The Role of Teachers in Implementing Curriculum Changes

David Thompson
Department of Computer
Science and Software
Engineering
University of Canterbury
Christchurch, New Zealand
dr.curiosity@gmail.com

Tim Bell
Department of Computer
Science and Software
Engineering
University of Canterbury
Christchurch, New Zealand
tim.bell@canterbury.ac.nz

Peter Andreae
School of Engineering and
Computer Science
Victoria University of
Wellington
Wellington, New Zealand
peter.andreae@ecs.vuw.ac.nz

Anthony Robins
Computer Science
Department
University of Otago
Dunedin, New Zealand
anthony@cs.otago.ac.nz

ABSTRACT
In 2011 New Zealand introduced computer science into high schools after a long period when computing was mainly focussed on training students to be users. The transition was rapid, and teachers had little time to upskill to prepare for the new topics, and yet there was widespread voluntary adoption of the new standards. The role of teachers and the national teachers’ organisation in making the change has been pivotal, and this paper reviews the changes from the teachers’ perspective. This story is intended to inform those planning similar changes in other countries, and provide a context for the next steps in NZ. The discussion centres around a survey of 91 teachers, which reveals strong intrinsic motivation from teachers to make the changes, a mixture of prior knowledge and skills that teachers shared with each other through peer support and online communication, a low level of confidence as teachers of computer science, and a need for further professional development.

Categories and Subject Descriptors
K.3.2 [Computer and Information Science Education]: Computer Science education

Keywords
teacher professional development, curriculum implementation

1. INTRODUCTION
Considerable work has been done around the world to introduce Computer Science (CS) and Computational Thinking (CT) concepts into formal school curricula, and some countries and states have initiated significant changes. For example, in early 2012 the Royal Society in the UK released a report that advocated sweeping changes to the ICT curriculum [11] that received support from the government; in New Zealand (NZ) new computer science standards were introduced in the final three years of high school in 2011 [3, 4]; in Germany new compulsory standards have been introduced in some regions since 2008 [7]; and in the US, the “CS10K” project aims to have 10,000 CS teachers in 10,000 high schools by 2015 [1].

Implementing such changes to school systems has required major structural changes to curricula and standards, but the key element in the success of the changes is having well-trained and confident teachers to deliver the new curriculum, and growing the numbers of such teachers has been of widespread interest [1, 8, 11, 12]. New teachers need to have subject knowledge and pedagogical knowledge to deliver the topics effectively. The history of computing in schools has often seen the subject evolve from areas such as commerce or using applications, where teachers have less technical knowledge and therefore need considerable upskilling to be able to teach CS topics as diverse as programming, algorithms, data representation, security, HCI and so on.

The ability to teach also depends on the teacher’s self-perception. Ni and Guzdial [15] observe that teachers’ perception of their professional identity can be a significant issue, and that in addition to appropriate training they need to be part of a community of CS teachers who can support each other and build a strong sense of identity.

To understand this better, we investigate the role that teachers have played in implementing the significant changes in the New Zealand computer science curriculum that was phased in from 2011. In this case almost no formal training was available, and furthermore, the changes were made quickly so teachers have had to upskill at short notice in a resource-constrained environment, which could lead to issues...
of teachers feeling out of their depth or unsupported. This ad-hoc and under-resourced approach raises doubts about whether the introduction can succeed, as the importance of dedicated computer science teacher training is well established [16].

Despite these issues, a strong teacher community emerged in NZ, and with some support from universities, industry and government, ad-hoc professional development became available which enabled teachers to essentially bootstrap the teaching of the new topics. Consequently a new CS curriculum was delivered in NZ in 2011 with positive student engagement and some good learning outcomes [5]. It is important to investigate such changes from a teacher’s point of view, since they have borne the brunt of the changes, and are still developing confidence teaching the new material.

In this paper we begin by looking at the role of teachers in implementing the introduction of computer science to high schools, and then report on a survey of teachers conducted in early 2012 in which teachers were able to reflect on the introduction of computer science in 2011.

2. IMPLEMENTING A NEW CURRICULUM

Computer science as a school subject was introduced to NZ high schools to be taught at the start of the school year in February 2011 as part of a range of new standards covering five strands within the “Digital Technologies” area. The standards are specifications of assessment requirements and effectively define curriculum content. The process of introducing the curriculum has been documented elsewhere [3, 4], but some key points to note are that computing in schools had a low status prior to the 2011 changes [9], the introduction was extremely fast (two years from conception to implementation), there was very little formal training for teachers, and yet there was remarkably widespread adoption of the new topics [4].

During the period that the new standards were introduced, the formal training offered to teachers mainly comprised a 3-day national symposium in November 2010 on the range of computing topics in schools (not all teachers could attend), regional workshops, and training on technology teaching in general. The recently formed NZ Association of Computing Digital and Information Technology Teachers (NZACDITT) organised local workshops and set up a national mailing list which was very active (over a thousand topics were discussed on the list in the year leading up to the standards going live). The association also developed a website for sharing resources (nzacdit.org.nz). A collaboration between the Ministry of Education and all Computer Science departments in NZ created a project to develop resources for this site, and to date some 7,000 links have been created that identify relevant (mainly free) resources for teaching the standards [14]. At the end of 2011 two duplicate two-day “CS4HS” (computer science for high schools) workshops were run, sponsored by Google Inc., and these were attended by about 90 teachers. Although the workshops are based on the model originated in the US [6], they were primarily focussed on upskilling teachers for the new standards.

The survey reported here was conducted after the first year of teaching the Level 1 standards (Level 1 corresponds to the third to last year of high school), and also after the CS4HS workshops, where teachers had been able to reflect on the year and prepare for the new Level 2 standards that were to be introduced in 2012.

Given the rapid introduction of the subject in NZ, the main source of qualified teachers has had to be existing teachers, most of whom had to upskill. There are other approaches to “growing” CS teachers, including retraining unemployed IT workers [13], coaching teachers as they introduce CS in their classes [8, 12], having academics partner with teachers to teach the topic initially [2, 10], and providing specific CS teaching training programs [16] including summer programs [8]. While there has been some progress in NZ on these approaches, the first year was primarily a grassroots approach to training, and the following survey reflects on how this worked from the teachers’ point of view.

3. METHODOLOGY

New Zealand digital technology teachers were surveyed between 24 January and 7 February 2012. Respondents were recruited through emails sent to the NZACDITT mailing list, which currently has 404 members. Because the group was formed to support teachers through the changes, this will have covered most teachers with an interest in the new standards (the description of the group is that it was “formed to strengthen, encourage and improve the teaching of a broad range of Computing, Digital and Information Technologies in NZ secondary schools”). As an incentive, the first 25 respondents were offered a $20 voucher, with a draw for one of 10 vouchers for the remaining respondents.

91 teachers from 71 schools responded to the survey (to put this in perspective, this is about 23% of the NZACDITT mailing list, and there are about 490 high schools in NZ). Of the respondents, 75 had used or intended to use the new Programming and/or CS standards. The remaining 16 would be involved in the other areas of digital technologies: information systems, infrastructure, digital media and electronics.

A range of schools was represented, with 82% of the respondents from public (state) schools, 12% from “integrated” schools (combined private and public funding), 4% from private schools, and one from a school support organisation.

51% of the survey respondents were female, and 46% of the respondents intending to use the Programming and CS standards were female. This is a reasonably balanced number considering that role models are an important influence in this discipline, and this balance is not normally found in university computer science departments where female students and staff are typically a significant minority. Despite this balance, a larger proportion of male teachers (91%) than female teachers (73%) intended to use the new programming and CS standards.

A majority (60%) of the respondents were aged 50 or older, with 45% in the range of 50 to 59 years old, and none under 30 years old. The low numbers of younger high school teachers in NZ is a general concern, but the near-absence of new recruits in the survey is particularly concerning for the future of the topic and is a matter that would benefit from further research. It will be interesting to see if the new standards attract more teachers; there is anecdotal evidence that this is the case, but it will take a few years for them to flow through the system. While the age of the teacher population is a concern for the long-term future of the subject, it does indicate that teachers with considerable experience are involved in the new subject, and with that they bring skills and influence that will be of value getting the subject established. 68% of the teachers had 10 or more years experience teaching, and only 4% had less than 4 years experience.
For those who did not intend to use the new Programming and CS standards, the most common reason was “Not confident to teach them” (51%), followed by the related issue of “Insufficient information / support available to know how to teach them” (39%). Note that respondents could give multiple reasons, so these categories can be overlapping. Only 22% indicated that they couldn’t fit the subject into their school program, indicating that if suitable support was available most could have adopted the new standards.

4. TEACHERS’ BACKGROUND

The background that teachers bring to the new subjects can include both subject knowledge and pedagogical knowledge. In computer science, the ability to program is a fundamental skill, but we also need to consider other areas of CS, as well as mathematical skills to underpin them, and pedagogical skills for fostering learning.

In terms of programming knowledge, 41% of all respondents were confident and/or experienced in programming in one or more languages, with 47% reporting only rudimentary programming skills and 12% unable to program. Looking at specifically the respondents who are teaching the Programming and Computer Science standards, those figures are in relatively similar proportion: 45%, 48% and 7% respectively. With under half of the respondents reporting confidence or experience in programming, professional development materials or programmes cannot assume that teachers will have strong programming skills. Developing programming skills takes time, although fortunately there are now a number of on-line and in-person courses available to teach programming to beginners.

Only 56% of all survey respondents indicated any specific qualification in the computing field. Specialist computer science qualifications were uncommon, with only 11% reporting a full computer science degree and a further 11% having full degrees in other computing or ICT areas (such as information systems). 10% had taken only some first- or second-year university papers, and another 10% had some other related qualification, such as a degree or certificate with a computing component. The most common qualification was having a sub-degree computing qualification such as a certificate or diploma (14%). 44% reported that they had no related qualification.

Looking at mathematical qualifications, 16% of all respondents had a degree in mathematics. 41% had some university papers or College of Education study, with a further 8% having some other kind of mathematics-related education or certification. 27% of respondents had only high school mathematics, and 7% reported no mathematical qualification at all.

5. COURSE IMPLEMENTATION

Respondents teaching the standards reported a range of motivations, both intrinsic and extrinsic, for adopting them during 2011. Of the 51 who reported their motivation, 90% wanted to provide better opportunities for students. Most (62%) had a personal interest in the topics. Some believed that adopting the new standards was good for the country (45%) or simply the right thing to do (47%). 2% felt it would give credibility to computing as a subject, and 8% were motivated by school management’s requirements. These responses reflect the grass-roots nature of the support for the new curriculum, rather than change being driven by a top-down mandate.

The new standards offer a lot of flexibility with course design. Teachers can combine a variety of standards to put together a course; typically programming and computer science would be combined to fill about half a course, and the remainder could be chosen from, say, media standards (such as web design) to make a course on web programming, or with electronics to make a course on embedded systems.

Table 1 shows the proportion of respondents able to adopt the new Level 1 standards (1.xx) in 2011, and their plans for 2012. Note that the Level 2 standards (2.xx) only became available in 2012. (Levels 1, 2 and 3 correspond to the last three years of high school respectively; Level 3 will be phased in during 2013). There are two programming standards (separating program design and implementation) and one CS standard available at each level1. The Level 1 CS standard covers algorithms, programming languages and HCI, and the Level 2 CS standard covers number representation, coding (cryptography, error detection and compression), and usability. Although 75 respondents had reported an intention to use the new standards earlier in the survey, only 44 had reported adopting them in 2011, and only 61 indicated plans to use them in 2012. It is possible that the remainder chose not to answer this question, or that they intend to introduce them after 2012.

The program implementation standard (1.46) was the most popular, which reflects it being the topic that teachers had the highest confidence in. This isn’t surprising since this is the area where more had qualifications and experience. The low adoption of the CS standard reflects the much lower levels of prior knowledge, experience, and confidence in this area. Considerable PD on this topic was provided at the end of 2011 through a CS4HS event, and more peer support would be available in 2012, which may have contributed to the significant increase in planned adoption, as well as a higher interest in Level 2 CS (54%) compared with the Level 1 CS (40%) in their first years of being offered. This increase is in contrast to the programming standards, which show a substantially lower rate of adoption planned at Level 2.

The choice of programming languages for the standards is flexible; at Level 1 the language only needs to support simple structures, whereas at Level 2 it must include functions or methods with parameters, and at Level 3 is requires some OO features. Of course, the same language could be

Table 1: Adoption of the new standards in 2011, and plans for 2012

<table>
<thead>
<tr>
<th>Standard</th>
<th>2011 (N = 44)</th>
<th>2012 (N = 61)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.44 (Computer science)</td>
<td>40%</td>
<td>56%</td>
</tr>
<tr>
<td>1.45 (Program design)</td>
<td>77%</td>
<td>77%</td>
</tr>
<tr>
<td>1.46 (Program implementation)</td>
<td>97%</td>
<td>93%</td>
</tr>
<tr>
<td>2.44 (Computer science)</td>
<td>n/a</td>
<td>54%</td>
</tr>
<tr>
<td>2.45 (Program design)</td>
<td>n/a</td>
<td>59%</td>
</tr>
<tr>
<td>2.46 (Program implementation)</td>
<td>n/a</td>
<td>66%</td>
</tr>
</tbody>
</table>

1The codes (1.44 etc.) used here are the draft numbers for the standards, and were in common use at the time of the survey. The standards now have formal codes: AS91074, AS91075, AS91076, AS91371, AS91372 and AS91373 respectively.
used throughout, but introductory languages like Scratch are popular (73%) at Level 1, and the wealth of material available to support teaching such specialist languages can make them an appealing choice for teachers. Visual Basic was the next most popular Level 1 language (15%) followed by Alice (13%) and Python (6%).

A broad range of programming languages have been chosen for use in programming at Level 2 or above, with some respondents considering multiple languages. Python is the most popular (78%) followed by Java (25%) and Visual Basic (18%). Other languages include Alice (10%), C# (10%) and ActionScript (3%). A number of other languages were in use at either Level 1 or Level 2 by one respondent each.

Student reactions to courses using the standards were mixed. Teachers reported that (in their view) courses attracted either a significant number of the highly capable (40%) or those who lacked the academic ability to perform well (46%), though typically not both at once (12%). This reflects the change of the subject from being a non-academic option to one that is academically demanding; some schools would have managed to communicate this to students and get the message across, but others may have found that they had cohorts who were expecting a course on using computers rather than challenging concepts and programming.

48% of teachers believed they had significant numbers of students who were pleased that they took the course, and 18% thought they had students who wish they hadn’t (with 10% of teachers in both categories). 42% felt they had classes with significant student numbers who had difficulty completing the work in the time available.

32% of teachers thought that a significant number of students found the content different to what they expected, suggesting a need to more clearly explain the courses to students and prime their learning expectations. From a positive point of view, it is apparent that many students were learning what CS is for the first time.

6. TEACHER CONFIDENCE

The confidence of teachers and their sense of identity relative to the subject area is an important consideration [15]. The responses show relatively low confidence among teachers in their ability to teach the new topics. Only 64% of those who taught the programming standard reported that they felt a positive level of confidence about teaching it; and only 44% of those who taught the computer science (algorithms, programming languages and HCI) standard expressed confidence. The latter topics are new to most teachers, but there was also a lack of cohesive material such as textbooks or websites that set out how to teach the topics at high school level. Many disconnected resources have been identified that teach a part of the topics [14], but teachers need material specifically written for the standard so that they don’t have to weed through a large variety of options.

Table 2 shows the details of the responses about confidence. It is notable that confidence in the programming standards was more highly polarised between confident and unconfident — this observation is also made of students learning programming [17]!

No distinctive patterns of confidence levels were found based on age categories or years of experience teaching, but in almost all cases, greater experience and confidence in programming is an indicator of greater confidence in both understanding and teaching the achievement standards, especially for the areas that require more implementation (1.46) compared with conceptual (1.44) or design work (1.45). The broad range in teacher experience levels can be a concern in peer support; for example, one respondent observed: “…I know that I am capable of learning this but feel totally useless and alone trying to sort it out myself. Everyone else seems to know exactly what programming is about.”

Teachers generally reported a lower level of confidence in teaching a topic than their level of understanding of it. It is rare for a respondent to be more confident about teaching the standard than they are about understanding it — a possible consequence of this being the first year of using the standards, and the limited availability of targeted support for CS pedagogy. One respondent commented: “I don’t need to know any more programming and CS, I need to know how to teach programming and CS better.”

Computer science topics inevitably involve some mathematics, and the teachers were asked to indicate if they would be comfortable explaining some specific CS-related math problems to a class. The problems are shown in Table 3, and Figure 1 shows the number of teachers who said they would be confident explaining them, grouped according to those who used the 1.44 (CS) standard, those who showed interest in using the new standards, and those who don’t intend to use them.

Table 2: Teacher self-rated confidence to teach new standards (number of teachers)

<table>
<thead>
<tr>
<th>Standard</th>
<th>1.44</th>
<th>1.45</th>
<th>1.46</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confident</td>
<td>6</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>Quite confident</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Quite unconfident</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Unconfident</td>
<td>11</td>
<td>15</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 3: Mathematical problems posed to teachers

<table>
<thead>
<tr>
<th>Topic</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logarithm</td>
<td>What is ( \log_{2}1024 )? (log to base 2 of 1024)</td>
</tr>
<tr>
<td>Hexadecimal</td>
<td>Convert the following hexadecimal number to decimal: 1A</td>
</tr>
<tr>
<td>Checksum</td>
<td>A checksum that is calculated by multiplying all the odd numbered digits by 2, and the even numbered ones by 1; sum the total and take the remainder when divided by 10.</td>
</tr>
<tr>
<td>Algebra</td>
<td>If ( n = 10 ), what is ( n(n-1)/2 )?</td>
</tr>
<tr>
<td>Exponent</td>
<td>What is ( 2^{10} )? (2 to the power of 10)</td>
</tr>
<tr>
<td>Binary</td>
<td>Convert the following binary number to decimal: 11001</td>
</tr>
<tr>
<td>Pixels</td>
<td>How many pixels are there on a 780 by 1024 screen?</td>
</tr>
</tbody>
</table>
Figure 1: Proportion of teachers confident to explain mathematical problems

confidence explaining fairly fundamental mathematical topics (such as dealing with the expression \( n(n-1)/2 \), which is common in the analysis of simple sorting algorithms, or calculating a checksum, which uses a relatively simple formula to achieve a powerful result), and they also indicate a relationship between confidence teaching mathematical topics and willingness to use the new standards.

All of these math topics are relevant to the new NZ standards, although some can be avoided with alternative approaches. For example, while logarithms are heavily used in CS (e.g. binary search, binary numbers, divide and conquer) and are associated with highly scalable algorithms, at high school level the notation needn’t be used. Students can simply address questions like “how many times can we repeatedly halve 1024 until we have just one item” or “how many bits do you need to represent 1023 in binary?”

Clearly there is a need for professional development (PD), and the survey also explored how it would be best delivered in a way that teachers could access it. Figure 2 shows the kind of PD that teachers were interested in. The graphs are separated into two groups: those who were less than a one-hour drive from a University / College of Education (66%), and those more than an hour away (34%). Access to PD is an issue for teachers out of town — 9 of the teachers surveyed had to drive over 3 hours to get to a main centre, and so could feel quite isolated. From Figure 2 we can see that for both groups most found having lesson plans provided to be a top priority, with self-paced study and short workshops also being attractive\(^2\). Regular courses (full-time or part-time) and evening workshops were less useful to those from out of town, and travel would be impractical for many in this situation, although there was still a group of these teachers who expressed interest in such courses. A total of 13 of the teachers said that a full-time course would be very useful, indicating that they would be prepared to take time away from teaching to upskill.

Regarding assessing students’ work in the new standards, 7% of respondents were quite confident in their ability. The number who felt confident or unconfident was similar (41% each) and 12% were quite unconfident. In assessing the fairness of external grading of their students’ results, 74% agreed or strongly agreed that they seemed fair, with 26% disagreeing or strongly disagreeing. Grading is an important issue, because in the first year of a course being offered there is a lack of experience for advising students on what examiners might be looking for. This is examined in more detail for these students in [5].

We have looked for information about teacher attitudes from their comments in their surveys. While generally well-motivated, several respondents reported a number of roadblocks to implementation, including:

- a lack of available support resources such as lesson plans, assessment exemplars and workbooks,
- difficulty finding quality material appropriate for familiarizing themselves with the topic,
- a lack of confidence or experience with programming, and the need for more beginner-level explanation, support and practice, and
- insufficient time or available PD opportunities to adequately prepare for the new standards.

When available, PD opportunities such as the CS4HS workshops and support from university-based experts have been well-received, and appear to boost confidence and self-efficacy. Support through the NZACDITT online community and local groups is also highly valued. However, calls for more regional PD and peer support outside of major centres underline the frustration and isolation of some of the smaller and more remote regional schools. There were also a few concerns raised about how to accommodate students opting to take the Level 2 standards without having

\(^2\)The length of the bars varies because the survey allowed teachers to give no response to each question.
first completed the Level 1 standard, and students who may be more focused on the design aspects of computing than the underlying mathematical concepts.

7. CONCLUSION

Although the new NZ computer science standards weren’t compulsory in schools, it has had a significant level of adoption. Based on the survey reported here, the impetus for rapid change has largely come from teachers’ intrinsic motivation rather than government or school leadership directives. The top reason given for adopting new standards was to “provide better opportunities for students”. Teachers have used familiar values from computing culture to achieve this: there has been open source sharing of resources and ideas; agile development of teaching methods; a bootstrap approach where a few teachers with advanced knowledge were able to help others get up to speed; peer-to-peer communication where local communities developed practices in the safe environment of relationships between individuals; and heavy use of online communication to share ideas and debate issues.

The introduction of the new material has largely relied on “grassroots” development of teacher expertise, and many teachers and their support networks have put in countless voluntary hours to take hold of this window of opportunity. This is feasible in the short term, but in the long term well-supported formal teacher professional development is needed [16]. Several teachers have indicated that they would be prepared to take time out from their career to upskill. The survey has shown that teacher confidence is an issue. Lack of confidence was the main reason given by teachers who didn’t adopt the standards, and about half the teachers who delivered the standards were not confident about teaching them. There is a clear call for professional development delivered in a way that is accessible for teachers in a variety of situations, as well as providing resources that will make it easier for them to deliver courses.

8. REFERENCES


