Computer science education for elementary school students:
Curriculum development and implementation

Farida Umranı, Sridhar Iyer & Malati Baru
Department of Computer Science and Engineering, Indian Institute of Technology Bombay

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Abstract:

Computer science has become an integral part of school education with e-learning, digital adaptive learning becoming the buzzwords. However, there are still several schools that are making a beginning in computer education and need to be more clear about what to teach at each level. We proposed a curriculum for elementary and middle school, developed teaching material for the same and tested it in a pilot school. It considers open source applications (edubuntu), but is operating system (OS) independent, thus allowing the respective schools to make a choice regarding the OS.

The national and some state education boards have defined a course for high school, but kept the content fairly open for elementary and middle school levels. In the absence of clearly defined computer science curriculum, computers could be relegated as entertainment devices. On the other hand, a systematic curriculum can be instrumental in developing algorithmic thinking and organization skills. This will not only lay a foundation for future programming skills, but develop important life-skills. Hence, there is a need for a well defined computer science curriculum that has a wider focus than mere skill acquisition. This paper outlines a detailed week-wise curriculum for elementary level along with the insights gained from the field study. In light of these, policy recommendations are suggested at the end of the paper.

To support the curriculum, study resources were developed in the form of a teacher’s handbook which was later upgraded to a text book. Each level addresses concepts, usage skills and social aspects. Each lesson has a computer-based activity (educational games/applications), measurable learning outcomes and a lesson plan for the teacher. Besides, a list of projects is included to encourage collaborative learning along with guidelines for assessment. In addition,
video modules are provided to assist teachers in getting familiar with the applications/activities. All the material is open source and available free of cost.

We implemented the curriculum for Standards I - IV at a private school in Mumbai. The field work was carried out for 10 months (July, 07 - April, 08) with each class having one computer lecture per week of 30 minutes duration. Maximum strength of a class was 34 students and four laptops were used to provide hands-on experience to the students. Each class was divided into groups of five to eight students and the computer use was monitored.

The elementary school students are avid learners and explore the various computer applications with minimal assistance. No gender differences are observed in computer proficiency and usage. Confidence of teacher with the technology positively impacts confidence of students. Computer-based activities interest the students and can be used for developing skills in other subjects. For example, students averse to solving mental math sums enjoyed TuxMath game requiring similar exercise. Working on the projects reinforced the concepts taught, encouraged creativity and boosted their self-confidence. Thus, the curriculum has a positive impact on elementary school students.
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1. Introduction

One of the goals of education is to develop mental capacities. Unlike the traditional school subjects which have become more or less marks-oriented, computer education provides an unique opportunity for boosting natural ways of learning. Lim, et.al. (2002) postulate that integration of ICT into the school curriculum is instrumental in developing a culture of thinking, lifelong learning and social responsibility. It is particularly important for developing countries to invest in computer education as this can be instrumental in building indigenous technological capability and greater independence in the long run (Hawkridge, 1990). Given the support for ICT in schools under government schemes such as Sarva Siksha Abhiyan, computer education has got a thrust in the past five years. Besides, civil society bodies as well as private computer companies have been instrumental in the process. But compared to developed countries, as well as developing countries such as China, the figures of computers in school are quite low. In India, less than 10 percent of all the schools have a computer and these are skewed in favour of urban areas (26.41%) while the rural areas (6.66%) are marginalized. Amongst the urban areas, six Indian states --- Chandigarh (73.65%), Sikkim (55.56%), Delhi (55.40%), Kerala (48.19%), Andhra Pradesh (43.48%), Nagaland (39.41%) have more than 35 per cent penetration of computers in schools. On the other hand for the rural areas, only three states --- Delhi (51.18%), Chandigarh (40%) and Kerala (36.87%), have more than 35% penetration of computers in schools (Mehta, 2005). Except for Delhi, there is a wide gap in computer penetration in schools in rural and urban areas of each state indicating the rural-urban digital divide.

Even when computers are considered for study in schools, the emphasis is largely on acquiring the technology (computers) per se and there is little deliberation on what should be the course content and what methodology is best suited to teach it. Private international schools have been the major frontrunners in computer assisted learning and other private and government schools are catching up. However, by and large there is little clarity on what should be taught under
In order to address this issue, a team at Department of Computer Science and Engineering, IIT Bombay proposed a curriculum for elementary and middle school, developed teaching material for the same and tested it in a pilot school. It considers open source applications on edubuntu platform, but is operating system (OS) independent, thus allowing the respective schools to make a choice regarding the OS. This paper is organised as follows: Section 1 has presented the introduction. Section 2 shares the experience of developing the teaching resources and section 3 presents the approach underlying the curriculum. Sections 4 and 5 discuss the methodology to teach the subject and insights from field implementation respectively.
2. Our journey to Computer Masti!

The process of designing the curriculum was initiated by a professor at CSE, IITB who along with others outlined week-wise plan for teaching computer science to elementary school students. At the outset it was decided that the curriculum will be OS independent and eventually provide an exposure to both the platforms – open source (edubuntu) and proprietary (Windows). The curriculum was reviewed by experts in India and abroad. After deciding on the content to be taught, teachers’ handbook was written for the first four levels. Each chapter in the handbook included a lesson plan, worksheet and website references for further reading. The course was implemented by the first author along with two teaching assistants in a pilot school located in Mumbai. In light of the field experience and reviewers' comments, the curriculum was modified and the teacher's handbook was upgraded to a textbook.

Each lesson in the textbook included aim, lesson outcome and the content tied by a loose story with three characters, a teacher in the face of a mouse (Moz), a boy (Tejas) and a girl (Jyoti). This was supplemented by worksheets, computer based activities (using open source applications), point to explore by the students, a lesson plan for the teacher and suggested web resources. One team member provided the basic lesson content which was converted into a story format by another member. Three rounds of review were done by each of the person involved and comments were invited by faculties at IIT Bombay. The book is available freely for educational use, under the creative commons license at http://www.cse.iitb.ac.in/~sri/ssrvm/.
3. About the Curriculum:

Hawkridge (1990) has identified different reasons for including computer science in schools (refer table 1). Depending on what is the rationale in a particular education system, a varied approach is adopted in designing the curriculum and its teaching. Computer science curriculum of the national and few state boards take the *societal* (computers being pervasive in present times, focus on acquiring basic technical skills) and *vocational* (prepare for a career in computer science, or application of technical skills in different vocations) approach to the curriculum. Private companies, such as Educomp that market educational software to the schools consider the *pedagogical* approach and focus on computer assisted learning for different subjects. They influence the education boards and schools in adopting their e-learning material. However, in all the cases, societal, vocational and pedagogic, only the behavioral aspect is considered and students are groomed to become ‘expert users’. On the other hand, the *catalytic* approach focuses on teaching information handling and problem solving skills. Curriculum based on this approach aims to develop computer fluency amongst the students and mentor them participate actively in constructing the technology.

**Table 1: Reasons for including computers in schools**

<table>
<thead>
<tr>
<th>Rationale</th>
<th>Basis</th>
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</thead>
<tbody>
<tr>
<td>Social</td>
<td>Computer skills are essential requirements in present information based society, hence school education should equip students with technical skills</td>
</tr>
<tr>
<td>Vocational</td>
<td>Prepare for jobs that require computer skills</td>
</tr>
<tr>
<td>Pedagogical</td>
<td>Use technology to enrich leaning experience, flexible and efficient course teaching</td>
</tr>
<tr>
<td>Catalytic</td>
<td>Computers as tools to change the education process through collaborative learning, relevant curricula and expand learning opportunities</td>
</tr>
</tbody>
</table>

We have adopted an eclectic (combination) approach to define computer science curriculum for primary school with the goal of developing computer fluency at the end of school education. We begin by focusing on the behavioral aspect and later widen the scope to cognitive aspects, refining mental capacities (through step-wise reasoning and logical thinking exercises) and teaching fundamental computer science concepts. A positive attitude towards computer technology is imbibed in the students through the various computer based activities and teaching methodology.
Ergonomic aspects such as posture, exercises are covered at each level to emphasize health values. There is a spiral organization of the curriculum so that students can continually build their knowledge upon their existing knowledge. At present teaching material for four levels are available. Levels I and II focus on skill acquisition (e.g. keyboard/ mouse skills) while Levels III and IV concentrate on building algorithmic thinking, reasoning and organizational skills using real-life experiences, computer applications and multimedia programming language (Scratch). Practice of specific skills is through open source educational games such as Educational suite GCompris, Childsplay. These activities not only provide opportunities for building the computer skills, but also sharpen the cognitive skills such as classification, similarities, differences, speech/audio/colour/pattern recognition, etc. The following paragraphs discuss how the curriculum can be taught to encourage active learning.

**Screen shots of Childsplay and GCompris, open source educational games**

![Screen shots of Childsplay and GCompris](image)

**Type simple words**

4. A guide to teach computer science at elementary school

The teaching methodology follows a four stage model that is outlined as follows:

a) **Exploration:** At the initial stage there is no direct teaching but students are asked to explore a particular application on their own. The teacher’s role is to provide positive reinforcement – appreciation, stars, etc for every right move by the student. It is essential that the students are motivated to learn and they are able to focus attention on the task at hand. In some cases, students can be asked to observe the teacher while s/he does a particular task on the
computer and then explore the application on their own. Dividing the class into groups of four/five students allows for collaborating and sharing resources amongst peers.

b) **Motivation for self-learning:** At this stage, the learner is actively involved in constructing new ideas/concepts based upon their current/prior knowledge. Computer based activities such as multimedia programming (e.g. Scratch) provide students opportunities for experimental learning. These activities are intrinsically interesting to the students and they discuss alternative strategies with their peers. The teacher’s role is to work as a mentor/facilitator and ask probing/open-ended questions instead of ‘teaching’.

c) **Reflection:** Students engage in social negotiation (debates/discussions) with peers and teachers to compare own understanding to that of others and create revisions to their current structures of knowledge. The teacher’s role is to provide individualized support and motivate the students to become active learners. Thus, the emphasis is on inquiry learning wherein students actively make observations, collect, analyze, and synthesize information, and draw conclusions.

The above methodology was followed in implementing the proposed computer science curriculum. The following paragraphs present the information gathered by this experience.

**5. Field Insights**

The first author implemented the curriculum for Standards I – IV at a private school in Mumbai. The field work was carried out for 10 months (July, 07 – April, 08) with each class having one computer lecture per week of 30 minutes duration. Maximum strength of a class was 34 students and four laptops were used to provide hands-on experience to the students. Each class was divided into mixed-sex groups of five to eight students and the computer use was monitored. Students were taught basic computer skills, ergonomic/safety values, applications such as paint, word processor, media player. Exercises in algorithmic thinking and logical reasoning were provided through computer based and paper-pencil activities. For standards III and IV, Scratch was taught through minimally invasive learning approach.
It was found that the elementary school students are avid learners and explore the various computer applications with minimal assistance. Given the urban setting and familial background, it is likely that students have had an exposure to computer technology. 74% of the students had access to a family computer. New technologies are prone to becoming engaging entertainment toys, hence young students find working on computers a vicarious experience. It was found that computer-based activities interest the students and can be used for developing skills in other subjects. For example, students averse to solving mental math sums enjoyed TuxMath game requiring similar exercise. Thus, computer science can be instrumental in sharpening competencies in other academic areas. Further, students worked on the projects at the end of the course. This exercise allowed for collaborative learning and reinforced the concepts taught, encouraged creativity and boosted their self-confidence.

No gender differences are observed in computer proficiency and usage. This may be due to controlled exposure provided in the school setting where every student was provided an equal opportunity to use the technology. It is likely that when girls have to compete with boys for computer usage, differences might show up. Field observation indicates that while girls preferred paint application, boys were keen on playing strategy games. However, a more elaborate study is required in order to make a conclusive statement on gender difference in application preference.

Confidence of teacher with the technology positively impacts confidence of students. This is in line with evidence from other studies that have highlighted the role of a teacher as a model that students emulate and transfer of positive computer attitude of the teacher onto her students. Hence, teacher training is an essential component of successful implementation of computer science
curriculum. However, this is overlooked and much is left on the teachers themselves. Given the premium of applying ICT skills to their teaching, teachers acquire the responsibility of acquiring these competencies on their own. A survey of secondary school math teachers by the author indicated that 70 per cent relied on private training institutes for computer training\textsuperscript{1}. Computer technician is absent in most of the school and the system administration falls on the computer teacher. In several schools, they have an additional responsibility of typing test paper of various subjects as other subjects may not have the technical skills or cannot spare time for the same. Thus, teacher training needs to be given due attention and resources need to be allocated in building technical sophistication of school teachers.

References


Further reading:
www.edubuntu.org/
scratch.mit.edu
www.alice.org/
childsplay.sourceforge.net/

\textsuperscript{1} These teachers attended Time 2007, Second National Conference on Technology and Innovation in Mathematics Education, 1 – 4 December, held at IIT Bombay