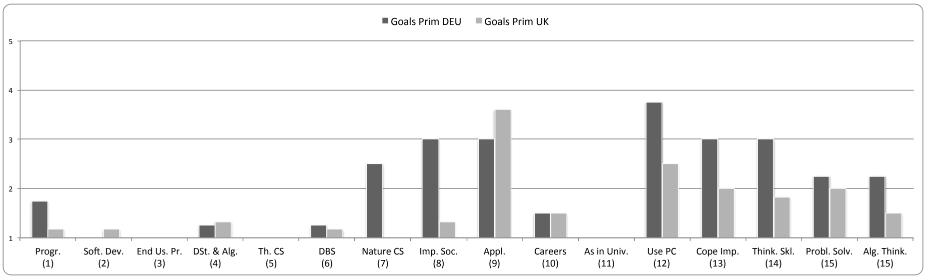


**Fig. 5.** Goals of lower primary education in CS (in UK and Germany) (4 and 6 experts answered)

By lower secondary, these differences are more marked (Fig. 6).

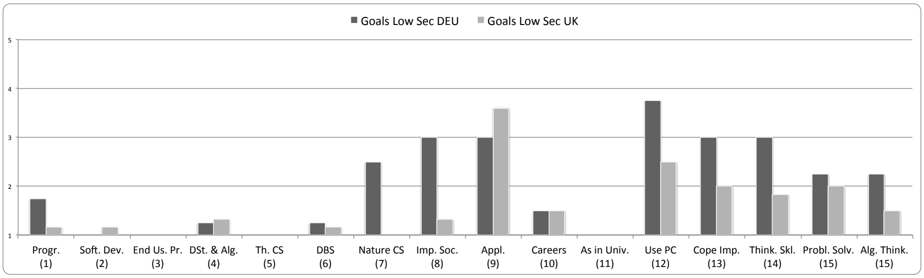


**Fig. 6.** Goals of lower secondary education in CS (4 and 6 experts answered)

By upper secondary, more UK teachers report that more software applications are taught in schools than German teachers (Fig. 7). However, Germany records more curriculum goals around problem solving, thinking skills, programming, and the nature of Computer Science.

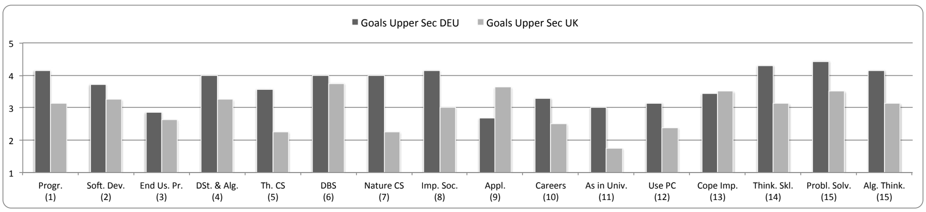


**Fig. 7.** Goals of upper secondary education in CS (7 and 8 experts answered)

# 4 Differences in curricula

## 4.1 UK perspective

The data gathered very much reflects the situation in England and Wales in the middle of 2011, when the survey was carried out. A short history of UK teaching of ICT and CS will demonstrate emerging trends.

Prior to the 1980s, programming had been taught in schools and in the age of the first small personal computers such as the BBC Micro, all students learned about hardware, binary arithmetic, and computer programming. The UK was seen as a leading force in the development of personal computing in schools and many children were inspired and engaged. A qualification was available to 14–16 year olds in Computer Studies. However, in the 1980s, CS essentially disappeared as a curriculum subject for under-16 year olds, being replaced by Information & Communication Technology (ICT) [4]. The National Curriculum was introduced into England and Wales, which focused on developing skills in software packages as well as other ICT soft skills. The most recent version of the National Curriculum for ICT (2007), which was a compulsory subject in schools up to age 16, had a focus on using ICT appropriately with the right tools and being able to evaluate effective use of ICT; Scotland, however, managed to retain Computer Studies as a topic in schools at this time. CS was retained as a subject in its own right post-16, but the number of students choosing to take this was diminishing due to the lack of understanding of the difference between ICT and CS [3].

Although it had been seen as important to give students in the UK digital literacy skills through the 1990s and the 2000s, this was obviously at the expense of CS topics. By around 2008, there was a realisation, through the development of the Computing at School group (CAS) in the UK that this was unsatisfactory and could suggest a reason for declining recruitment figures to study CS in higher education. Concerns were expressed that ICT lessons were “boring” and did not engage or enthuse students as well as focusing too much on basic digital literacy. The Royal Society thus launched a consultation on the matter in 2010.

The Royal Society released its report entitled “Shut Down or Restart: The way forward for Computing in UK schools” at the end of its 18 month consultation period, describing the teaching of CS in many schools as “highly unsatisfactory” [18]. The recommendations included increasing the number of teachers trained to teach CS, improving in-service training, and providing more technical resources for schools. The Secretary of State for Education has subsequently announced that the National Curriculum for ICT is to be discontinued from September 2012. It will remain compulsory to teach ICT from ages 5 to 16, but schools no longer have a prescriptive program of study and are encouraged to include more CS.

The media, as well as industry and academics, have been quick to react to these comments, and there is now a rapid pace of change within England and Wales to a broader, more academic, curriculum, combining ICT and CS. There is an increased focus on reducing the amount of time spent learning to use software applications and bringing in introductory programming into the lower secondary stage. This includes learning Scratch, Kodu and simple Python programming, in addition to the development of multimedia and animation skills that were formerly part of the lower secondary curriculum. We have now seen the introduction of several qualifications at the upper secondary stage that students can study from ages 14–16 in CS. The Computing at School group has had a very significant role to play in both advocating and implementing these developments.

### 4.2 Germany perspective

In order to understand what current developments imply, we need to discuss the history of CS education in Germany. CS started very early in Germany (in the 1970s). The first two decades were dominated by a succession of four didactical approaches to teaching CS at the school level (for a more in depth discussion see [6]).

The initial approach, with virtually no practical impact, was called hardware orientation [8], and based on a cybernetic philosophy, grounded in the understanding that digital technology is completing the technological evolution of mankind by entering the third and last stage. The first stage was the invention of tools to augment limbs (or: extremities) with tools (like a hammer). The second approach was the invention of machines to augment physical strength. Digital technologies are seen as the final stage, as they are augmenting intellectual power, by a process called *objectivation*, the segmentation of problems in a digital representation. Therefore, it was seen as necessary to teach basic principles of the hardware, and not to start using a higher order programming language, because using e.g. loops would prevent from focusing on and understanding the fundamental basic process of digitalization. At this point, a counter movement started and proposed algorithms as the central point of interest, and the need to start with a higher order programming language in order to teach algorithmic problem solving, and to introduce basic algorithms and algorithmic strategies (sorting, searching, abstract data types, recursion). Programming projects were introduced as a means to foster these learning goals.

The third approach at this point in history criticised the algorithmic approach for being somewhat detached from the use of CS in everyday life and from appropriately teaching the impact of CS. It was termed 'use orientation'. Programming projects should show the impact or usefulness in real life, like digitizing the library, or the grocery store. Essential (but in practice often neglected) was a reflection on the impact of such a project on the users or society in general.

The last of the so-called classical approaches in CS school education in Germany strengthened this focus on users, and suggested to shorten programming, in order to gain time for discussing impact; because in the meantime (mid 80s) the personal computer was invented and a lot of applications were developed so that problem solving with computers was also possible by using software applications.

In 1986, national regulations introduced a mandatory subject for teaching these topics, but focusing on use of IT (ICT) in lower secondary school [7, 11]. An additional and optional subject called Informatics was also introduced for upper secondary school (and in lower secondary as well in some parts of Germany). In a way, the last approach of the classic views described above became ICT, whereas Informatics was oriented towards algorithm-oriented approach and also to the third, more critical, phase.

In late 80s, Informatics was well established in school, but came into a crisis in the 90s [13], due to lower enrolments, lack of clarity of educational goals, and demands for change due to new programming paradigms.

There are now several newer approaches for conceptualizing CS as a subject in school in Germany, see e.g. [2, 5, 12, 16].

Current developments in Germany are focusing on improving the situation in lower secondary education, for which educational Standards (Bildungsstandards 2008) have been developed by the Gesellschaft für Informatik (GI), the German Computing Society. While most issues could be solved easily during development of standards, some issues have been the main focus of discussion [14]: A) Should there be a programming standard? Or should it be modelling, or modelling and implementing? Is programming a central topic (a content standards), or merely a practice, and thus a process standard? In the end, it became a process standard named Modelling and implementing. B) Is the topic of CS, man and society one associated topic (one content standard) or merely something that permeates every part of the curriculum? Or, when included as a process, does it face the danger of becoming implicit or even being left out of everyday teaching practice? In the end, it became a content standard.

Contextualized teaching is proposed as a model to foster the development of teaching units that implement and help to disseminate the standards (examples are teaching units on Chatbots as introduction to artificial intelligence, email as introduction to cryptography, or mobile phones as introduction to privacy and understanding information and data). Other examples currently being developed are focusing on including hardware, using some of the current and increasingly-popular hardware gadgets like Arduino, Scratch boards, Raspberry Pi or .Net Gadgeteer.

## 5 Discussion

It is apparent that the responses showed some differences in the topics taught at school between Germany and the UK. It would appear that both countries have a similar focus in primary school, but that the difference is quite significant by the time students reach age 14. In primary school, most teaching focuses on the use of ICT and software applications, although there is a strong focus on ethics also in primary school in Germany. There are other themes that emerge from the data, where we can look at differences and similarities in relation to the way CS is taught in school. We will discuss these themes in more detail in the following sub-sections.

**Ethics in Computing**. In Germany, there is a focus on privacy and ethics from primary to upper secondary as this has been a focus within the curriculum for several decades. In the UK, ethical issues are discussed with pupils at all levels of their education, but mostly within the context of internet safety and areas such as data protection. This appears within the ICT curriculum so it is unusual that the UK experts did not feel that this was a significant topic that had been covered.

**ICT versus CS**. When looking at the full range of topics from primary to upper secondary, there is some progression from using computers and application – ICT – to programming, database, algorithms, to CS.

In the UK, throughout the stages, there is a focus on application, hence ICT, is maintained. In Israel, in contrast, the upper secondary conceptualization seems very closely related to CS as taught at the university level.

It can be seen from our data that coverage of ICT and CS topics differs in different countries, according to the national perspective. We surmise that different countries can learn from the good practices of each other.

**The role of programming**. Again, there are differences that can be noted between countries. In Israel, the curriculum contains a strong focus on programming, advanced programming, data structures and algorithms, and on programming projects, according both to our data and the literature. In Israel, programming projects are likely to be done by individual work [9], whereas in Germany, programming projects are almost always done in groups, or within the whole class. The UK seems to report less involvement with programming projects until reaching the upper secondary stage.

The current trend for primary and lower secondary education, in many countries, is to introduce visual environments such as Scratch and Kodu that make programming fun and accessible to younger children. This is appearing within the curriculum in both UK and Germany, but probably this trend occurred earlier in Germany. However in some countries, there still is the problem that there are not enough teachers who are fully trained to teach CS. The danger might be that the teacher does not have the understanding of the programming concepts underlying the environment to be able to facilitate the development of basic programming principles and might still perceive using such tools as learning to use an application as opposed to learning the principles of programming.

**Understanding the nature of CS**. This topic is essential if we are going to give children a head start in CS. However, the data does not yet give us the evidence that this is uniformly introduced to children in school. In upper secondary there is more teaching of understanding the nature of CS according to the data, but this may be in non-compulsory courses that small numbers of children sign up for (we do not have data for this).

**Identifying trends in CS at school**. A longitudinal study would give firm evidence of trends in the teaching of CS in schools. We will be able to further our understanding of the way that CS is delivered in schools in different countries by repeating this data collection exercise at a later date. However, the evidence from published curricula and professional associations indicates that there are trends towards teaching more CS in school and having less focus on digital literacy. If these trends really do exist, can we suppose that in a few years' time all countries may be covering the same topics within the broad area of CS? Although we have noted differences between the UK and Germany throughout the study, the changing curricula suggests that these differences are already diminishing.

On the other hand, we might see different traditions or cultures with regard to CS education: In Israel, we see a strong focus on CS as it is conceptualized and taught in academia. In Germany, this focus is true for the algorithmic oriented approach from the 80s, but was widened afterwards. Now the focus is – according to our data – on the societal impact of CS, and on 'nature of CS' – teaching a suitable conceptualization of CS – which might became necessary due to a weaker link to the academic image of CS. In the UK, the focus is on applications, probably due to the history where ICT was the central subject and was only recently supplemented by CS. It will be interesting to see how the development proceeds: Towards the Israeli model, or towards the German model – or towards a unique integration of ICT (and applications) into a CS curriculum.

Further work will include using the questionnaire to collect data from school teachers and experts in Asia about the content of CS education there.

# 6 Conclusion

The data suggests that at the time of the survey Germany has a broader focus on Computer Science in its schools than the UK. The UK data shows that many topics are covered, but there is an increased emphasis on teaching students to use software applications. This disparity is starting to be addressed within the UK. Although Germany has managed to have a continuity of teaching Computer Science (as Informatics) within the school curriculum throughout the history of digital technologies, the UK is starting to catch up.

The situation in the UK is rapidly changing. Teachers are now trying to adapt rapidly to these changes and in-service and appropriate pre-service training of CS teachers for England, Wales and Northern Ireland is needed (Scotland already has CS within the curriculum). The intention is that establishing a broad and balanced curriculum, we can use experiences from a range of other countries. In addition, through these experiences, we can develop teacher education programs and new curricula that will be of wide interest.

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