

# Computer Science (CS) Education in Indian Schools: Situation Analysis using Darmstadt Model

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Computer science (CS) and its enabling technologies are at the heart of this information age, yet its adoption as a core subject by senior secondary students in Indian schools is low and has not reached critical mass. Though there have been efforts to create core curriculum standards for subjects like Physics, Chemistry, Biology, and Math, CS seems to have been kept outside the purview of such efforts leading to its marginalization. As a first step, using the Darmstadt model from the ITiCSE working group that provides a systematic categorization approach to CS education in schools, we coded and analyzed the CS situation for the Indian schools. Next, we focused on the motivation category of the Darmstadt model and investigated behavioral intentions of secondary school students and teachers from 332 schools in India. Considering the CS subject as an educational innovation, using Rogers' Theory of Diffusion of Innovations, we propose a pedagogical framework for innovation attributes that can significantly predict-adoption of the CS subject among potential-adopter students and teachers. Data was analyzed to answer research questions about student and teacher intentions, influence of gender, school management, and school location in adopting CS. Interestingly, girls, urban students, teachers, and private schools were seen favoring the adoption of CS. An important issue that needed to be addressed, however, was the interchangeable use of terms like CS, Informatics, ICT, and digital literacy. Through our article, we offer a promising picture of the educational policy directives and the academic environment in India that is rapidly growing and embracing CS as a core subject of study in schools. We also analyze the factors that influence the adoption of CS by school students and teachers and conclude that there is a very positive response for CS among educators and students in India.

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

General Terms: Computer Science Education, Indian K-12 Education, Adoption of Computer Science Subject

Additional Key Words and Phrases: Darmstadt model, Theory of diffusion of innovation, ICT education

## ACM Reference Format:

Raghu Raman, Smrithi Venkatasubramanian, Krishnashree Achuthan, and Prema Nedungadi. 2015. Computer science (CS) education in indian schools: Situation analysis using darmstadt model. *ACM Trans. Comput. Educ.* 15, 2, Article 7 (May 2015), 36 pages.  
 DOI: <http://dx.doi.org/10.1145/2716325>

## 1. INTRODUCTION

The adoption of Information and Communication Technology (ICT) and CS (CS) in K-12 education has been an important topic of study and research in several countries. The Royal Society Report on the state of Computing Education in schools in the UK highlights the fact that the delivery of Computing Education is not up to the mark,

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DOI: <http://dx.doi.org/10.1145/2716325>

mainly due to the lack of trained teachers and the necessary infrastructure [Furber 2012]. Wing [2006] is of the view that Computational Thinking is completely absent from the K-12 education despite its ubiquitous nature. The Ofsted report on ICT in schools in the UK [Ofsted 2011] mentions a decline in the number of students opting for the ICT subjects since 2007 with fewer girls choosing to continue to study ICT. This has prompted the schools to take up initiatives to boost students' enrollment in ICT-related courses. According to the National Science Survey of India [Shukla 2005], Math has remained the most preferred subject for secondary school students pursuing careers in the Sciences. Fifty percent of the students in this survey indicated Physics, Chemistry, Biology, and Math as their preferred subjects as compared with just over 1% who indicated their preference for CS, which is offered as an elective subject. This is a factor that has contributed to its marginalization. In the case of CS, just 15% of the students indicated their satisfaction with the teaching facilities. This proportion is strikingly low when compared with 60% of the students who indicated their satisfaction with teaching facilities for the Sciences. The number of schools offering CS at the senior secondary level has also been strikingly low compared to those offering other Science subjects. The availability of trained and qualified personnel to teach CS has also been a challenge. For schools, the Science teachers have always been assigned priority, followed by other teachers having some knowledge of computers. However, one of the primary reasons for the relatively lukewarm response to CS may be because it is a relatively new subject being taught in an education system that is slow to change.

Launched in 2004 in India, the ICT@Schools is a government-sponsored scheme focusing on students becoming computer literate from the age of six. The National Curriculum Framework (NCF) 2005 advocated proper balancing of content between the Informatics Practices (IP) and CS curricula, but the bias toward computer literacy and the curriculum that includes this in primary and middle school cannot be ignored. The senior secondary school curriculum for CS and IP emphasizes programming skills with 30% marks reserved for computer-based practical classes. In fact, the distinction between CS and IP today, albeit a bit blurred, is further complicated by the introduction of a new subject—Multimedia Technology (MMT).

The Indian school system today does not have as rigorous a syllabus for CS as it does for the Sciences. Other than the Central Board of Secondary Education (CBSE) that oversees 13,500 schools in India with formal CS offerings for its 17 million students, most of the 29 states of the country seem to focus more on computer literacy—keyboarding and the use of application software. This is very similar to the ACM/CSTA study by Wilson et al. [2010], which highlights a similar situation in the United States. Equally disturbing is the fact that recently, 21 State Boards in India unanimously decided to adopt core curriculum in Biology, Physics, Chemistry, and Math at the higher secondary level in collaboration with the Council of Boards of Secondary Education and CBSE, yet CS did not figure into these discussions. The situation is made worse by the lack of certified CS teachers. This scarcity of CS teaching staff may be attributed to the absence of formal training and certification programs for them in both the preservice and in-service phases.

Compounding matters is the fact that most often the terms digital literacy, ICT, and CS are used interchangeably by educationists, teachers, and as a consequence, also by their students. This creates the illusion that CS is already being taught and integrated at the school level and as a result, efforts to improve the situation for CS education at school often ends with giving more importance to digital literacy or ICT. In 2009, a subcommittee of the Central Advisory Board of Education (CABE) was set up under the Chairpersonship of the Secretary, Department of School Education and Literacy, Ministry of Human Resource Development (MHRD), the Government of India. This committee was entrusted with the task of suggesting (a) guidelines for the use of ICT in school education, (b) strategies for teachers' capacity building in ICT usage, and

(c) the appropriate level for introduction of computer literacy among school students. This paved the way for the National Policy on ICT in School Education, 2011.

Realizing the importance of CS skills for students, the education systems in many countries began to introduce CS as a subject in formal school curricula. For example, Germany introduced CS as a compulsory subject [Hubwieser 2012]; in the United States, the CS10K project aimed at training 10,000 CS teachers in 10,000 high schools by 2015 [Astrachan et al. 2011]; in New Zealand, new CS standards were introduced at the high school level in 2011 [Bell et al. 2012]; in India, CS and IP were introduced as elective subjects for senior secondary school students. Given this widespread initiation of CS into mainstream academic curricula, training of the existing and the new teachers to deliver the new curriculum and increasing their numbers has proved to be a daunting task. The CS subject demands considerable up-skilling from being simply ICT-literate to having a deep technical knowledge in order to teach CS topics such as algorithms, data structures, operating systems, and programming.

This article focuses on categorizing the current state of CS education in the Indian school system using the Darmstadt model proposed by ITiCSE working group [Hubwieser et al. 2011]. The article seeks to then identify the dominant innovation attributes that can significantly predict the diffusion of the CS subject among students and teachers. The adoption of an educational innovation is a matter of individual preference and users' motivation—in this case potential-adopter teachers and students. Hence, we consider both these key stakeholders in our study and focus on how they influence each other. The overall motivation of the article is apply the Darmstadt model to education in India and use the Theory of Innovations to see how the Indian education system could rapidly adopt CS as a mainstream subject rather than providing just ICT training and giving a secondary treatment to CS. Our article is organized as follows. In Section 2, we present related work. In Section 3, we apply the Darmstadt model to the Indian schooling system. Specifically, in Section 3.8, we discuss the results of our survey of teachers and students regarding the adoption of CS. We conclude in Section 4.

## 2. RELATED WORK

### 2.1. CS Education and the Darmstadt Model

To be able to categorize and analyze the state of CS education across the world, Hubwieser et al. [2011] proposed the Darmstadt model as part of the working group “Informatics in Secondary Education” at the ACM-ITiCSE Conference in 2011. Such a model enabled easier and uniform interpretation of research results about CS education in schools in various settings. The quality of CS education not only depends on the support from Government and curricular content, but also on the knowledge and capabilities of teachers teaching CS subjects. Hence, effective teacher training in CS is imminent. According to Ragonis et al. [2010], dedicated CS teacher preparation programs should be developed, and only teachers with formal CS backgrounds should be allowed to teach CS in secondary schools. It is not enough to have a generic Science teacher teach CS. Consequently, there have been efforts made to develop CS standards like the ACM/CSTA and the IFIP-TC3.

### 2.2. Diffusion of Educational Innovation

A number of educational researchers have argued that using Rogers' [2003] Theory of Diffusion of Innovations is an effective way to examine the adoption of innovations by schools and teachers [Sahin and Thompson 2006; Yates 2004]. Rogers [2003] defined diffusion as “the process in which an innovation is communicated through certain channels over time among the members of a social system.” His Theory of Attributes states “the perceived attributes of an innovation are one important explanation of the rate of adoption of an innovation.” The theory states that an innovation is perceived

based on its relative advantage, compatibility, complexity, trialability, and observability. For an innovation to diffuse faster, the potential adopters must perceive that innovation as (1) having an advantage relative to other innovations, (2) being compatible with the existing practices and values, (3) being simple, (4) being open to trial on a limited basis before adoption, and (5) offering observable results. These concepts will be used to identify the factors primarily influencing the adoption of CS in schools.

While applying the Theory of Diffusion of Innovations to CS adoption, for the variable Relative Advantage the relevant questions are centered round the theme of “Do teachers and students feel that CS is important for meeting the needs of school education?” The compatibility of CS as a subject with other subjects like the Sciences is evaluated by considering both teachers’ and students’ existing values, past experiences, and needs. Teachers and students who perceive CS to be a valuable subject like the Sciences will find it compatible and be more eager to adopt it. Complexity questions can be phrased as “Will CS as a subject require more of my teaching time versus other subjects like Physics, Chemistry, Math?” and “Is computer programming hard to learn?” Trialability becomes an attractive feature of CS if teachers and students can try and practice CS and that they can discontinue if they do not want it. Equally important, if teachers and students are able to observe their counterparts who have already adopted CS, it may help influence their stance on the subject. Other significant factors affecting the adoption of CS may relate to the kind of support offered by the school when installing proper computer laboratory infrastructure in addition to the overall attitude of the school management toward the new subject.

Surry [1997] focused on the importance of studying the adoption and diffusion of innovation in the field of Educational Technology. The success of any innovation, he maintained, can be gauged by examining the proportion of potential adopters who have successfully adopted it. While examining how innovations diffuse in an organization, researchers have empirically found that, when viewed over time, the rate of diffusion forms an S-shaped curve that represents a cumulative distribution of adopters. The curve rises slowly at first, because the rate of adoption is slow initially, and then accelerates to a maximum value until it reaches the point of inflection. Thereafter, the rate of increase slows down until the remaining individuals have initiated the process of adoption too. The actual adoption and use of educational innovations entails long-term effort. Hence, the main focus has to be on improving the dissemination [Henderson and Dancy 2011; Tsai et al. 2011]. School administrators and other governing agencies play a key role in this dissemination of educational innovations [Ghosh 2000]. Teachers, in fact, play a very crucial role in implementing innovations in the classroom and it is their willingness to adopt and integrate innovation that directly influences the adoption process [Gess-Newsome et al. 2003].

Employing Rogers’ framework, Bass [1969] proposed a mathematical model as a nonlinear differential equation for the diffusion of an innovation in a social group essentially through two mechanisms, viz., external influence like mass media and internal influence like word of mouth. The solution of the differential equation yielded the well-known S-shaped curve that has been commonly observed in innovation diffusion studies. The Concerns-Based Adoption Model (CBAM) is another well-established model, but it is used to investigate only the teachers’ concerns toward an innovation [Hall et al. 1977].

### 3. APPLICATION OF THE DARMSTADT MODEL TO CS EDUCATION IN THE INDIAN CONTEXT

#### 3.1 Educational System

India has always been on the global map with respect to education since the ancient times. The gurukulas (residential schools) and centers of higher learning like

Takshashila and Nalanda that attracted large numbers of students from all over the world testify to the same. The educational system in India has always aimed at providing holistic education to students from different segments of the society. In fact, evidence documented by early colonial administrators in India points to the prevalence of extensive educational institutions that have catered to all sections of the society, including women [Dharampal 1983].

Today, both the Central and State governments control the educational system in India, with the former playing a significant role in setting the educational policies. The MHRD lays the educational policies of the country, while the Department of School Education and Literacy of the MHRD develops and monitors school education. The National Council of Education Research and Training (NCERT) formulates the curriculum. Established to assist and advise the Central and State Governments on academic matters related to school education, the NCERT today, provides support for school development, teacher training, and enables the penetration of educational policies into different schools. The various boards that monitor and control the curriculum of private and public schools are the following:

- the different state boards;
- the Central Advisory Board of Education (CABE);
- the Central Board of Secondary Education (CBSE);
- the Council for the Indian School Certificate Examinations (CISCE); and
- the National Institute of Open Schooling (NIOS).

Throughout the nation, both the public and the private schools follow the 10 + 2 system. Students undergo 10 years of primary and secondary education, after which they undergo 2 years of higher secondary education. Primary education is offered at two levels, namely, (a) the lower primary level and (b) the upper primary level. Some private players provide 2 to 3 years of pre-school divisions.

CABE is the highest advisory body to advise the Central and State Governments in the field of education. Established in 1920, it provides a forum for widespread consultation and examination of issues relating to educational and cultural development.

The CBSE is a Board of Education for public and private schools, under the Union Government of India. The Board conducts final examinations every spring for Classes 10 and 12. The Board primarily focuses on innovations in teaching-learning methodologies by devising student-friendly and student-centered paradigms and reforms in examinations and evaluation practices. In a circular dated 23/10/2003, titled “Status of Computer Based Courses at +2 Level,” CBSE maintained that it offered three CS courses, namely, CS, Informatics Practices and Multimedia, and Web Technology. Though the exact date of introduction of these subjects is not known, we can infer that they were introduced prior to 2003 or in early 2003. The circular is important as far as CS courses are concerned since CBSE has directed schools to give the same level of treatment to the CS course as accorded to the main courses.<sup>1</sup> In another circular, CBSE mentioned a revision of the curriculum for the CS-related courses and the introduction of Multimedia and Web Technology as an elective subject.<sup>2</sup>

The CISCE Council has been constituted so as to secure suitable representation of Government of India, State Governments/Union Territories in which there are schools affiliated to the Council, the Inter-State Board for Anglo-Indian Education, the Association of Indian Universities, the Association of Heads of Anglo-Indian Schools, the Indian Public Schools’ Conference, the Association of Schools for the ISC Examination and members co-opted by the Executive Committee of the Council.

<sup>1</sup><http://cbse.nic.in/circulars/2003/circularno.26.pdf>.

<sup>2</sup><http://cbse.nic.in/circulars/2003/circularno.5.pdf>.



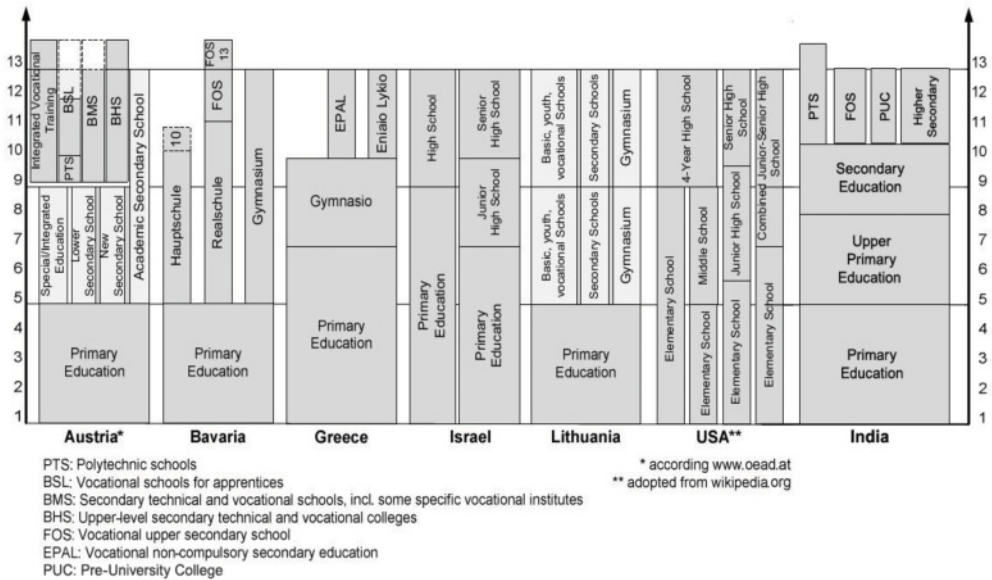


Fig. 1. Educational system in India in comparison with other countries.

The NIOS, formerly known as the National Open School (NOS), was established in 1989. It provides a number of vocational, life enrichment, and community-oriented courses besides general and academic courses at the Secondary and Senior Secondary levels at school.

Figure 1 depicts the different schooling levels depending on the student's age. While the illustration is sourced from the model propagated by Hubwieser [2013], the information pertinent to the Indian school system has been obtained from various sources including the CBSE and state government educational websites.

**3.1.1. Subject Organization.** Throughout India, the curricular framework is more or less uniform except for the languages offered in different states of the country. Naturally, the approach and content varies across the states. At the primary level, students study Math, the Languages, English, and Social Science. At the secondary level, students study Math, the Languages, English, Sciences, and Social Science. These are compulsory subjects throughout India and complement those areas that need holistic development, which is why students are also simultaneously introduced to environmental, physical, arts, and work education. In addition to the main subjects, students may also choose one additional Language or the Foundations of Information Technology.

At the higher secondary level, students are allowed to choose an academic stream that will mainly prepare them early on for higher studies and finally, their careers. The Sciences, Biology and Math, CS, and Commerce are among the oft-preferred streams. In certain states in India, students attend Junior College after completing their secondary education. Schools normally work 6 days a week in order to comply with the 45 hours per week requirement of the Right to Education Act of 2009. The main subjects are allotted six to seven periods a week and cocurricular subjects are allotted one to three periods a week.

**3.1.2. Enrollment.** The MHRD publishes annual data on the number of schools, the amenities available here, the budget allotted, and enrollment numbers of students belonging to different genders and sections of the society. As per the 2010–2011 data,

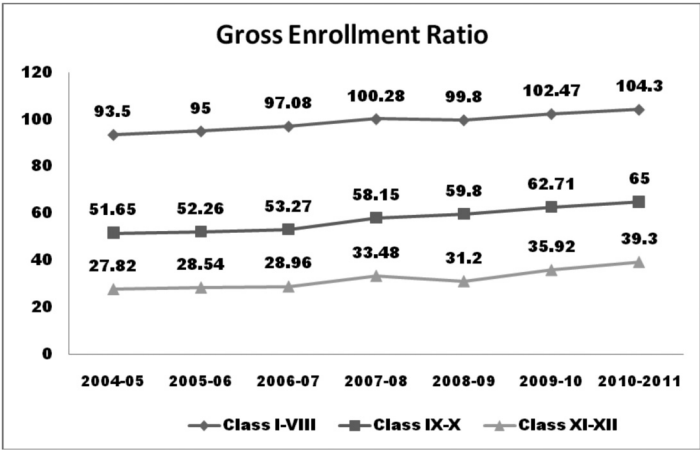


Fig. 2 Gross enrollment ratio from 2004 for educational levels.

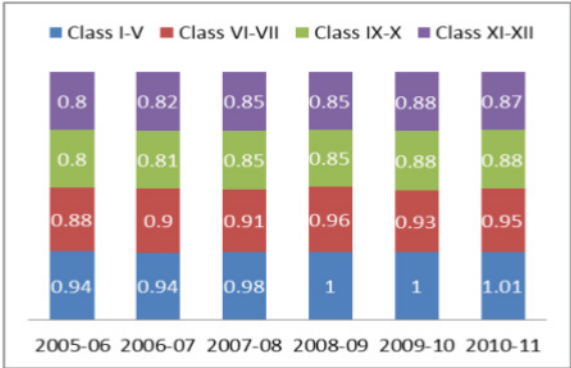


Fig. 3. Gender parity index since 2005 for educational levels.

India had about 1.4 million schools offering primary, secondary, and higher secondary education across its states. The total number of enrollments was about 240 million with 47% being girls.<sup>3</sup>

Figure 2 shows the increasing Gross Enrollment Ratio (GER) in India starting from 2004 for different classes of students. The MHRD launched several schemes, like the Right of Children to Free and Compulsory Education Act, mainly focusing on providing primary education to rural children to further increase enrollments.<sup>4</sup>

Figure 3 represents the Gender Parity Index (GPI) at different educational levels starting from 2005. GPI is the ratio of the number of females enrolled to the number of males enrolled. We see that the number of females is very close to the number of males enrolled, though it equals only occasionally. Government schemes like the National Scheme of Incentives to Girls for Secondary Education are aimed at improving the enrollment ratios for girl students.<sup>5</sup>

<sup>3</sup>[http://mhrd.gov.in/statistics\\_data](http://mhrd.gov.in/statistics_data).

<sup>4</sup>[http://mhrd.gov.in/sites/upload\\_files/mhrd/files/RPE-2010-11.pdf](http://mhrd.gov.in/sites/upload_files/mhrd/files/RPE-2010-11.pdf).

<sup>5</sup>[http://mhrd.gov.in/sites/upload\\_files/mhrd/files/AR\\_2012-13.pdf](http://mhrd.gov.in/sites/upload_files/mhrd/files/AR_2012-13.pdf).

### 3.2. Social-Cultural Factors

*3.2.1. History of ICT and Informatics in Indian Schools.* This section examines the history of the ICT policies in India. India was one of the first few countries to introduce computers at the work place, both business and academic. With the burgeoning demand for people with ICT and core CS skills, and the pressing need to keep abreast of technological advancements, it became imperative to provide ICT education right from school. Today, computers and such enabling technologies are part of our everyday lives so it is critical to develop people's ICT skills, which include learning to use a computer and train children on core CS [Brinda et al. 2009]. As early as 1985, the Ministry of Education and the Department of Electronics jointly launched the Computer-Aided Literacy and Studies in Schools (CLASS) project. The project aimed at initiating a CS-based curriculum and teachers' training program [Banerjee 1996]. Recognizing the imminent need to bridge the digital divide among students of various sections of the society, the MHRD launched the ICT scheme in 2004. This scheme is aimed at enhancing the quality of education by helping schools establish their ICT infrastructure. The scheme not only focused on ICT skills, but also on the introduction of CS subjects at the secondary and higher secondary levels. Establishment of the ICT infrastructure in schools broadly involved making computers and devices for technology-enabled learning available. It also entailed offering digitized educational content, training teachers to use computers and teach CS, providing Internet connectivity, and developing school management systems.

As per the policy document, the National Policy on ICT in School Education envisioned "preparing youth to participate creatively in the establishment, sustenance and growth of a knowledge society leading to all round socioeconomic development of the nation and global competitiveness." The overall objectives of the MHRD policy on ICT were to introduce ICT in schools and as a part of the curriculum, ICT for the unified management of schools, establish ICT infrastructure in schools, develop and make available digital content, and ensure capacity building of teachers and academic administrators.

As per the policy document, providing ICT literacy and competence is structured into several stages, depending on the educational levels of the student and the teacher. In the Basic Stage or stage 1, students and teachers are exposed to computers to carry out day-to-day tasks like connecting to the Internet, using emails, and managing external devices. In the Intermediate Stage or stage 2, they were expected to learn to use, install, and uninstall software applications, search/browse the Internet, and perform advanced tasks. The Advanced Stage or stage 3 would involve the creation of individual applications using databases, learning through collaborative networks, and developing higher order problem-solving capabilities. This was expected to be in line with the different stages maintained by the ACM Computing Curricula for K-12 students, which was structured into four levels starting with the foundational concepts in CS to higher order algorithmic thinking and problem solving [Tucker et al. 2006].

Significant efforts by the Indian Government have resulted in putting together an effective curriculum for imparting ICT and CS education in order to satisfy the goals of the NCF. As per the model Curriculum for ICT in Education prepared by NCERT,<sup>6</sup> the curriculum is organized into six themes: connecting with the world, connecting with each other, interacting with technology, creating with ICT, possibilities in education, and reaching out and bridging the divide.

As mentioned earlier, in addition to ICT skills, the MHRD introduced CS subjects at the higher secondary level where students could learn programming in different languages. The curriculum for the same was designed based on students' needs.

<sup>6</sup><http://scert.cg.gov.in/ict2014/pdf/ICTCurriculum.pdf>.



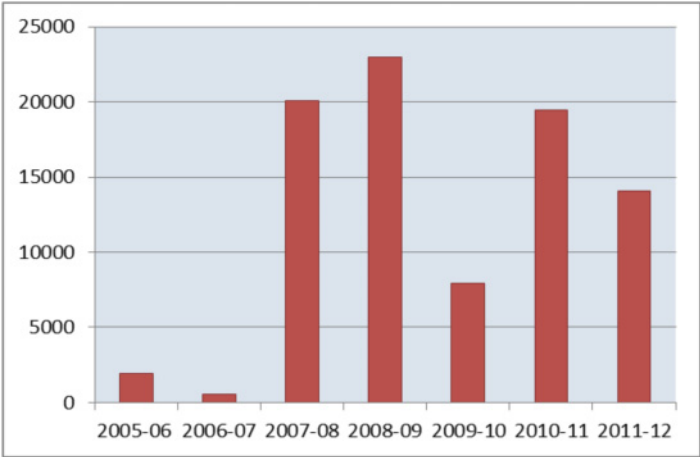


Fig. 4. Yearwise approved number of Smart Schools. (Source: mhrd.gov.in)

Table I. Syllabus of CS-Based Electives in CBSE Higher Secondary Schools

Computer Science		Informatics Practices		Multimedia and Web Technology	
Class XI	Class XII	Class XI	Class XII	Class XI	Class XII
Computer Fundamentals	Object-Oriented Programming	Introduction to Computer Systems	Networking and Open Standards	Introduction to Computer Systems	Database Concepts
Introduction to C++/Python	Data Structures	Introduction to Programming	Programming using Java	Web Development	Networking and Open-Source Software
Programming Methodology	DBMS	RDBMS	RDBMS	Web Scripting	Webpage Development
Programming in C++	Boolean Algebra	IT Applications	IT Applications	Multimedia and Authoring Tools	Multimedia Authoring Tools
	Networking and Open-Source Software				

Through the elective courses shown in Table 1, students gained knowledge of developing and using software applications. The syllabi for these courses were revised keeping in mind the emerging trends in ICT as well as the needs of the industry.

Under the ICT scheme, the MHRD approved nearly 89,000 ICT-enabled schools called *Smart Schools* across India since 2005 as shown in Figure 4. Sixty-three smart schools joined the existing institutions in 2011–2012. This scheme benefitted many of the individual states of India and offered high-quality education.

With India being a large nation having a diverse population that speaks different vernacular languages, the adoption of ICT in education opened up great possibilities of bridging the gap and making resources available to a significant proportion of the citizens. Through the use of technology in education, the government proposed to empower children and the youth from both the rural and urban areas, while nurturing their creative, problem-solving, and entrepreneurial skills through the courses shown in Table I.

*CS at the Secondary Level:* Students of Classes IX and X have the option of the studying one additional subject apart from the two compulsory language subjects. They may choose an additional language or opt for the course on Foundation of Information Technology. Here, students learn about the basics of IT, which includes knowing the hardware components of a computer and the different types of software. They learn about different operating systems (OSs) including Android and are introduced to Windows. They learn to use Microsoft (MS) Office tools proficiently and undergo hands-on training on the same. Students of Class X learn about the Internet, the different protocols, web services, databases, HTML, and the application of IT in different domains.

*CS Subjects at the Higher Secondary Level:* Given the growing global need for people who are not only comfortable with computers and their usage but can also solve real life problems using them, CS is increasingly being offered as an elective subject at the higher secondary level. Introducing CS at the school level prepares students early on for higher studies and careers in CS. Three CS-based subjects, namely, Computer Science, Informatics Practices, and Multimedia and Web Technology are offered as electives to higher secondary school students. Students have to choose between Computer Science and Informatics Practices and can choose Multimedia and Web Technology along with it. Computer Science and Informatics Practices differ significantly in their content.

—*Computer Science:* The syllabus for Computer Science has been designed with the objective of providing students with a basic knowledge of computers, enhancing their problem-solving capability through programming, and providing knowledge about databases. Students learn object-oriented programming using C++. For the 2013–2014 curriculum, most schools introduced the Python language. The number of periods allotted to programming was also significantly higher than the other portions of the syllabus. This is done to ensure that students gain sufficient exposure and hands-on training in programming. Students also undertake projects to learn to develop full-fledged text-based Graphical User Interface (GUI) applications. In Class XII, students learn data structures and Boolean algebra.

—*Informatics Practices:* Informatics Practices, as a subject, is more oriented toward getting familiarized with computer systems and developing web-based applications using HTML and Java. Initially, students familiarize themselves with the various hardware components of a computer and learn about different OSs. Later, students learn to use an Integrated Development Environment (IDE) for designing and developing interfaces and applications with a Relational Database Management System (RDBMS) as the back end. Students are also introduced to e-Governance, e-Business, and e-Learning as IT applications.

—*Multimedia and Web Technology:* The syllabus for Multimedia and Web Technology has been designed keeping in mind the industry requirements for professionals with web development experience. Apart from learning the basics of computers, students gain exposure to core web development concepts like client and server side scripting. The focus is largely on web development using HTML, XML, and VB script. Students learn to use multimedia manipulation software and create simple posters and applications using the same.

Figure 5 shows the allocation of teaching hours per component for each of the electives. This further highlights the differences among the various CS subjects, in terms of the content and the main focus.

In all the three subjects, of the total 180–190 hours of teaching, 40% is allotted to practical classes where students gain hands-on experience in developing simple

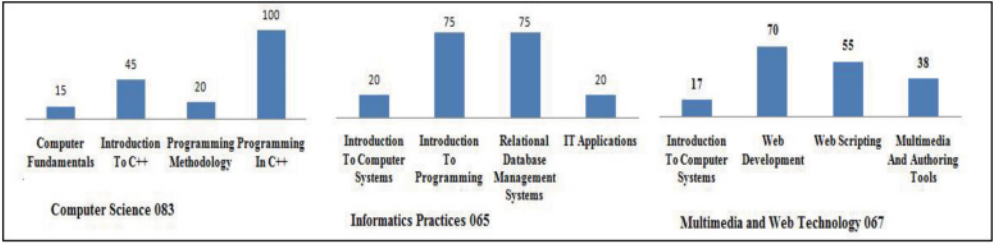


Fig. 5. Total teaching hours for different components of the various CS-based courses.

Table II. Types of Schools in India

Type of Management	Geographical Scope	Students Catered To
Central Government	Urban: Kendriya Vidyalayas	Children of transferable government employees
	Rural: Navodaya Vidyalayas	Talented rural children
State Government	Urban and rural	Urban and rural children
	Tribal areas	Tribal children
Municipal	Cities	Underprivileged children of different linguistic communities
Private —Aided by Government —Unaided	—Urban and rural — Primarily urban	—Privileged and underprivileged children —Primary children of the elite

Table III. Percentage Enrollment in Classes I–VIII in Different Types of Schools

All Government-Managed Schools	Private Aided Managements	Private Unaided Managements	Private Managements
65.01	8.30	24.28	32.59

(Source: DISE Flash Statistics 2011–2012).

applications. For core subjects like Physics and Chemistry, 180 hours are allotted for theory, while 28 hours are allotted for practical classes in an academic year.<sup>7</sup>

**3.2.2. Personal Factors of the Students: Age, Gender, Social, and Immigration Background.** India has a wide variety of schools catering to a diverse population—public schools, private schools, rural schools, and centrally sponsored schools [Choksi et al. 2010]. Table II illustrates these types.

The enrollment percentages in these schools for the year 2011–2012 are highlighted in Table III. These enrollments clearly indicate that the majority of students are in Government-managed schools and hence, any initiative taken, when focused on these students, will have a significant impact on the entire educational system of the country.

A look at the subject-specific enrollments can only help sharpen the focus of CS education research at the school level. As per the subject-wise enrollment data available for CBSE schools for 2012–2013, nearly 99,000 students registered for the CS (code 083) course, 28,000 for Informatics Practices (code 065), and only 2,677 registered for Multimedia and Web Technology (code 067). Figure 6 shows the enrollment of students in thousands for the various courses in Class XII. Above each bar is indicated the average marks scored by students in each of the subjects. Detailed analyses of the data reveal that on an average, girls scored more marks than boys in all these subjects.

<sup>7</sup>[http://cbse.nic.in/currisyllabus/Secondary\\_Sch\\_Curriculum-vol-1-2014.pdf](http://cbse.nic.in/currisyllabus/Secondary_Sch_Curriculum-vol-1-2014.pdf).

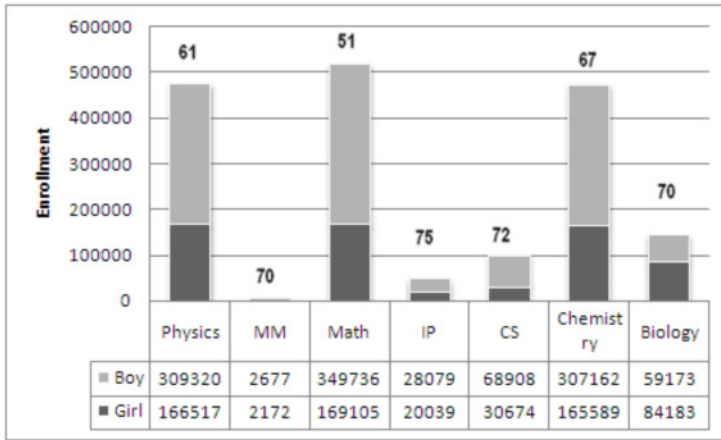


Fig. 6. Gender-wise enrollment (thousands) in various courses 2012–2013 (average marks indicated above each bar).

Table IV. Availability of Facilities in Rural and Urban Schools as per 7th AISES

	Total Secondary Schools	Science Lab	Computer Lab
Rural	63,576	33,659	10,716
Urban	27,165	19,350	13,603
	Total Higher Secondary Schools	Science Lab	Computer Lab
Rural	20,794	15,995	7,094
Urban	19,140	16,095	11,575

As far as CS subjects are concerned, the number of girls enrolled was low compared with the number of boys enrolled. This was also reflected in the number of girls taking up CS as a subject of choice for higher education. The low enrollment numbers for girls in CS programs has been a cause for concern not just in India, but across well-developed nations like the US, the UK, and Germany. Robust and well-designed CS programs may be required to specifically cater to the needs of girl children in India.

**3.2.3. Technoeconomic Development.** India is often seen as a technologically advanced nation and a favorite outsourcing destination. As per the World Bank survey of 2010, India has about 91 million Internet users. Though enterprises have demonstrated tremendous technological advancement, computers are yet to enter many households in India. The census report of 2011 indicates that about 90% of India's total population is yet to own computers. In the urban regions, only 18.7% of households own computers.<sup>8</sup> However, the ICT@School scheme has considerably impacted the availability of computers in schools. As per the 7th All India School Education Survey, 26% of Secondary Schools and 46% of higher secondary schools have computer labs.<sup>9</sup> A detailed analysis of this data, presented in Table IV, shows that while 50% of the total schools have Science lab facilities, only 25% have computer education facilities. This strengthens the need for more ICT- and CS-related initiatives, in both rural and urban areas.

The data presented in the 7th AISES Report on the number of schools offering (teaching) different subjects, having qualified teachers to teach the subject, and the enrollments in these subjects, further substantiates the fact that the focus on CS as a

<sup>8</sup>[censusindia.gov.in/2011-Common/NSDI/CensusInfo\\_India\\_2011.pdf](http://censusindia.gov.in/2011-Common/NSDI/CensusInfo_India_2011.pdf).

<sup>9</sup>[http://www.ncert.nic.in/programmes/education\\_survey/pdfs/Specific\\_Facilities.pdf](http://www.ncert.nic.in/programmes/education_survey/pdfs/Specific_Facilities.pdf).

Table V. Gender-wise Enrollments in Various Subjects as per 7th AISES

	Number of Schools		Enrollment		
	Teaching	Having Qualified Teachers	XI–XII		
			Boys	Girls	Total
Chemistry	10,655	9,187	708,274	375,097	1,083,371
Physics	10,638	9,152	706,227	373,449	1,079,676
Math	10,880	9,689	482,608	254,893	737,501
Biology	10,222	9,014	493,571	293,314	786,885
Computer Science	2,336	2,122	117,167	65,846	183,013

Table VI. Marks Allotted to Different Topics for CS Subject

Topic	Marks
Review of C++ covered in Class XI 12	12
Object-Oriented Programming in C++	12
Data Structure and Pointers	14
Data File Handling in C++	06
Databases and SQL	10
Boolean Algebra	08
Communication and Open-Source Concepts	08
Total	70

subject of academic interest is to be modified as: relatively low compared with other subjects as shown in Table V. Also, there are not many who are adequately qualified to teach CS.

### 3.3. Examination and Certification

In most states of India, public examinations called Board Examinations are conducted for all students of classes X and XII. The marks attained here are considered for admission into Universities, professional courses, polytechnics, and other higher education institutions. The examinations have a theory component—whose question paper is common across the state, and a practical component—conducted in the respective schools. Each state follows a different scoring pattern for the exams. CBSE conducts the Senior School Certificate Exam for Class XII students and the Secondary School Exam for Class X students. Each subject is scored on 100 marks and the pass criterion is 33%. Students who fail in subjects are provided a second chance through the Compartment Exam. The CBSE introduced the Continuous and Comprehensive Evaluation (CCE) system right from the primary schools to enhance the quality of education and monitoring by teachers. After the introduction of the CCE, the CBSE made the Class X public exam optional—a move that has been hailed and criticized by the public.

For CS courses too, the exams allot 70% marks to theory and 30% to the practical. The practical exams are held at the school level and the marks are submitted to the boards to be added to the theory marks. For the CS course for Class XII students, the distribution of marks across various topics is highlighted in Table VI.

Questions in the exam test the depth of understanding of the constructs of a programming language. About 20% of the marks are allotted for testing the higher order thinking skills of students. A sample question is shown in Figure 7.

The duration of practical examinations is 3 hours. Students are expected to write one full program in C++ (now Python), 5 SQL queries, present previously done project work, and document all the exercises done so far. The programming component carries 10 marks and all other components carry five marks each. The blueprints for the course



Write a function in C++ to combine the contents of two equisized arrays $A$ and $B$ by adding their corresponding elements as the formula $A(i)+B(i)$ , where value $i$ varies from 0 to $N-1$ and transfer the resultant content in the third same-sized array $C$ .
Which C++ header file(s) will be essentially required to run/execute the following code? <pre>void main() { int Rno=465; char SName[]="Ajay Bhascar"; cout&lt;&lt;setw(6) &lt;&lt;Rno&lt;&lt;setw(25)&lt;&lt;SName&lt;&lt;endl; }</pre>

Fig. 7. Sample questions for CS subject.

Table VII. Marks Allotted to Various Topics for Informatics Practices and Multimedia and Web Technologies

Informatics Practices		Multimedia and Web Technologies	
Topic	Marks	Topic	Marks
Networking and Open Standards	10	Computer System	5
Programming	25	Web Technologies	10
RDBMS	30	Web Development	40
IT Applications	5	Multimedia and Authoring	15
Total	70		70

How many times will each of the following loops execute. Which one of these is an entry loop and which is an exit loop?	Give the output for the following code segment: <pre>&lt;html&gt; &lt;body&gt; &lt;% sometext = "Bye!" max=Len(sometext) For i=0 to max newtext=Left(sometext,i) response.write(strReverse(newtext)) response.write("&lt;br&gt;") next %&gt;</pre>
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(a) Informatics Practices sample questions (065) (b) Multimedia and Web Technologies sample questions (067)

Fig. 8. Sample questions for courses 065 and 067.

Informatics Practices (065) and Multimedia and Web Technologies (067) are shown in Table VII.

As per the blueprints of the various CS-related subjects, 20% of marks are allotted to test the “*Knowledge*” instructional objective, 30% is allotted for testing the “*Understanding*” objective, and 50% is allotted to testing the “*Application*” objective. This allocation shows the emphasis laid on applying what has been learnt. Sample questions from Informatics Practices and Multimedia question papers are shown in Figures 8(a) and 8(b), respectively.

### 3.4. Teachers in Indian Schools

Teachers are one of the most important factors in implementing educational processes. The subject and pedagogical knowledge that lies with the teacher along with the motivation levels they possess directly affects the quality and learning outcomes of the student. Teacher quality is influenced by the teacher’s status, remuneration, conditions of work, and academic education as well as professional training [Siddiqui 2009]. Research has shown that the most powerful indicators of teacher quality are relevant subject content studies coupled with skills in teaching [Watson 2005].

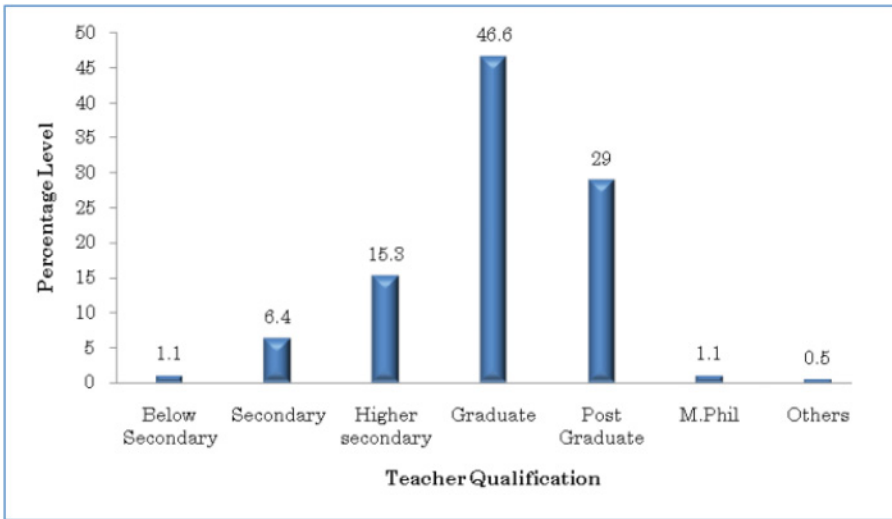


Fig. 9. Teacher qualification in Indian secondary schools.

The Rashtriya Madhyamik Shiksha Abhiyan scheme was launched with the objective of enhancing access to secondary education and improving its quality.<sup>10</sup> Quality reforms included increasing the number of teachers so as to reduce the pupil-teacher ratio to 30:1 and provide for in-service training of teachers.

The factors relevant to the teachers' influence on the quality of School Education include the following:

- Teacher Qualification*: Teacher education, Professional experience
- Teaching Methodology*: ICT, Teacher training
- Teacher Motivation*: Status, Salary teaching, Recognition
- Teaching Challenges*: No detention policy, Computers, Teacher absenteeism

**3.4.1. Teacher Education.** The Teacher Education policy in India is guided by NCF for Teacher Education (NCTTE) and places different demands and expectations on the teacher, all of which need to be addressed by preservice and in-service components of teacher education [Siddiqui 2009]. Other focus areas of the NCFTE include CS education in schools and e-learning [Siddiqui 2009]. Shulman [1987] lists various categories of knowledge that teachers should possess, such as content knowledge, pedagogical knowledge, curriculum knowledge, knowledge of learners and of educational contexts, and goals. Though the teachers' knowledge of the subject area contributes to the quality of teaching as measured by student learning outcomes, it is not conclusive as an indicator of teacher quality [Byrne 1983; Ashton and Crocker 1987]. Grossman [1990] states the importance of the interaction between subject content knowledge and effective teaching methods and Darling-Hammond [2000] supports the same view stating that "the degree of pedagogical skill may interact with subject matter knowledge to bolster or reduce teacher performance."

Both government and CBSE schools require a minimum qualification of a 3-year Bachelor's degree and a 1-year Bachelor's in Education (B.Ed.) degree to teach grades 9 and 10, as shown in Figure 9. There is an additional requirement of a Master's degree in a related subject to teach grades XI and XII. The undergraduate and the graduate

<sup>10</sup>[http://mhrd.gov.in/rashtriya\\_madhyamik\\_shiksha\\_abhiyan](http://mhrd.gov.in/rashtriya_madhyamik_shiksha_abhiyan).

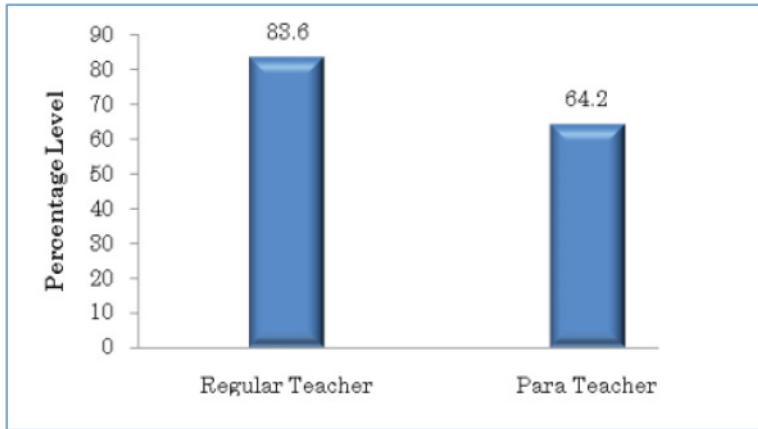


Fig. 10. Teachers with undergraduate or higher degree in secondary schools.

degrees provide the subject and content knowledge to the teacher, while the B.Ed. degree is focused on pedagogical knowledge, teaching methodology, and ICT. The majority of the teachers in schools that offer Secondary Education have an undergraduate or higher degree.

The Curriculum Guide and Syllabus for Information Technology in Schools developed by NCERT, India, expects basic competencies of teachers to achieve the objectives of computer education at the secondary level. Hence, computer education is an important component of teacher education and includes introduction to computers, OSs, applications of computers in teaching, software packages, and computer languages. With the legislation of the Right of Children to Free and Compulsory Education Act,<sup>11</sup> India's need for additional qualified and trained teachers is even greater than before.

To meet the shortage of qualified teachers, schools may hire para-teachers or full-time contract staff in schools. These personnel may generally be from among the same community, albeit less qualified than the full-time teachers. A para-teacher is normally appointed on a fixed salary that is less than what is paid to the regular full-time teacher. Figure 10 shows the percentage of teachers in schools that offer Secondary Education with undergraduate or higher degrees.

**3.4.2. Teacher Educational Institutes.** The proliferation of private teacher training institutions granted recognition by the NCTE for teacher education courses has increased the opportunities for those wanting to train to become teachers. There are about 1,103,457 enrollments for teacher education courses, such as D.Ed., B.Ed., M.Ed., and others. The courses recognized by the NCTE on an all India basis are tabulated in Table VIII. The National Council for Teacher Education has developed the guidelines and framework for the Teacher Eligibility Test (TET) that needs to be taken by all teachers.

**3.4.3. Teacher Training.** According to the 2011–2012 MHRD, “Report to the People on Education,” the reforms in the Teacher Education Program include the development of a NCF of Teacher Education (2009), the principles laid down in the Right of Children to Free and Compulsory Education (RTE) Act, 2009, and the minimum academic and professional qualifications laid down for appointment of teachers. The Ministry has also prepared a set of strategies for organizing training of untrained teachers by the State Governments. Further, the ICT in Schools Scheme includes the capacity enhancement

<sup>11</sup>[http://mhrd.gov.in/sites/upload\\_files/mhrd/files/rte.pdf](http://mhrd.gov.in/sites/upload_files/mhrd/files/rte.pdf).

Table VIII. Capacity for Teacher Education in Teaching Methodology

Recognized Courses	Number of Government Institutions	Approved Intake—Government	Number of Private Institutions	Approved Intake—Private	Total Intake (Government + Private)
Elementary (D.Ed.)	757	49,089	4,831	2,98,278	3,47,367
Secondary (B.Ed.)	224	20,031	5,730	6,09,486	6,29,517
M.Ed.	102	3,672	790	25,285	28,957
B.P.E.D.	19	1,284	538	28,150	29,434
Others	76	16,760	800	51,422	68,182
Total	1,178	90,836	12,689	10,12,621	11,03,457

Source: [http://www.teindia.nic.in/Files/AWPB/Guidelines\\_TES-June-2012.pdf](http://www.teindia.nic.in/Files/AWPB/Guidelines_TES-June-2012.pdf).

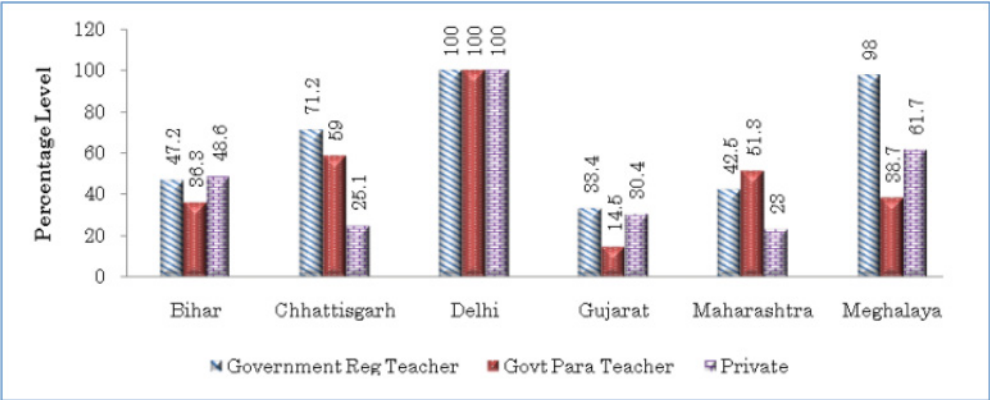


Fig. 11. Percentage of teachers trained.

of all teachers in computer education. One area of concern raised by this report is the quality of training imparted with the heads of schools reporting that though the teachers have received training, many still lack the capacity to teach. Figure 11 shows the percentage of teachers trained in different states. The states have been randomly selected from the MHRD report on education.

In India, where it is difficult to meet the large demand for in-service teacher training in terms of the requisite teaching skills that need to be imparted, training in specialized areas, such as computer education, is naturally a bigger challenge. The goal of computer education for teachers as defined by the MHRD is to cover basic hardware and software knowledge, basic knowledge of the Internet, web-based tools and cyber security, the effect of computer education, and the use of ICT in education.

An example of a success story is the Kerala state’s IT@School program that provides both preservice and in-service teacher training in basic computer education. A study of ICT usage in 1,000 schools in the two states of Gujarat and Karnataka in India, finds that the majority of the 6,239 school teachers surveyed were without any training in ICT tools [Bharadwaj 2007]. Consequent to this, focus on CS subjects by teachers has been very minimal.

Internationally, universities are rising to the challenge of encouraging CS education by empowering the teachers [Liu et al. 2011; Olympiou and Zacharia 2012]. Carnegie Mellon University organized the first Computer Science for High School (CS4HS) workshop in 2006 to address the decline in enrollment in CS undergraduate programs in the US. According to Blum et al. [2008], “this workshop provided high school teachers with

course materials and information to show the breadth and application of CS to their students with the hope that this will help increase excitement about computing as a potential path for high school students when they enter college.” Google sponsored universities to develop CS4HS Teacher Development workshops in CS and computational thinking in the US, Canada, Europe, China, and Australia.

*CS Education to Teachers:* In India, many international companies offer computer education to schools in collaboration with educational agencies. Empowering teachers with ICT training and tools, Intel’s Teach India initiative kick-started in Mumbai, Bangalore, and Delhi in 2000 through its Intel Teach program [Price et al. 2010] aimed at preservice and in-service teacher training. Intel offered programs for both in-service teachers that catered to the curriculum teachers followed and the postservice programs that supported teachers in integrating technology into the future classrooms. Intel has done numerous projects spanning over 19 states and union territories and has so far impacted over one million teachers.

Recently, Oracle Academy offered free teacher training to the 14,500 CBSE-affiliated schools in India.<sup>12</sup> The CBSE Training by Oracle Academy in the first rollout offers training to identify “Master Trainers” using both the virtual and on-site training formats. This includes Alice Workshops and Java Fundamentals Institute for Computer Science teachers to teach the basics of 3D animation and object-oriented programming. Students learn to use free and open-source software platforms, such as Alice, Greenfoot, and Eclipse. One of the most important aspects of CS with modern-day relevance is problem solving, which is also the focus of the training programs that emphasize partitioning problems into smaller tasks and creating algorithmic expressions to solve them. The training is split between in-class and virtual-class sessions over an 8-week period.

Under the Partners in Learning initiative, Microsoft and Kendriya Vidyalaya Schools (KVS) joined hands to start the Project Shiksha program<sup>13</sup> to train teachers and students to accelerate computer education in school environments by providing tools, programs, and practices. Teachers’ training at KVS schools is done after school hours over a 2-week period. Since its implementation in 2007, the project has partnered 13 state governments to set up Shiksha academics and trained 741,000 government school teachers.<sup>14</sup>

*3.4.4. Blended Learning Model for Teacher Training.* In a country like India, with a huge need for teacher training, the blended learning model may be suitable for parts of teacher education. Amrita University’s distance learning platform called A-VIEW [Bijlani et al. 2011] has been used by Indian Institutes of Technology (IIT) Bombay and other universities to provide large-scale teacher training programs across universities in multiple states in India. The Tata Institute of Social Sciences offers an MA in Education program that has a 3-week on-site course followed by a 12-week course using Moodle.<sup>15</sup> Models such as the A-VIEW Teacher Training program and the TISS MA Education can be used to train school teachers across the nation.

*3.4.5. Teaching Methodology.* The CBSE has modified the assessment process from year-end exams to CCE, which include formative assessments, such as project work, presentations, review reports, assessments, and two term-end summative assessments. The CBSE has also provided extensive training for CCE, and thus, contributed to the

<sup>12</sup>[http://www.cbseacademic.in/web\\_material/circulars/2013/13\\_oracle%20letter%20to%20website.pdf](http://www.cbseacademic.in/web_material/circulars/2013/13_oracle%20letter%20to%20website.pdf).

<sup>13</sup><http://www.kvsangathan.nic.in/ProjectShiksha.aspx>.

<sup>14</sup>[http://www.microsoft.com/india/msindia/msindia\\_up\\_partnerslearning.aspx](http://www.microsoft.com/india/msindia/msindia_up_partnerslearning.aspx).

<sup>15</sup><http://moodle.tiss.edu/>.



emergence of a newly empowered group of teachers who have changed the teaching methodology in CBSE schools. The CBSE has mandated smart classrooms in all schools, or ICT-enabled learning. Government schools are also being provided with computer labs though the number of computers in a school may be few, thus limiting the time that a student can use a computer.

**3.4.6. Teacher Salary and Status.** A person trained in CS has alternate career paths that are much more lucrative and respected than a career in teaching. Thus, those who teach CS at schools include not only those who love teaching but also those who did not get higher paying industry jobs or who desired more flexibility and shorter work hours. The status of a teacher in Indian schools is directly proportional to the grade they teach and high school teachers have the highest status within the school hierarchy. In government schools, the teachers are employed by the state, and their salary is determined by their educational qualification, experience, and rank, but no component of the salary is based on performance.

The 9th Pay Commission Report provided a considerable increase in the pay scales of teachers with the higher starting salary for senior higher secondary teachers [Babu et al. 2010]. Depending on the nature of the private school, teachers may be paid far less at the low-end private schools and much higher in elite private schools, which charge exorbitant fees. In a large-scale study with 300 schools in the state of Andhra Pradesh, Muralidharan et al. [2011] found that the teacher performance pay program that included either group bonuses based on school performance or individual bonuses based on teacher performance were effective in improving student learning outcomes. They showed that at the end of 2 years of the program, students in incentive schools performed significantly better than those in comparison schools by 0.28 and 0.16 Standard Deviations (SD) in Math and Language tests, respectively.

**3.4.7. Teacher Recognition.** The Scheme of National Award to Teachers<sup>16</sup> was started with the object of raising the prestige of teachers and giving public recognition to outstanding teachers. The President of India awards the National Award to Teachers on the 5th of September (Teacher's Day) every year to give public recognition to 374 meritorious teachers working in the primary, middle, and secondary schools. Another 43 "Special Awards" are for teachers who have done outstanding work for integrating inclusive education in schools and in the education of children with disabilities in regular schools. Further, to encourage the use of ICT in schools, "Using ICT for Innovations in Education" national awards are awarded to 87 teachers. Each winning teacher is awarded with an ICT Kit, a laptop and a commendation certificate and encouraged to mentor others in their area and further train other teachers in the use of ICT in teaching.

**3.4.8. Teacher Absenteeism.** A few studies have pointed out high teacher absenteeism in government schools and the lack of accountability [Chaudhury et al. 2006]. This may be attributed to the fact that in government schools, the teacher jobs are secure and the annual increments are based on the number of years, rank, and experience of the teachers rather than their performance. Private schools have the flexibility to provide teacher compensations based on education, experience, and performance.

**3.4.9. Teacher Access to Computers.** Bharadwaj [2007] reports that the use of computers in education is very limited in the country when measured in terms of the number of schools that have computer labs (20.4%), the availability of a budget in schools for its implementation (6.5%), the number of teachers trained in computer education, the per capital availability of hardware, and so forth as shown in Figure 12. It further

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<sup>16</sup>[http://mhrd.gov.in/national\\_award](http://mhrd.gov.in/national_award).

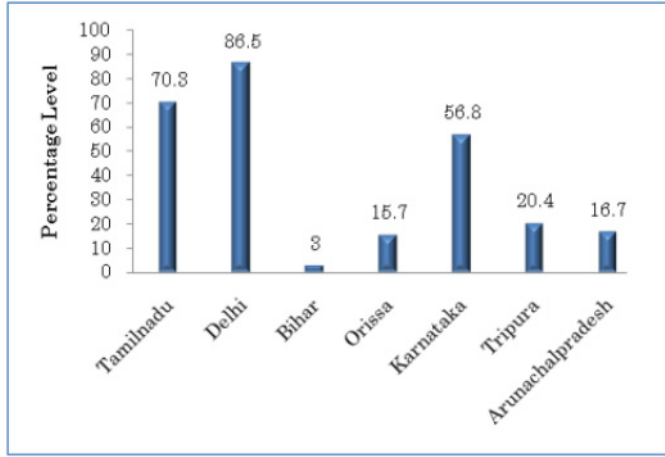


Fig. 12. Percentage of secondary schools with computers 2011–2012: States shown as per Bharadwaj [2007].

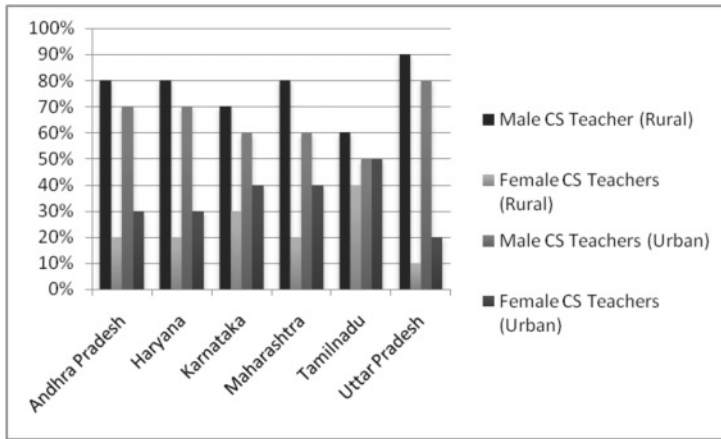


Fig. 13. Gender statistics in computer teachers (rural and urban).

finds that 75.2% of the Karnataka teachers and 71.4% of the teachers in Gujarat did not have access to computers at all. The MHRD’s road map for computer education includes creating and upgrading the computer infrastructure at schools, building basic CS capacities in teachers, and encouraging the use of ICT for their own continuous professional development.

**3.4.10. Gender Statistics in Computer Teachers.** In 2010, about 46% of the total teachers in schools between 2010 and 2011 were female teachers across the country (<http://www.dise.in>). Urban areas had higher percentages of female teachers at almost 67% compared with rural areas that stood at 39% percent. Irrespective of school types, a significant difference was also noticed in the case of female teachers in private schools (almost 55%) and for those under government management (almost 41%). However, the percentage of female teachers in the field of CS proved to be lower than the male teachers here, for both the urban and rural areas. Figure 13 shows the percentage of teachers based on gender in both urban and rural schools.

Table IX. Important National Level ICT Policy and Program Initiatives in Education

1972	Educational Technology Scheme was introduced
1984	CLASS program (Computer Literacy and Studies in Schools); BBC microcomputers—12,000 were distributed to secondary and senior secondary schools
1986	National Policy on Education (NPE) Formulated
1989	216 DIETs (District institutes of Education Technology) started
1992	CLASS was folded into 8th 5-year plan; 4,898 schools given BBC microcomputers, hardware maintenance
1998	National Task Force on IT—made recommendations for “IT for All by 2008” scheme; Vidyarthi Computer Scheme—financial aid for students; Shishak Computer Scheme—financial aid for teachers; School Computer Scheme; Internet for everyone by 2003
2000	Public-Private Partnerships began to boom; Intel Teach India program; National Curricular Framework (NCF) laid out
2001	SSA (Sarva Shiksha Abhiyan) with emphasis on primary or elementary education
2002	National Working Group on Elementary and Adult Education—recognized need having computer facilities and made the decision to support one or two schools in areas of 7–8 km radius;
2004	ICT@Schools program launched (CLASS and ET were combined into this); Establishment of SMART schools; EDUSAT (Education Satellite) launched
2005	National Curricular Framework (NCF) 2005 published; National Knowledge Commission (NKC) was established;
2009	2009: Right to Education (RTE) bill passed; “Rashtriya Madhyamik Shiksha Abhiyan” program started that laid emphasis on quality of secondary education; National Mission on Education through ICT launched
2010	National Knowledge Network (NKN) to provide connectivity to educational institutions launched
2012	National Policy on ICT for School Education launched

### 3.5. Educational Policies

Access to quality education is fundamental to the socioeconomic and technological development of any country. For the majority of students it is their performance in the last 4 years of school that has a binding effect on the professions they get qualified to pursue. Creating a literate India has been of foremost importance for all those engaged in education. In the first three decades most policies were focused on economic development, alleviating poverty, improving the Gross Domestic Product (GDP), and infrastructure development.<sup>17</sup> Pogrow [1986] and Geiss [1986] indicate that the federal policies were impactful in schools only if they helped remove market barriers preventing the use of cutting-edge technologies for education and invested in research and development aimed at improving learning that would otherwise have been ignored. Since 1980, however, the government of India initiated concerted efforts to give education the boost it deserved. The importance of policies related to CS education and their impact on today's society is well described by Stephenson and Dovi [2013]. The bottom line is that knowledge of CS could make all the difference between the haves and have-nots, and this is of immediate import. In India, the most dominant national and state policies and programs shaping the adoption of CS and ICT knowledge are described in this section and chronologically listed in Table IX.

*3.5.1. National Policies and Programs.* In this section, we highlight the various ICT- and CS-based policies in India. We initially focus on the ICT policies because the policies

<sup>17</sup><http://planningcommission.nic.in/plans/planrel/fiveyr/welcome.html>.

that were launched early in India were ICT centric. Looking at the global need for CS-educated people, these policies evolved to include CS-education-based components in them. Recognition of the usefulness of ICT in education came as early as 1972 with the introduction of the Educational Technology (ET) scheme that saw the creation of six State Institutes of Educational Technology (SIET) in the country.<sup>18</sup> Later, in 1984, the CLASS was initiated by the central government as part of which, over 12,000 computers were given to secondary and senior secondary schools along with financial grants for annual maintenance.

The (NPE was formulated in 1986, and its action plan for implementation was created in 1992.<sup>19</sup> The NPE emphasized the role of ET to improve the reach and quality of education for students and training of teachers. As the first step toward formally inducting CS and ICT in schools, the NCF 2005 described how educational needs should be addressed in the schools.<sup>20</sup> The framework accentuated the differences and the importance of including CS and ICT curricula and recommended areas, such as algorithms, general problem-solving strategies, iterative processes, and role of computing in modern society to be included in the school curricula. Needless to say, a critical factor that may enable such education is the availability of computing resources. A determined effort to improve the hardware and networking infrastructure is fundamental to the diffusion of CS education in the Indian context.

The National Task Force on information technology and software development constituted the “IT for all by 2008” program in 1998<sup>21</sup> with objectives of ensuring availability of computer infrastructure and facilities for learning. The policy detailed providing incentive programs for students (Vidyarthi Computer Scheme), teachers (Shishak Computer Scheme), and schools to buy computers and proposed to ensure Internet availability in every school, polytechnic, college, and public hospital by 2003. As part of the “IT for Masses” campaign spearheaded by the Ministry of Communications and IT,<sup>22</sup> the Vidyarthi Computer Scheme was expanded to cover 10 schools per block (and India can be divided into 6,000 development blocks) with a total of 60,000 schools with 600,000 computers with a minimum computer-to-student ratio of 1:20. For Internet connectivity in schools, the state governments played an active role in procuring it locally with the support of the central government. A very large initiative with regard to the gigabyte level connectivity termed the National Knowledge Network (NKN) was recommended by the National Knowledge Commission (NKC). Although significant strides were being made to incorporate computer education in schools, a comprehensive policy with stakeholder roles and responsibilities was still necessary for its adoption. After several deliberations between various central government and state government partners, experts, and school administrators, the most recent version of the National Policy on ICT for School Education was released in 2012.<sup>23</sup> The highlight of this policy was the development of a model Curriculum for ICT (CICT) that would include conceptual knowledge enhancement and enable the development of generic skills. ICT literacy modules that were categorized as basic, intermediate, or advanced levels were introduced as electives in the Class XII curriculum for both the private and government schools, and the depth of the coverage of the curricula depended on their existing ICT infrastructure. The competencies and course levels were left flexible for teachers

<sup>18</sup><http://www.teindia.nic.in>.

<sup>19</sup>[http://www.ncert.nic.in/oth\\_anoun/npe86.pdf](http://www.ncert.nic.in/oth_anoun/npe86.pdf).

<sup>20</sup><http://www.ncert.nic.in/rightside/links/pdf/framework/english/nf2005.pdf>.

<sup>21</sup><http://it-taskforce.nic.in/it2008.htm>.

<sup>22</sup><http://itformasses.nic.in/recontant.htm>.

<sup>23</sup>[http://mhrd.gov.in/sites/upload\\_files/mhrd/files/revised\\_policy%20document%20ofICT.pdf](http://mhrd.gov.in/sites/upload_files/mhrd/files/revised_policy%20document%20ofICT.pdf).

to run multiple modules serially or in parallel. The program hoped to ensure student exposure to the advanced levels prior to leaving school.

The Indian Government has always recognized that computer education should not just be stressed as a must-learn topic for school students based on their competence levels but it should be viewed as a necessary solution to improve the learning experience, quality, and effective management of schools. This vision led to the laying out of a far more comprehensive program<sup>24</sup> that covered the need, an action plan, implementation alternatives, and curriculum development for diverse education institutions, that is, schools, vocational institutes, open and distance learning institutes, and those that cared for children with special needs. The main components of the ICT in School program included the following:

- Creation of partnerships between the central and state governments for computer education in terms of financial incentives, methodologies for procurement of hardware, Internet connectivity, and so on. More than 96,000 schools in 35 states and union territories have received funding to implement the program.
- Creation of SMART schools with an emphasis on computer education, skills, and values for the next millennium. 150 such schools were planned and 63 of them have been sanctioned in 11 states.
- Teacher-related interventions that span engagement, training, and incentives for them.
- Development of e-content by CIET (Central Institute of Education Technology), SIET, and regional institutes (Regional Institutes of Education).

Today, this program is the main driving force behind making computer education a common theme in rural and metropolitan schools and bridging the digital divide across socioeconomic and geographic segments. With the consistent diffusion of the program across the states, employment of competent teachers with the right qualifications and training as mentioned in Section 3.4 of this chapter is coming to the fore.

For its implementation, the ICT in schools program enumerated partnerships between the central, state government departments, private agencies, and NGOs among others. In terms of overall responsibilities, the national agencies such as NCERT, CIET, NIOS, and State Councils for Educational Research and Training (SCERT) were given the responsibility of developing the curriculum, identifying resources, and undertaking teacher capacity building programs. On the other hand, the state agencies were to take the responsibility to facilitate the program effectively by defining norms, standards, and guidelines for phased implementation and evaluation with the help of NGOs and public-private partnerships (PPPs). Figure 14 shows the coverage of schools per state.<sup>25</sup> States representative of the North, South, East, and West have been plotted in Figure 15. The figure indicates the gap in coverage across the Southern states and the Eastern states with the former having a maximum number of school participations and the latter having the least.

Some of the national flagship programs promoting computer education in schools include the following:

- Sarva Shiksha Abhiyan (SSA): This program was initiated for the universalization of elementary education, and creating an environment of free and compulsory education to the children of 6–14 years of age in alignment with the constitutional mandate Right to Education bill (RTE 2009). Among other objectives, this program covered community computer education, such as computer awareness and literary at the

<sup>24</sup>[http://mhrd.gov.in/ict\\_school](http://mhrd.gov.in/ict_school).

<sup>25</sup><http://www.cietncert.org/ICT-Schools/Implementation/status-implementation>.



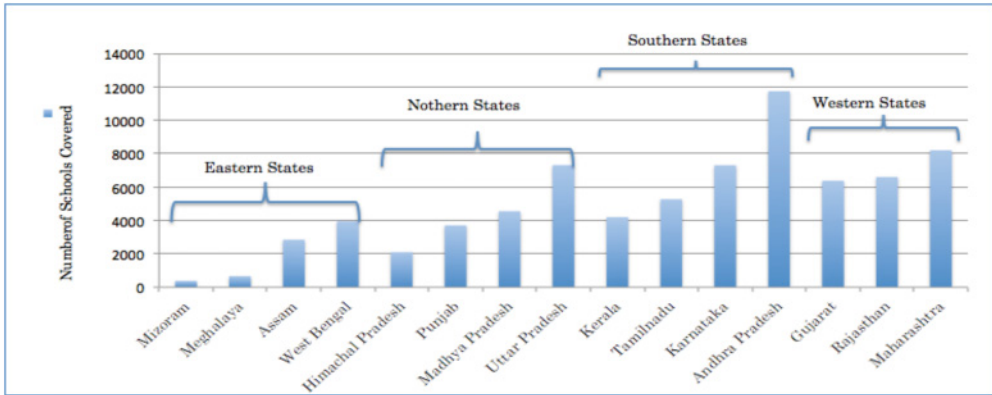


Fig. 14. ICT in schools coverage across the Indian states.

upper primary school level, initiating a reduction in drop-out rate, enhancing the joy of learning, and so on. The SSA framework created a division for “Innovation” to cover computer-aided learning (CAL), which was considered critical and budgeted at Rs. 50 lakhs per district each year to achieve its goals.<sup>26</sup>

- Rashtriya Madhyamik Shiksha Abhiyan (RMSA): This scheme started in 2009 targeted secondary education with an emphasis on the improvement of the quality of school education.<sup>27,28</sup> As part of the many additions to improve quality, an extensive assessment of school facilities—especially laboratories to teach subjects such as CS—was undertaken and this resulted in the establishment of new computer labs and/or up-gradation of the existing ones. The program also included teacher training initiatives. Thus far, 9,636 new schools have been benefitted and 34,300 schools have been approved to be upgraded, among which, there will be 19,641 computer rooms.
- Education Satellite (EDUSAT): In 2004, the Indian Space Research Organization (ISRO) launched the world’s first education satellite (EDUSAT) completely dedicated to the educational needs of school and college students. To date, there are more than 49,000 terminals deployed across the country. The EDUSAT centers in the state have served as large-scale refresher induction training centers for teachers.

**3.5.2. Funding Norms for National ICT Programs.** The central government has established specific financial incentives and norms for supporting the national ICT programs in congruence and partnership with state governments (ICT 2004). The state governments are expected to submit a Computer Education Plan (CEP) to the MHRD. Once approved, the central government takes the responsibility of bearing 75% of the costs, while the state governments are expected to foot the remaining 25%. The North Eastern states such as Sikkim are extended more support from the central government and their cost structure displays a ratio of 90:10.

**3.5.3. State Programs.** The state governments play the most pivotal role in shouldering the primary responsibility of driving the quality of education in their respective states. The NKC has recommended more flexibility, decentralization, and provision of resources to the states to achieve their stipulated goals.<sup>29</sup> The SCERTs have been successful in the implementation of the various national programs in a cost-efficient way

<sup>26</sup><http://ssa.nic.in/quality-of-education/CAL-07.pdf>.

<sup>27</sup>[http://mhrd.gov.in/rashtriya\\_madhyamik\\_shiksha\\_abhiyan](http://mhrd.gov.in/rashtriya_madhyamik_shiksha_abhiyan).

<sup>28</sup>[http://planipolis.iiep.unesco.org/upload/India/India\\_Scheme\\_secondary\\_education.pdf](http://planipolis.iiep.unesco.org/upload/India/India_Scheme_secondary_education.pdf).

<sup>29</sup><http://www.aicte-india.org/downloads/nkc.pdf>.

with the effective partnerships between government and private industry resulting in interconnected clusters of villages with a central hub.<sup>30</sup> In the next few sections, we shall take a look at the state level policies in four representative states, namely, Kerala, Delhi, West Bengal, and Karnataka.

*3.5.4. IT@School—Kerala (South India).* Kerala state's IT@School program has been extremely successful in integrating digital content, educational software, and teacher training in a structured format. The program supports 1.6 million students from Class VIII to XII in 2,738 schools in 14 districts of Kerala.<sup>31</sup> The program began in 2002. The teachers are trained in basic computer literacy first, that is, operating system, office application, web browser, and email followed by software and hardware installation. The state has also developed its own operating system (IT@school GNU/Linux) that is now being used statewide and emphasized embracing free and open-source software (FOSS)-based education in more than 8,000 of its schools. The existing training structure for preservice and in-service training incorporates computer training as well in a structured way. Also, the promotion of the optional Malayalam (local language) interface in software tools has made it easier for its overall acceptance in schools. Kerala has also roped in its teachers in contributing to the CS curriculum as part of the periodic SCERT workshops. This allows teachers to own up and co-create the content being taught.

*3.5.5. Computer Education Project—Delhi (North India).* The Department of Education in Delhi sets policies, implements, and governs more than 1,000 schools and 40,000 staff that cater to over 1.1 million children. SCERT in Delhi has in its road map two key initiatives, that is, “*Teach the Teachers program*” initiated to upgrade the skills of teachers and the setting up of computer labs across all government schools. Delhi has implemented several innovative initiatives to attract its young students to use and learn more about computers and the Internet.<sup>32</sup> The Computer Education Project was started in 2000 by the Delhi government to impart computer education. So far, the project has established 512 computer laboratories covering 638 schools and 635,000 students. CALtoonZ, a specialized computer-aided learning program set up in government schools assists teachers with the skills and technology to engage students in an interactive environment.

*3.5.6. West Bengal (East India).* The West Bengal IT Policy 2003 focused on setting up the requisite infrastructure to support ICT projects in the state, and address IT in education to expand the knowledge base of citizens in the state. The ICT in Schools Scheme has empowered many schools with SCERT and DIETs creating e-content for them. UNICEF and IETS (IL&FS Education and Technology Services Limited) developed a capacity building initiative in the field of computer literacy called “Double Click” for destitute girls among tribal areas. The NIIT@schools program has been active in providing a computer literacy training program at secondary schools.

*3.5.7. Karnataka (South India).* In 1997, the state announced the IT policy Mahiti (The Millenium Information Technology Policy of Karnataka) to take ICT to all schools. The Mahiti Sindhu program focuses on computer education and its applications, the basics of programming, and the enhancement of the levels of learning in curricular subjects through computer-aided education. Since 2001, approximately 2,009 government aided secondary schools have acquired the facility and infrastructure under the grants

<sup>30</sup><http://scert.cg.gov.in/pdf/ict1.pdf>.

<sup>31</sup><https://www.itschool.gov.in>.

<sup>32</sup>[http://delhi.gov.in/wps/wcm/connect/doi\\_t\\_scert/Scert+Delhi/Home](http://delhi.gov.in/wps/wcm/connect/doi_t_scert/Scert+Delhi/Home).

provided.<sup>33</sup> Students in grades VIII, IX, and X have been the main beneficiaries of the project. They now have the opportunity to take this course in English or in the local language, that is, Kannada. Four sessions per week are set aside for computer and computer-aided education. The Azim Premji foundation also started the Computer Assisted Learning program in 2001 to provide state-of-the-art learning centers for English and computer study in rural Karnataka. In partnership with the state government, the computer assisted learning centers (CALC) grew to 55 in number and in 11 districts in Karnataka. Today, CALCs exist in over 14 states.

*3.5.8. Enhancing Cooperation with Nonprofit International Organizations.* The America India Foundation began its digital equalizer program in 2002 by bringing technology to schools and assisting teachers and students with learning in a collaborative, project-based approach. By equipping each school with a computer center and educational resources, the digital equalizer curriculum tries to cater to students from grades VI to X and provides computer literacy, Internet research, and exposure to pedagogical methods for use in the school curriculum. So far, in 14 states, this program has impacted 2,421 schools in 78 districts, with 29,306 teachers and 852,517 students.

The dot-EDU project provides technology tools for teachers and training (T4) to attain the goals set by the SSA. The project is cosponsored by USAID (United States Agency for International Development) and implemented by the Education Development center, Inc. (EDC) and government and NGO partners.<sup>34</sup> The project is under implementation in seven states.

*3.5.9. Enhancing Cooperation with Influence of Universities in Empowering School Education.* Premier institutes such as IIT, Amrita University, National Institutes of Information Technology, and International Institutes of Information Technology (IIITs) have actively worked toward developing technology, tools, and frameworks to improve the educational needs of schools. A few examples are highlighted here: the Project Sahayika<sup>35</sup> was built in collaboration with IIT Kharagpur to provide school children with a knowledge network through which they can navigate concept-based and topic-based contents. Amrita University's Center for Research in Advanced Educational technologies (CREATE) [Nedungadi et al. 2013] has developed online science laboratories with support from the Department of Electronics and Information Technology (DeitY) and in collaboration with the Center for Development of Advanced Computing (CDAC).

*3.5.10. Technical Infrastructure and Implementation Schemes.* The technical infrastructure for CS education comes primarily from the ICT@School scheme based on the 2005 National Policy on Education implemented throughout India. The program focuses on providing the right infrastructure with optimal utilization at lowest cost in every school.<sup>36</sup> The core ICT infrastructure includes the basic accessories required for enabling usage and teaching of CS and ICT, and these include hardware, software applications, and peripheral devices, such as printer, scanner, projector, digital camera, and audio recorders. At the very minimum, computer laboratories have between 10 and 20 networked computers allowing access to 40 students at one time. The procurement and implementation of this infrastructure is primarily controlled by the State. Each state groups its schools in districts and each district has a set of schools that take up the implementation through a single BOOT (Build Own Operate Transfer) operator or

<sup>33</sup><http://dsert.kar.nic.in/html/chapter06.html>.

<sup>34</sup><http://dot-edu.edc.org/projects/indiastory.htm>.

<sup>35</sup><http://www.medialabasia.in/index.php/research/projects/education>.

<sup>36</sup>[http://mhrd.gov.in/sites/upload\\_files/mhrd/files/revisedpolicydocumentofICT.pdf](http://mhrd.gov.in/sites/upload_files/mhrd/files/revisedpolicydocumentofICT.pdf).

a vendor. The vendor builds, owns, and operates this equipment, and at the end of the contract period transfers it to the school.

**3.5.11. Research Funding and Policies.** One of the largest premier policies undertaken by the MHRD, Government of India is the National Mission on Education through the ICT (NMEICT). A major initiative under this mission is the launching of the Sakshat Portal as a one-stop gateway to an open-house of knowledge with a US \$4 billion budget.<sup>37</sup> A substantial portion of the funding has been allotted to create and host digital content and virtual laboratories with a special focus on CS.

### 3.6. Media

Educational challenges often plague institutions when there is a lack of coordinated effort between the students, the teachers, and the schools to overcome archaic practices and embrace newer approaches [Hew and Brush 2007]. Unless the schools take proactive steps to use governmental programs to improve infrastructure and the teachers adopt current trends in mass media [Tucker 1996; Sadaf et al. 2012], the digital gap in education will continue to persist. This section presents a spectrum of global print and web media that are available to CS students and teachers but we do not claim this to be an exhaustive list of all media resources.

As mentioned in Section 3.2, there are mainly three courses (course codes 083, 065, and 067) offered to students in the areas of CS at the senior secondary levels (i.e., grades XI and XII). Computer science (course code 083) or Information practices (course code 065) courses broadly cover the following topics over 2 years, providing both theoretical and practical training. (1) Computer fundamentals and Boolean algebra: One of the most comprehensive books prescribed for CS students is “Fundamentals of Computers” [Rajaraman 2010]. The book has 17 chapters covering the objectives of computers, fundamentals of how computers are built and programmed from a hardware and software perspective, and gives an introduction to computer networks, graphics, and multimedia and touches on emerging trends in higher order computing such as Cloud computing, utility computing, and grid computing. (2) Programming methodology and problem solving using C++. More recently, Python is being offered as an alternative choice to learning C++.<sup>38</sup> Books such as “Python Programming: An Introduction to CS” [Zelle 2010] show how Python can be utilized to break down complex problems. (3) Introduction to data types, variables, structured data, user-defined functions, mathematical functions, event programming, SQL, and so on, referred from books such as “Database Primer” [Date 1983]. (4) Computer system organization and computer networks [Tanenbaum 2003] that teach of devices (input, output, storage, etc.), types of software (system, application, and utility), communication protocols and network architectures. For the optional course, Multimedia Web and Technology (course code 067), the students are trained in web development, web scripting, and multimedia authoring tools.

Motivating students and enhancing their desire to learn by supplementing traditional pedagogies with educational technologies has been of primary interest to educational institutions, teachers, the government, and the technology community as a whole. With the advent of Web2.0 technologies, the depth of coverage and diversity of educational topics a student can be exposed to has grown exponentially in the past decade. Although a lot of video lectures, e-textbooks, and tutorials are available, content developers are moving toward providing customizable and adaptive learning experiences to the learner. Simultaneously, social media platforms have provided

<sup>37</sup><http://www.sakshat.ac.in/pdf/missiondocument.pdf>.

<sup>38</sup>[http://cbseacademic.in/web\\_material/Curriculum/SrSecondary/2015\\_Senior\\_Curriculum\\_Volume\\_1.pdf](http://cbseacademic.in/web_material/Curriculum/SrSecondary/2015_Senior_Curriculum_Volume_1.pdf).

interactivity promoting collaborative online learning. This accessibility is further enhanced with the use of tablet PCs [Kurtz et al. 2007].

The World Wide Web continues to serve as the primary gateway for disseminating knowledge and information to millions of teachers and students. ACM and its partnership with code.org have pioneered the promotion of CS at K-12 institutions extensively through their innovative programs and advocacy campaigns. In 2013, during the Computer Education Week, through the “hour of code” program, a staggering 11 million students from 167 countries undertook the coding tutorial in just 1 week [Layton 2013].

Programming is the most common subject taught online in CS. Problem solving with numerous online programming exercises, at the basic and advanced levels in more than 35 programming languages supplemented by forums for discussions are available for K-12 students on websites, such as codechef.com. Sites such as girldevelopit.com not only provide online learning exercises but also conduct hands-on mentoring sessions. These along with many similar websites cater to students who are technologically savvy. Khan Academy,<sup>39</sup> on the other hand, has incorporated more real-time visualizations into the programming environment that makes a deeper impression in the students by allowing them to immediately see the impact of changes they have made in the program. Using Javascript and Python environments, this organization teaches object-oriented design, animation, logic, looping, and so on, through the use of practical examples of scientific applications to create enthusiasm and appreciation among students.

Reviewing some of the computer education blogs, it is clear that K-12 CS teachers author many of the popular ones.<sup>40,41</sup> Sharing best practices and facilitating understanding of cutting-edge areas, applications, research, societal issues, and discussions allow teachers to stay updated with the latest developments and share their own experiences on a daily basis. There are also blogs that focus on specific topics, such as the innovative use of the Raspberry Pi, programming pedagogy (<http://milesberry.net>), and so on, that provide valuable information on teaching computing at schools.

*Wikipedia, Wikispaces, and Social Media:* Wikipedia is one of the most commonly referred information repositories. Although syndicated authorities do not approve its content, many participate and contribute to its humongous content to make it popular and comprehensive. Portals exclusively for CS<sup>42</sup> and Wikispaces for easy authoring of content, publishing, and creation of activities for schools and teachers make each of these very convenient resources.<sup>43</sup> Social media, such as Facebook [Goh et al. 2013] and Twitter are more commonly used as teaching aides to create and provoke dialogs on various thematic topics, and get immediate feedback from students about their understanding or even problem areas. Also, these are used to maintain calendars and publicize events. As an example, Alt et al. [2006] discussed how CS could be taught effectively by exemplifying features of social networks, thereby exemplifying real-world applications that could be used to teach CS.

The positive effects of using Web 2.0 technologies have been evident in the direct dependence of students on them to drive conceptual understanding [Hew and Cheung 2013].

### 3.7. Extracurricular Activities

Research in CS education has mostly focused on enhancing conceptual understanding of the students. However, the goal of CS education should also include assisting students

<sup>39</sup><https://www.khanacademy.org/cs>.

<sup>40</sup><http://blog.acm.org/csta>, <http://teachcomputing.wordpress.com>.

<sup>41</sup><http://blog.acthompson.net>.

<sup>42</sup>[http://en.wikipedia.org/wiki/Portal:Computer\\_science](http://en.wikipedia.org/wiki/Portal:Computer_science).

<sup>43</sup><http://pdchandler.wikispaces.com/>.



with the application of these concepts to different situations. Knowledge construction, cognitive learning, and competency development should be the focus in the design and structure of CS curricula [Knobelsdorf and Vahrenhold 2013]. One of the ways to effectively enhance this process is by encouraging participation in programming contests and Olympiads that are structured to develop problem-solving and algorithmic thinking [Armoni 2011].

The Indian National Computing Olympiad<sup>44</sup> is the most prestigious and competitive national contest in CS that tests algorithmic and combinatorial aptitude of students. The Indian Association for Research in CS conducts the Olympiad with the CBSE Board for students in grades VIII–XII and in two stages. The first stage includes screening students by conducting two types of zonal contests, namely, Zonal Informatics Olympiad and the Zonal Computing Olympiad. More than 8,000 students participate yearly across 40 centers in India and 25 students are selected. In the second stage, the selected students undergo an intensive training camp to further develop their algorithmic and interactive problem-solving skills and compete in the International Computing Olympiad. Mukund [2013] indicates that the main factors deterring participation are the nonexistence of CS as a core subject and poor representation of its importance at schools. However, students can still practice and compete to sharpen their programming skills on sites like [codechef.com](http://codechef.com) that allow multiplatform, online, coding competition.

The National Cyber Olympiad (NCO) conducted by the Science Olympiad Foundation (SOF), a nonprofit private organization, is a yearly event and caters to international participants from Asia and the Middle East. Students undergo a 1-hour exam that tests their mental ability, logical or analytical reasoning, and technical skills. Forty percent weightage is given to their understanding of computers and IT. Students receive their international, national, and school rankings for their performance and the schools that are part of this are given “school cyber quotients” for the students’ performances. If students have international rankings within 500 and/or state rankings within 10 and are from top cyber quotient schools, they are allowed to participate in the next screening round. This event encourages large-scale participation as SOF provides gold, silver, and bronze medals to schools that have more than 10 students participating. Also, students between the II and XII grades are allowed to participate. The winners receive cash prizes of Rs. 1 lakh and Rs. 50,000 for bagging International first and second ranks, respectively.<sup>45</sup>

The Google Code In (GCI) contest is unique in that its main objective is to allow high school and senior secondary school students between the ages of 13 and 17 to participate in open-source development. Google selects a project from 10 open-source organizations and lists tasks that require coding in a variety of programming languages, or creating documentation, or marketing outreach, or working on user interfaces for each of them. The students earn points for each task that is completed. At the end of the contest, each organization selects the top two contributors and a total of 20 winners are announced. In the past 6 years since 2007, this contest has attracted participants from 89 countries. In 2013 alone, 2,300 participants registered for the event.

The International Institute of Computer Technology conducts various competitions such as the National Computer Science Competition for computer science fundamentals, National Schools Programming Competition focused on programming, National Schools Computer Graphics Competition to test proficiency in graphics, and National Schools Animation Competition to highlight aptitude for 3D animation. The contests

<sup>44</sup><http://www.iarcs.org.in/inoi>.

<sup>45</sup>[http://articles.timesofindia.indiatimes.com/2012-07-06/mumbai/32565116\\_1\\_felicitates-science-olympiad-foundation-chief-guest](http://articles.timesofindia.indiatimes.com/2012-07-06/mumbai/32565116_1_felicitates-science-olympiad-foundation-chief-guest).

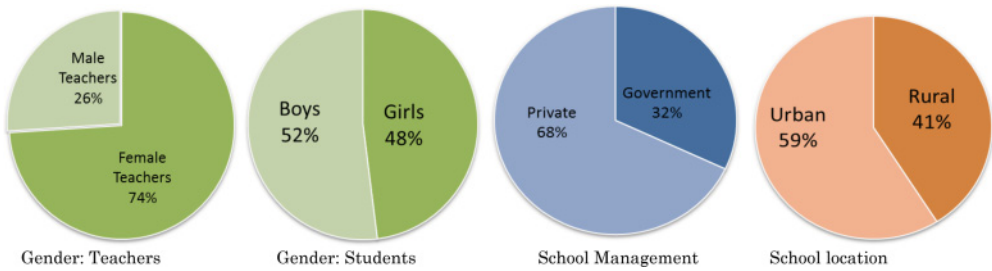


Fig. 15. Study demographics.

draw participation from more than 500 schools across 18 states of India. In addition, recognition is also accorded to the 180 best-performing schools (10 from each state) and 135 best principals.

The Computer Literacy Foundation of India, an NGO supported by SilverZone,<sup>46</sup> an active member of CSTA, conducts two international events, namely, the International Informatics Olympiad and the International Computer Graphics Competition inviting participants from the grades III to XII. The IIO assesses computing and IT aptitude of students, while the ICGO looks at the creativity, graphical talents, and documentation skills. Students compete at five different levels based on their age, that is, Sub-junior wing (grades III and IV), Junior wing (V and VI), Lower middle wing (VII and VIII), Upper middle wing (IX and X), and the Senior wing (XI and XII).

### 3.8. Research and Results

Drawing upon the literature on the Diffusion of Innovation, we conducted a study to investigate how teachers and students perceived and experienced the CS subject. Our research questions centered on what previous experiences and motivations would influence their decisions to adopt CS. We investigated two groups of characteristics, which were the independent variables—innovation characteristics and environment characteristics along with the interinfluence between teachers and students.

Participating in our study were 10,292 students and 996 teachers from 332 schools. Schools were chosen to represent private and government run schools from both the rural and urban locations as seen in Figure 15. A five-point Likert-scale-based questionnaire was administered to understand students' and teachers' perceptions of the factors that influenced the adoption of CS in school education. We developed the current scale with items largely adapted from the diffusion research conducted by Moore and Benbasat [Moore and Benbasat 1991] that focused on the adoption of information technology. The survey consisted of nine independent research variables hypothesized to be a factor affecting the adoption. We hypothesized that innovation attributes like Relative Advantage, Compatibility, Ease of Use, Trialability, Observability, Perceived Enjoyment, School Support, Peer Influence, and Teacher and Student influence positively affected their intentions to adopt CS as a subject.

From the survey shown in Figure 15, we observe that 68% of the students felt that CS should be a compulsory subject just like Physics, Chemistry, and Math. Here, by Relative Advantage we mean the advantage that CS has over other subjects like Physics, Chemistry, and Math. We have specifically focused on how easy it was for students to score marks in CS. 74% felt that it was relatively easier to get marks in CS compared to Physics, Chemistry, and Math. An overwhelming 81% of the students had a positive attitude toward CS saying learning CS was enjoyable (Perceived Enjoyment). About

<sup>46</sup><http://www.silverzone.org/clf.asp>.

56% of the students felt that CS was mainly about learning programming, while 45% of the students said CS was mainly about how computers worked. Equally interesting was the students' overwhelming response that there were more career opportunities for CS students (68%) and that there were greater higher studies opportunities for them too (59%). A majority of the students indicated that girls were as good as boys at programming (59%) and that studying CS was just as appropriate for girls as it was for boys (62%). Confirming the importance of CS-trained and certified teachers, 82% students responded that it was difficult to learn CS without a teacher to explain it (Teacher Influence). This made CS a difficult subject to teach/learn and hence has low Ease of Use. When asked if the focus of the curriculum should shift more toward CS early in the school years, 54% responded with a "strongly agree."

Interestingly, 54% of teachers were not in favor of making CS a compulsory subject like Physics, Chemistry, and Math. Sixty-nine percent of the teachers agreed that formal certification in CS was essential. A majority of the teachers also felt that schools should provide adequate computer laboratory facilities.

Regression results confirmed that the decision of whether or not to adopt CS was highly dependent on factors like Relative Advantage of CS, Compatibility, Ease of Use, School Support, and Teacher Influence. School Support has been seen as being essential in motivating teachers to take up teaching CS. A significant difference was seen among students though, with urban students favoring the adoption of CS. Interestingly, girls were seen to favor adoption of CS, while private schools were more in favor of adopting CS in their schools.

It must be said that if the new subject is difficult to teach or requires a complete new pedagogy (Compatibility), then there is a natural tendency for teachers to avoid it. So, we recommend that school management invest in teacher training in CS and provide adequate lab facilities for them to practice. In addition, hosting seminars and workshops to sensitize both teachers and students about CS could also be a good way forward.

This study, we believe, has offered a positive outlook not just with regard to the existing policy directives for educators and school teachers to understand what factors influence students' and teachers' decisions on whether or not to adopt CS, but also with regard to the academic environment across India that is maturing enough to wholeheartedly embrace CS as a subject of study in schools.

#### 4. CONCLUSIONS

The integration of CS education into the formal school curriculum has become a prominent trend in educational systems across the world. This is mainly due to the increased benefits of computing technologies flowing into schools in countries that are well integrated into the global economy. But CS as a stand-alone subject in the school curriculum is still an emerging paradigm and countries around the world are still challenged by its slow adoption among both teachers and students. An important issue requiring address here is the interchangeable use of terms like CS, Informatics, ICT, and digital literacy. This clarification is expected to facilitate strong basis for teacher training, curriculum development, assessment of students' competencies, and so on.

Our main focus in this article was to categorize the state of CS education in India using the Darmstadt model and subsequently identify dominant attributes that could predict its successful adoption by teachers and students. Our coding scheme involved the time period from 1980 to 2013. This research has provided a deeper investigation of the CS education as guided by the framework of Rogers Theory of Perceived Attributes. In this study, we proposed that certain characteristics of CS education as an innovation could account for the degree of acceptance of innovation by teachers and students.

The results of this analysis indicate that Relative Advantage, Compatibility, Ease of Use, Teacher Influence, and Student Influence are positively related to the acceptance of innovation. A significant finding here was that the students from urban areas and private schools favored the adoption of CS as a subject. Interestingly, girls were seen to be more favorable to the adoption of CS. A unique approach of our study was to examine the adoption intentions of both teachers and students considering there were strong indications of interinfluence between them. Though there have been efforts to create core curriculum standards for subjects like Physics, Chemistry, Biology and Math, CS has been kept outside the purview of such efforts, essentially leading to its marginalization. Current state school standards have largely focused on ICT literacy ignoring teaching CS concepts like algorithms, data structures, and so forth. The recently proposed A Model Curriculum for ICT in School Education by Central Institute of Educational Technology is a step in the right direction as is the National Policy of ICT for School Education since quality CS education may need foundational ICT training. It also focuses on the important aspect of teacher training and capacity building of teachers.

There is a definite difference in the adoption of technology at regional and state levels. The Southern states of India, due to their innovative programs and effective partnerships with NGOs and private industry, seem more progressive in implementing the national policies and making significant impact with the use of ICT and CS for teaching and learning purposes. Observing the achievements of various initiatives and programs, the main conclusion is that, without full involvement of trained teachers, none of them will be successful. Private industry has been very successful in penetrating the landscape of school education and by providing the much needed resources.

The ubiquitous nature of computing technology and its impact on every aspect of human existence accentuates the need to integrate its understanding very early on in the educational curriculum of K-12 students. The Government of India in the past 20 years has developed comprehensive national policies, implementation plans, allocated budgets, and undertaken intensive investment on infrastructure. These have resulted in provisioning of computer laboratories and Internet connectivity to millions of students. Simultaneously, the CBSE board, playing a pivotal role in shaping the K-12 educational norms, has formalized courses in ICT and CS.

Despite these interventions in the right direction by the government and PPPs, CS education has not yet reached a majority of the K-12 Indian students. The fundamental reasons for this blow are (1) suboptimal use of infrastructure, (2) lack of understanding on the need for CS, (3) poorly qualified teachers, and (4) existence of CS courses as “optional” courses in most curricula. Further, these are only offered at the senior secondary school level. Needless to say, an overhaul of the educational curriculum is necessary to bridge this gap of stark deficiency in creating CS literates. Either of the two popular schools of thought, that is, adopting CS as a core subject [Tucker et al. 2006] or integrating computing into existing courses, such as biology, health, and arts, as in the ECSITE model [Goldberg et al. 2012] can transform the exposure and appreciation to CS. More notably, a wider demographic of students will be enabled to learn about its importance. Hubwieser [2013] describes the tangible success of mandating CS learning in German schools resulting in increased interest in the study of CS in Germany. A program that introduces the basics of computers and scratch programming [Tucker et al. 2006; Iyer et al. 2013] as part of the primary school curriculum and covers various aspects of computing across the 12 years of school education would be ideal. In reality, such a radical change would be difficult to introduce and implement in a short period of time.

Our recommendation would be to morph the existing emphasis on ICT tools in the K-12 curriculum to its governing foundations. As an example, one could look at tools such as Microsoft Word and Excel, go beyond feature demonstration, that is, explain

how data is structured and processed using computer programs, and this would be far more beneficial to teach and develop conceptual understanding. Second, instead of classifying the courses based on programming languages, that is, Python versus C++ as is done for senior secondary students, exposure to a combination of both structural and functional programming would provide broader understanding. Third, in order to overcome language barriers, a challenge in many parts of India, it is important to provide local language versions of relevant text, online materials, and tools for wider adoption of CS.

The technologies for adoption of e-learning or smart classrooms are still very nascent and students in India rely on classroom coaching by teachers as their primary means of education. The knowledge and skills of these teachers directly affect the student aptitudes. Teaching CS necessitates the recruitment of qualified professionals and nodal agencies, such as CBSE and NCERT to maintain training schedules for new subject introductions. However, for CS teachers, we further recommend that a periodic certification process be introduced to keep them updated on new technology trends and ensure up-gradation of quality in their teaching practices.

The recommendations for teacher preparation based on the NCATE (National Council for Accreditation of Teacher Education) accreditation standards specifically for CS education are valid and could be adapted and be more aligned to the learning requirements. Access to repositories of information and innovative use of Web 2.0 tools should be inculcated in their training programs. Incentives provided by the State or Central Government based on the level of certification would help sustain the interest and attract CS graduates into the teaching profession. Leading academic universities should take proactive roles as done by Amrita University in offering workshops and professional development programs in various aspects of computing to teachers and students.

One of the key national metrics indicative of the proliferation of CS education and its proficiency in schools is the country's representation at international computing events. At a more granular level, this is a function of the number of participating students and their performance. Competitions and contests not only help to showcase the capabilities of students, but stimulate development of talent in those that are committed. Integrating online programming exercises as part of the curriculum or focused workshops from authentic sources (such as [codecademy.com](http://codecademy.com), [girldevelopit.com](http://girldevelopit.com), [code.org](http://code.org)) can dramatically influence the landscape of CS education in India.

Many of the skills related to how the web works, the way information flows through the social media, and to the use of digital tools are in the domain of CS. As a priority, ICT needs to be augmented by a strong focus on CS skills in schools.

## APPENDIX—ACRONYMS

- AISES, All India School Education Survey
- A-VIEW, Amrita Virtual Interactive E-Learning World
- CBSE, Central Board of Secondary Education
- CIET, Central Institute of Education Technology
- CLASS, Computer-Aided Literacy and Studies in Schools
- CS, Computer Science
- CS4HS, CS for High Schools
- CSTA, CS Teacher Association
- DIET, District Institutes of Education Technology
- EDUSAT, Education Satellite
- FOSS, Free and Open-Source Software
- HTML, Hyper Text Markup Language
- ICT, Information and Communication Technologies



- IFIP-TC3, International Federation for Information Processing Technical Committee 3
- IP, Informatics Practices
- ITiCSE, Innovation and Technology in CS Education
- MHRD, Ministry of Human Resource Development
- MMT, Multimedia Technology
- NCERT, National Council of Education Research and Training
- NCF, National Curriculum Framework
- NCFTE, National Curriculum Framework for Teacher Education
- NCTE, National Council for Teacher Education
- NKN, National Knowledge Network
- NMEICT, National Mission on Education through the ICT
- NPE, National Policy on Education
- NSS, National Science Survey of India
- RDBMS, Relational Database Management System
- SIET, State Institutes of Educational Technology
- SMART
- SQL, Structure Query Language
- SSA, Sarva Shiksha Abhiyan
- VB, Visual Basic
- XML, Xtended Markup Language

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Received March 2013; revised December 2014; accepted January 2015